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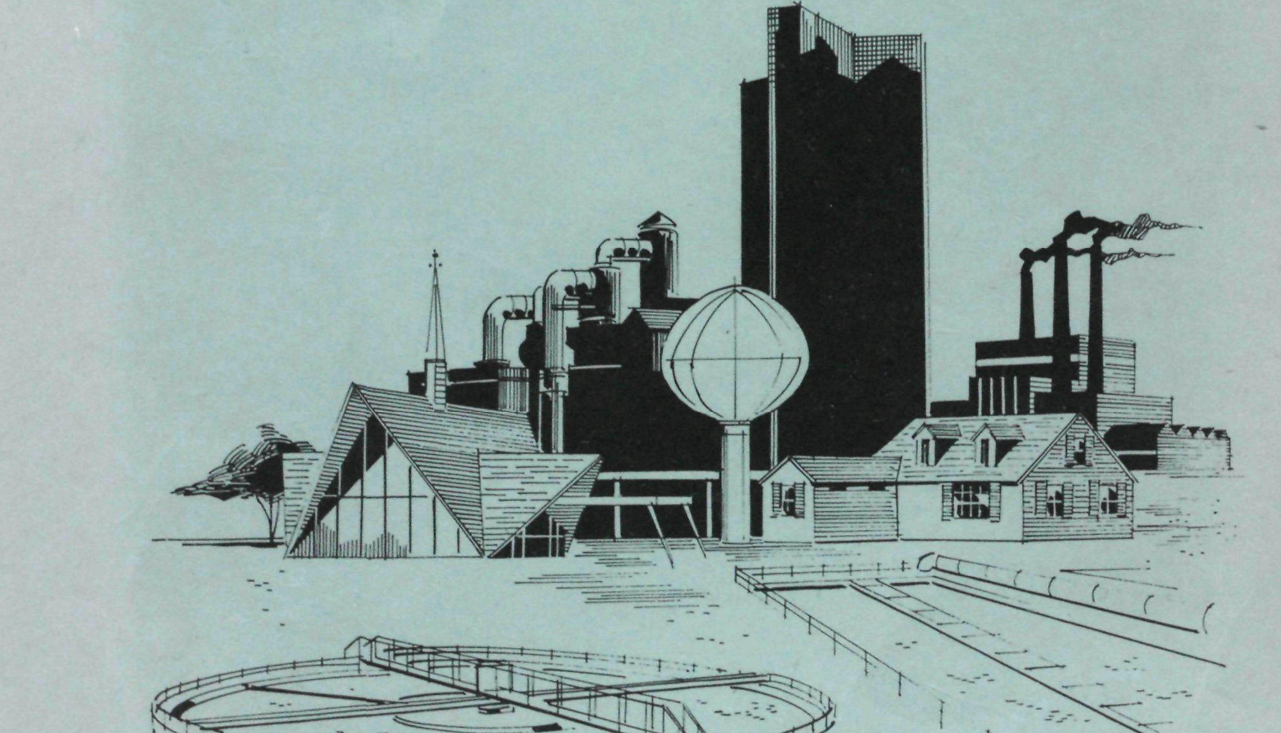
Disposal of Wastes from Water Treatment Plants



.S. DEPARTMENT OF THE INTERIOR ● FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

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DISPOSAL OF WASTES FROM WATER TREATMENT PLANTS

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

DEPARTMENT OF THE INTERIOR

by

American Water Works Association

Research Foundation

2 Park Avenue, New York, N. Y. 10016

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August 1969

FWPCA Review Notice

This report has been reviewed by the Federal Water Pollution Control Administration and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Federal Water Pollution Control Administration.

Disposal of Wastes from Water Treatment Plants

ABSTRACT

This report is an intensive study of the disposal of wastes from water treatment plants. The wastes include filter washwater; sludge resulting from coagulation, softening, iron and manganese removal processes; diatomaceous earth filtration; and ion exchange brines. The control of pollution from these wastes is a high priority problem for the water utility industry.

A series of four status reports describe in detail what is known of the research, engineering, plant operation, and regulatory aspects of the problem. A special report reviews current technology and analyzes costs of disposal methods, based on data collected from fifteen operating plants. A conference was organized to provide expert evaluation of each report and to extend the data available.

Final reports were prepared by committees of conference participants to identify future needs for information in each aspect of the waste disposal problem. These reports recommend substantially expanded programs of research and demonstration. They include extensive lists of specific problems which must be investigated to develop effective and economical technology.

Committee reports also recommend establishment of a central service to promote the planning of research and development, and to implement effective programs of new or improved technology. The service would collect, coordinate, and disseminate data on all aspects of water treatment plant waste disposal problems.

This report was submitted in fulfillment of Research Grant 12120 ERC (formerly WP 1535-01-69) between the Federal Water Pollution Control Administration and the American Water Works Association Research Foundation.

KEY WORDS

Waste Disposal	*Operation Maintenance*
Waste Treatment	Cost Analysis
Water Treatment	Regulation
Sludge Treatment	Surveys
Ultimate Disposal	Utilities - Water Works

CREDIT FOR ILLUSTRATIONS

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Photographs and drawings illustrating Report on Current Technology and Costs, pp. 133-238.

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FOREWORD

The disposal of wastes from water treatment plants is not a new problem. The majority of plants dispose of solids removed during the treatment process by returning them to surface waters. Under recently enacted federal and state legislation, however, these wastes are generally considered pollutants - as are the wastes from any industry.

The water utility industry must now take action to solve its problem of waste disposal. The number of U.S. water treatment plants producing sludges from coagulation processes is reported by Russelmann (1968) to be about 3,600. The quantity of solids resulting from municipal water coagulation processes is estimated by Hudson (1968) to total about 1,000,000 tons per year.

These wastes are highly variable in composition, containing the concentrated materials removed from raw water and the chemicals added in the treatment process. The wastes are produced continuously, but are discharged intermittently. Since the wastes from each plant are different, no specific treatment process will yield the same results. In fact, while a variety of alternative treatment methods are available, there may be only one or two methods applicable to a specific location.

Experience in the disposal of these wastes has been very limited. The American Water Works Association Research Foundation has undertaken to survey the present state of knowledge on this problem, and to identify additional information needed.

The present report includes a series of four status reports covering research, engineering, plant operation, and regulatory aspects of the problem. A special report provides information on current technology and costs. A two-day conference was organized to critically review, evaluate, and enlarge upon the prepared reports. The series of four reports on future needs were prepared by committees of conference participants. These reports identify specific research and development studies required to support an action program.

The purpose of the report on disposal of wastes from water treatment plants is to provide current information on the nature of the water treatment plant waste disposal problem, and to assist water utilities in solving the problem. The report describes technology presently available, defines new approaches to the problem, and suggests future directions for the coordination and dissemination of information.

This project was supported, in part, by a research grant awarded to the AWWA Research Foundation by the Federal Water Pollution Control Administration, U.S. Department of the Interior. Grant Project Officer was William J. Lacy, Chief, Industrial Pollution Control Branch, Division of Applied Science and Technology.

The AWWA Research Foundation is a non-profit corporation organized to promote basic and applied research activities in the water utility field. The Research Foundation serves to initiate and coordinate research in the technology, operation, and management of water supply systems.

A Project Advisory Committee assisted the Research Foundation in the development of this report. Members of the Committee were:

James C. Lamb, III
Robert B. Dean
Richard I. Dick
John W. Krasauskas
Walter K. Neubauer
Donald P. Proudfit
Lee Streicher
Edwin C. Weber

Engineering consultants were employed by the Research Foundation to prepare the report on current technology and costs. Their report includes data collected by visits to fifteen water treatment plants, selected to provide examples of various disposal methods, and also includes model studies. The consultants were:

Donald D. Adrian
John H. Nebiker

The AWWA Research Foundation staff for the project on Disposal of Wastes from Water Treatment Plants was:

Harry A. Faber, Research Director
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Section 1

REPORT ON WHAT IS KNOWN

CONFERENCE INTRODUCTORY STATEMENT

Harry A. Faber

Wastes from water treatment plants are, today, recognized as an industry-wide pollution problem. The solution of this problem is not simple. It involves research, engineering, plant operation, and regulatory aspects.

The AWWA Research Foundation considers this a problem of high priority. It has undertaken to prepare a comprehensive state-of-the-art report to determine what is known and what is needed. The report will be designed to assist the water utility industry in developing effective and economical control measures.

This Conference has been organized to provide an expert overview of a series of status reports. The participants have been selected: (1) to critically review the reports, (2) to extend the data available, (3) to advise concerning future needs.

Background

The problem of water treatment plant waste disposal is not new, and has been studied before. Thirty years ago, in 1937 and 1938, research was conducted at the Chicago Experimental Filter Plant. The detailed report prepared by Herbert Hudson evaluated the quantity, characteristics, thickening, and dewatering of sludge. Unfortunately, this report was not published.

In 1946, the American Water Works Association appointed a committee to study and report on the disposal of wastes from water purification and softening plants. The 8-man committee included three individuals who are attending this Conference: W.W. Aultman, chairman; and A.P. Black and K.E. Shull, members of the committee. That committee published six reports, the first in 1947 and the last in 1953. These reports constituted a comprehensive review of the state-of-the-art about 20 years ago.

The 1953 report of the committee noted that more than 96 percent of 1,530 reporting plants discharged sludge to streams or lakes without treatment, and 3 percent discharged sludge to drying beds. About experimental work done in water treatment plants with vacuum or pressure filters for dewatering sludge, the report stated that none of the respondents (to a questionnaire) knew of any such experiments. The last report of the committee includes the statement:

"At present very few water purification plants are actually prohibited from discharging filter washings and sludge from basins into streams or lakes, but there is a definite trend toward enactment of federal and state laws to prevent the pollution of these waters. In the future the disposal of such wastes is likely to be a matter of increasing concern to designers and operators of water purification plants."

It is evident that the future, anticipated in that statement, has now arrived. For example, a Staff Report of the Ohio River Valley Water Sanitation Commission, in April 1968, pointed out:

"Within the past year or two, all of the six states on the Ohio River have established policies that eventually will lead to the control of water plant wastes, not only on the Ohio River but on tributary streams as well. Implementation of these policies, in fact, has already resulted in the construction of a number of control facilities on tributary streams in five of the states."

Three individuals participating in this Conference are from ORSANCO states: G.H. Eagle, Ohio; Edgar Henry, West Virginia; and H.B. Russelmann, New York.

The changing situation is also evidenced by the recent publication of several important technical reports. The authors of three such publications are at this Conference:

P.W. Doe, in 1966-67, published on extensive report titled "The Disposal of Wastes from Water Treatment Plants," in the Journal of the British Waterworks Association.

Donald D. Proudfit, in June 1968, published a paper titled "Selection of Disposal Methods for Water Treatment Plant Wastes," in the AWWA Journal.

Walter K. Neubauer, in July 1968, published a paper titled "Waste Alum Sludge Treatment," in the AWWA Journal.

Conduct of the Conference

Jerome Weisner, while President Kennedy's science advisor, defined the word research: "to look again - we didn't find anything the first time." In this Conference, we will "look again" at the problem of water treatment plant waste disposal: not because "we didn't find anything the first time," but because the earlier studies need to be brought up to date and expanded.

The major work on this new study of the problem has, to date, been done by an Advisory Committee. The Committee held a planning meeting in August, 1968, to assist the Research Foundation in organizing the report and in developing plans for this Conference.

The invaluable services of this Committee are recognized. It has really served as a working committee rather than as an advisory committee. Each individual member of the Committee made important contributions to the project by preparing, under a short deadline, the status reports sent in advance of the Conference.

The AWWA Research Foundation has also been assisted by a team of consultants responsible for a study of current technology and costs. The consultants selected operating plants illustrating varied water treatment and waste disposal methods, collected engineering and operating data, and prepared the report. They also compiled the basic reference bibliography.

Now we have come to the review stage. The Advisory Committee members and the consultants are meeting at this Conference with a small group of invited participants. Each individual has been selected because of his special competency in one or more aspects of the waste disposal problem. Together, their contributions will evaluate, critically review, and enlarge available data.

The first day of the Conference is devoted to the presentation and discussion of status reports. The Advisory Committee members responsible for the preparation of a report will guide the discussion. All conferees are invited to raise questions, report experience, and suggest additional items for inclusion in the final report.

The morning of the second day of the Conference will be devoted to meetings of four small committees, assigned to prepare summary reports on future needs. The afternoon session of the second day provides for the presentation and open discussion of each committee report. This will be the final opportunity for additional questions, comments and recommendations.

I welcome you to the Conference on Disposal of Wastes from Water Treatment Plants. Your presence is evidence of your interest in solving this problem.

* * *

STATUS REPORT ON RESEARCH

Richard I. Dick and Robert B. Dean

The limited research efforts in the past on handling and disposal of wastes from water treatment plants have been consistent with the attention given to the sludge disposal generally, but are not in proportion with the present magnitude of the problem. Some of the exceptions to this general lack of research on disposal of wastes from water treatment plants are noted in this section.

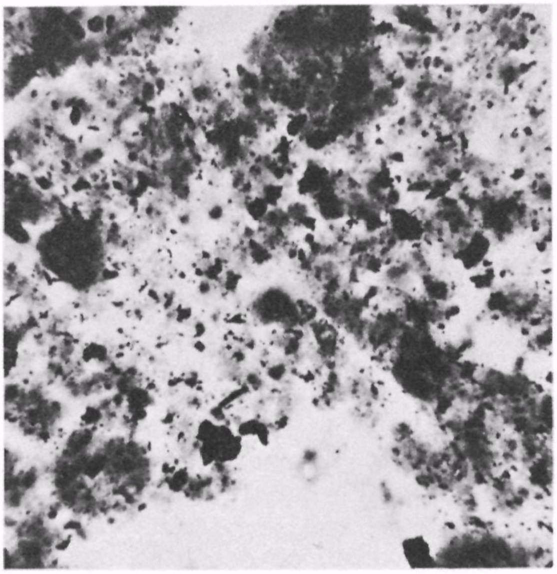
REVIEWS OF RESEARCH

Several review papers on waste disposal from water treatment plants have appeared, and their contents are not repeated here. Summaries of research results were included in AWWA committee reports on water treatment plant wastes (Aultmann, 1947; Haney, 1947; Hall, 1947; Black, 1949; Haney, 1949; and Dean, 1953). Additional reviews have been published by Mace (1953), Wertz (1964), and Aultmann (1966). Results of British research relating to disposal of wastes from water treatment plants have been reviewed in Civil Engineering (Anon., 1949) and more recently by Young (1968).

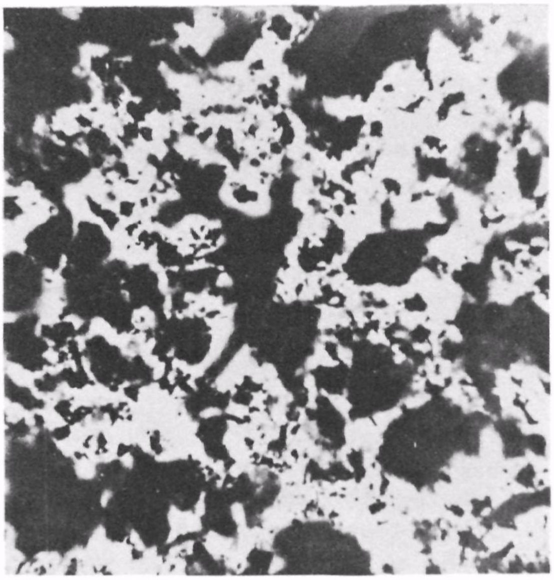
Results of research on characterization of water treatment plant wastes have been summarized recently by Russelmann (1968). Gauntlett (1963) prepared a comprehensive review of literature relating to settling, compaction and dewatering of water treatment sludges. An extensive review of water treatment plant sludge disposal practices including research accomplishments and needs has been presented by Doe (1967).

Reports on Research

Investigations of the chemical and physical characteristics of alum sludges and filter backwash wastes have been reported by Gates and McDermott (1966 and 1968) and by Neubauer (1966 and 1968). The

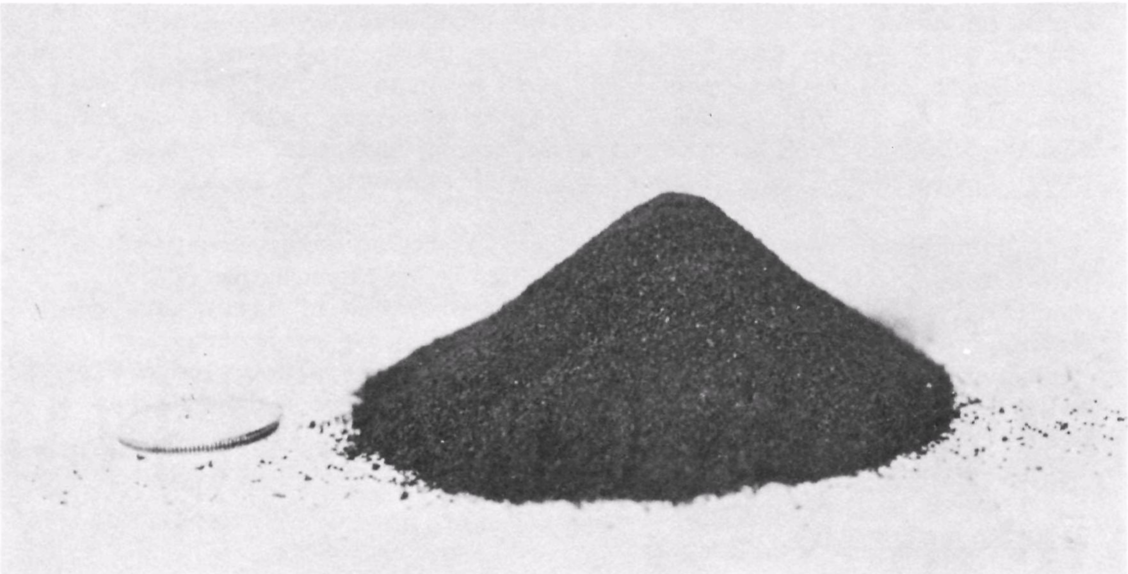


x 100
Unfrozen Sludge



x 100
Frozen Sludge

Photomicrographs - Alum Sludge



Sludge Solids - From Freezing, Thawing, and Drying Processes

- Coin on the left is a dime

volatile solids content of the sludges examined varied from about 20 to 35 percent. Almquist (1946) reported that the average 5 day BOD of sludge from 13 Connecticut filtration plants was 337 mg/l. The average solids concentration of the sludges was 1.3 percent.

Both Neubauer and Gates and McDermott reported that alum sludge was non-Newtonian. Babbitt and Caldwell (1939) summarized earlier data by Gregory which indicated water treatment plant sludges to be plastic in their rheological behavior. Some recent studies by Lagvankar and Gemmell (1968) and Hannah et al. (1967) have given information about the basic physical properties of the floc particles which comprise sludge and on how conditions in flocculators affect these properties.

Much of the reported research on water treatment plant sludges has had as its goal the alteration of the physical properties to facilitate removal of water. Extensive basic studies on conditioning and dewatering of alum sludges have been report by Gauntlett (1964 and 1965).

Freezing. Palin (1954) reported on experiments conducted by Clements and his colleagues on improving the dewatering characteristics of alum sludges by freezing. After freezing and thawing, a 2 percent alum sludge settled by gravity to 20.2 percent and could be filtered to a concentration of 33.9 percent solids by weight. Doe et al. (1965) reported that freezing could be most economically accomplished in a batch process involving a 90 minute freezing period and a 45 minute thaw period. The slow freezing period was essential but no advantage was realized by further reduction of temperatures after freezing had occurred.

Bishop and Fulton (1968) recently noted that freezing processes are economically unattractive except in northern climates where nature can provide freezing conditions free of charge. Natural freezing has been used sucessfully at Copenhagen to dewater alum in sludge lagoons (Christensen, 1968). After two years of sludge application to a depth of 1.4 m per year, the amount of remaining dried sludge had a thickness of 4 cm.

Heat. Palin (1954) investigated the possibility of conditioning alum sludges by heat treatment. Considerable improvement in sludge dewaterability was realized at temperatures and pressures below those of the normal Porteous process.

Acidification. Webster (1966) found that use of sulfuric acid to lower pH improved performance of gravity thickners because of the effect of pH of floc particles.

Polyelectrolytes. Doe (1967) reported on his experiments which indicated that while polyelectrolytes could improve the specific resistance and the compressibility index of alum sludge, both beneficial effects could not be achieved simultaneously. Gates and McDermott (1968) reported that filtration characteristics could be improved by application of certain polyelectrolytes. Neubauer (1968) found polyelectrolytes to be ineffective but the addition of lime improved the filterability of one alum sludge. Sankey (1967) found that vacuum filtration of alum sludge was not possible without chemical conditioning. Two percent by weight of hydrated lime was used in his experimental work.

Thickening. The need to reduce the moisture content of sludges in order to reduce the cost of sludge treatment and disposal practices has prompted research on thickening of waste sludges. Roberts and Roddy (1960) noted that the practicality of recovery of alum from clarification sludges is limited by the thickening characteristics of the sludge, and reported on laboratory and pilot plant experiments involving sedimentation of alum sludges. Doe et al. (1965) indicated that thickening was necessary to assure economical performance of the process for conditioning sludge by freezing. Alum sludge was concentrated from 0.5 to 1.9 percent solids in a gravity thickener.

Basic information on the settling characteristics of the calcium carbonate slurries is available from literature on thickening research - as for example, that by Comings et al. (1954). Gates and McDermott (1968) and Neubauer (1966) presented information on settling behavior of alum sludges and filter backwash wastes from various water treatment plants. Flotation characteristics of alum floc were reported by Katz and Wullschleger (1957).

Sludge Dewatering

Filtration. To accomplish volume reduction beyond that possible by thickening, sludge dewatering techniques have been explored. Vacuum filtration of alum sludges has been investigated by Gates and McDermott (1968) and Neubauer (1968). Gates and McDermott found the specific resistance of alum sludge to be 0.1×10^{10} to 0.44×10^{10} sec^2/g. In Buchner funnel tests, Neubauer found that a diatomaceous earth precoat was necessary to produce a cake with 20 percent solids. A 99 percent solids capture was realized.

Experimental work on dewatering of alum sludges by wedge wire filters, vacuum filtration, and filter pressing were conducted by Sankey (1967). It is estimated that capital costs would be lowest for vacuum filters and that operational costs would be lowest for wedge wire filtration. However, filter presses were the method of choice because they gave the lowest annual cost.

Centrifugation. Centrifugation of alum sludge was evaluated by Neubauer (1968), but was not pursued in detail because only 6 to 12 percent cake solids could be achieved. Webster (1966) reported that alum sludge could be dewatered to over 18 percent solids by use of a filter press. Sparham (1965) reported on use of wedge wire filters for dewatering sludge bases on pilot plant studies.

Sand Beds. Neubauer (1968) found that alum sludges could be dewatered on sand drying beds to 20 percent solids concentration within 100 hrs. with 97 percent solids capture. Loading rate was 0.8 lbs/sq ft. Neubauer considered sand drying beds to be more economical than vacuum filtration or other methods for dewatering alum sludges.

Lagoons. Experience with lagooning of softening sludge was summarized by Howson (1961). He concluded that most lime sludges will air dry in properly designed lagoons with supernatant removal facilities to about 50 percent moisture. Neubauer (1968) concluded that deep lagoons were incapable of dewatering alum sludge to the extent that it could be disposed by landfill.

Reclamation of Chemicals. Reclamation of chemicals from waste sludges for reuse has been investigated as a means of minimizing disposal costs. Proudfit (1968) reviewed results of studies which showed it possible to reduce the volume of sludge requiring disposal of a St. Paul, Minnesota softening plant by 83 percent by recalcination. Proudfit also described plans to regenerate alum and recalcine lime at the Minneapolis, Minnesota plant.

Palin (1954) investigated recovery of alum for reuse by use of concentrated sulphuric acid and concluded that cost of the process would be attractive because of the reduction in the sludge disposal problem. Chlorine was used in the reclamation process to combat the difficulty due to release of color colloids during the recovery process. Additional experimental work relating to alum recovery has been reported by Webster (1966).

Acidification. Chojnacki (1967) reported on reclamation of coagulants from clarification sludges. When coagulation was accomplished with a mixture of ferric and aluminum salts, 5 percent sulfuric acid was the most effective regenerant. The highest purity of recovered coagulants was obtained when 50 to 75 percent of the stoichiometric acid requirement was used.

Recalcination. Basic technology relating to recalcination of lime softening sludges has advanced well beyond the basic research phase and has been demonstrated in full-scale installations such as at Miami (Black *et al.*, 1951). Albertson and Guidi (1967) have described removal of magnesium precipitates from softening sludges prior to recalcination by means of centrifugation. Krause (1957) reported 40 to 65 percent reduction in magnesium by centrifugation at the Lansing, Michigan recalcining installation.

Use of Alum Sludge. Possibilities for reclamation of alum sludge for use in industrial processes was considered by Palin (1954). Its physical properties and high proportion of impurities rendered alum sludge impractical as in adsorbent. He reported on a successful use of sludge in a refractory industry for purposes of altering the rheological behavior of slip and to serve as a source of aluminum for manufacture of refractories. Palin also considered the possibility of using alum sludges from waters in contact with vegatative products as a source of "humic acid" as did Stockwell (1939). Use of dewatered softening sludge for street base stabilization at Boca Raton, Florida was reported by Hager (1965).

Palin (1954) considered the greatest potential use of alum sludge to be as a rubber filler. In this case, the humic acid would serve as an extender and the alumina as a filler in vulcanization. Other possibilities considered by Palin were use of alum sludges as wetting agents for insecticides, binders for briquettes, and for medicinal uses.

Land Disposal of Sludge. Dean (1968) emphasized the need for considering the chemical nature of wastes prior to their ultimate disposal to assure that they are returned to a sector of the environment with which they are compatible. Sankey (1967) considered land disposal of dewatered alum sludge to be the most satisfactory method of final disposal. Application of sludge at a rate of one inch per year had no effect on normal vegetation. Sankey proposed that a program involving stripping of top soil, spreading of dried cake, and resoiling, would be most satisfactory.

Dean (1968) reported that small quantities of aluminum hydroxide clog soil and make it unfit for agriculture. Doe (1958) found that spreading of alum sludge on the land sealed the soil and killed vegetation but that plants were able to grow in the soil after winter freezing had destroyed the colloidal structure of the sludge. Land application of alum sludge dewatered by freezing has been reported by Doe et al. (1965) to be a satisfactory means of disposal. Vegetation grows on the dewatered solids.

Smith (1948), who reviewed sludge disposal practices from New England water treatment plants, indicated no account of interference of water treatment plant sludges, other than softening sludges, with sewage treatment.

Ultimate Disposal. Residues produced by advanced treatment of wastes create ultimate disposal similar to those at water treatment plants. The nature of residues produced in advanced treatment of wastes has been reviewed by Dean (1968). Much of the recent research relating to these residues has been summarized in a recent report of the Advanced Waste Treatment Branch of the FWPCA, (Federal Water Pollution Control Administration, 1968), and work at the South Tahoe Public Utility District has been summarized by Slechta and Culp (1967). From their pilot plant studies, Slechta and Culp concluded that alkaline methods of alum recovery were not economically feasible, and that alum recovery by the acid method was feasible if alum was used for clarification but not if alum was used for phosphate removal. Lime used for phosphate removal could be economically reclaimed.

Mulbarger et al. (1968a) have described studies on improvement in the dewatering characteristic of sludge produced by lime clarification of waste water treatment plant effluents. In related studies, Mulbarger et al. (1968b) investigated thickening, dewatering, and recalcination of lime sludges from a laboratory batch waste effluent treatment system. The chemical quality of the effluent was found to have a significant effect on the characteristics of the sludge produced. It was necessary to waste some reclaimed sludge to avoid the accumulation of inert material.

CURRENT RESEARCH

Doe's report (1967) includes a tabulation of 17 research projects being conducted throughout the world relating to water treatment plant sludges.

Aluminum Phosphate Sludges. Dr. J.B. Farrell heads an FWPCA in-house program on the recovery of soluble aluminates from aluminum hydroxide-aluminum phosphate sludges derived from the treatment of wastewater with aluminum salts. In this work separation of phosphate from aluminum is of first importance and so attention has been given to the basic process with concurrent precipitation of the phosphate as a calcium (aluminum ?) phosphate. Description of the work has recently been published by J.B. Farrell, B.V. Salotto, R.B. Dean, and W.E. Tolliver in the Chemical Engineering Progress Symposium Series No. 90, Volume 64, pages 223-239, 1968.

Another FWPCA in-house project, also under the direction of Dr. Farrell, is a study of the freezing of these same aluminum phosphate sludges as an aid to dewatering. Some of this work is being carried out in the laboratory in a deep-freeze cabinet and the field activities will be carried out at Ely, Minnesota. Again, the emphasis is on sludges containing phosphates as well as aluminum but recovery of aluminate is not being stressed.

Under FWPCA Contract 14-12-154, Johns-Manville is investigating the use of a moving bed filter for concentrating aluminum phosphate sludges derived from secondary effluents. This filter does a good job of clarifying fluffy flocs including aluminum hydroxide and activated sludge. Further dewatering of the filter backwash is effectively accomplished on precoat vacuum filters. Further information on this project can be obtained from Dick Bell at Johns-Manville, P.O. Box 159, Manville, New Jersey 08835.

Monsanto Research, under FWPCA Contract 14-12-199, is studying the market for phosphates recovered from waste treatment sludges. There may be some application to lime sludges from water treatment plants. Lime recovery is also being practiced at South Lake Tahoe under FWPCA Grant WPRD 52-01, again on secondary plant effluents. Robert Dean serves as technical backup on this project.

Freezing. The City of Milwaukee is studying sludge freezing under FWPCA Grant WPRD 71-01-68. While this applies to activated sludge, much of the work involving refrigeration economics will apply equally well to the freezing of alum sludges. Dr. Farrell is the coordinator.

Mathematical Models. Two FWPCA contracts relating to sludge disposal concern mathematical models. Contract 14-12-194 to Rex Chainbelt deals with the mathematics of clarifiers, and 14-12-416 to General American Transporation Research Corporation deals with the mathematics of coagulation and sedimentation. In each case the objective is to set up a computer program that will apply to the design of equipment. Robert Smith is project officer for both contracts.

Pipeline. Pipeline transport of sludge is being studied by the Rand Corporation of Cleveland under FWPCA Contract 14-12-30 and by Bechtel Corporation under 14-12-156. Mr. Harold Bernard is in charge and Dr. Farrell is technical backup. The Rand contract involves constructing a pipeline in Morgantown, West Virginia, to handle sewage plant sludges. Bechtel is studying the transport of sewage plant sludges, dredging spoil, water plant residues, and other wastes at the Cadiz test facilities which were built to study the transport of coal in pipelines.

Treatment and ultimate disposal of calcium carbonate, aluminum hydroxide, and ferric hydroxide sludges produced from pilot plant treatment of effluent from the District of Columbia Waste Treatment Plant is currently under study. Sludge thickening, dewatering, and reclamation processes are being evaluated.

University Research. Centrifugation of water treatment plant sludges is being studied at the University of Cincinnati. The effect of chemical additives on dewatering characteristics of sludge from the Cincinnati water plant is being investigated.

Studies at the University of Massachusetts in the area of water treatment plant sludges relate to the dewatering characteristics of sludges in lagoons. Factors influencing dewatering and drying rates are being evaluated to assist in design of land disposal systems.

At the University of Illinois, studies are underway on the thickening and vacuum filtration of alum sludges. The basic mechanisms involved in thickening of softening sludges are also being studied.

State Data. A study of the criteria for design and operation of facilities for water pollution control from softening plants is being conducted by Burgess and Niple for the Ohio Department of Public Health. Information is being gathered on treatment processes, and ultimate disposal techniques relating to softening sludges.

The Illinois Section of the AWWA through its Water Resources Quality Control Committee has undertaken a study of the effect, if any, of wastes generated by water treatment plant on potential or existing water supply sources as well as other legitimate users of water. Existing methods of water treatment plant waste disposal are being assessed, the quantities of waste generated in water treatment are being studied, and information is being collected on the chemical, physical, and biological characteristics of the wastes.

Municipalities. A research program is underway at the Shoremont Water Treatment Plant at Rochester, New York, on use of natural freezing to alter the physical nature of alum sludge.

The City of Dayton, Ohio is conducting research in conjunction with their lime reclamation plant. Work is underway on techniques for reducing magnesium content of the recalcined lime and to develop a process for economic recovery of magnesium.

The City of Atlanta Department of Water Works is conducting extensive experimental work on reduction of moisture of alum sludge. Vacuum filtration, air flotation, centrifugation, and pressure filtration have been evaluated. Of these techniques, the filter press, using lime as a filter aid, has found to be the most successful and resulted in 99.9 percent recovery and 30 percent cake solids. Lime solutions are capable of dissolving some aluminum hydroxide as metastable calcium aluminate, and the possibility of recycle of filtrate to take advantage of its aluminum content in the coagulation process is being considered.

* * *

DISCUSSION OF STATUS REPORT ON RESEARCH

MR. DICK: Presumably, the reason that more research has not been done on this problem is that the disposal of water treatment plant wastes has not been considered to be a pressing problem in the past. Today it is clearly a significant problem, and we are going to need much more research in this area in the future. I think it is important to point out that recent studies in advanced waste treatment technology have revealed similar problems.

Studies of water treatment plant waste disposal sponsored by New York State - those by Neubauer, and by Gates and McDermott - are recent exceptions to the usual lack of information on the basic chemical, physical, and biological properties of these wastes. They found that alum sludges were non-Newtonian, as have previous workers. Some early work by Gregory indicated water treatment plant sludges in general to be plastic in nature. Other evidence would suggest that they are probably thixotropic.

Other basic work in this area recently has dealt more with water treatment than with waste disposal, but it might provide information on the basic physical characteristics of the sludges. I refer to work by Gemmell, Hannah, and Hudson, on factors influencing the specific gravity and physical properties of floc produced in water treatment processes.

One of the physical properties about which we know very little is the settling and thickening characteristics of suspensions produced in waste treatment plants. With softening sludges there is not the great problem that there is with alum sludges and some information is available from basic, studies of carbonate suspensions.

Alum sludge thickening is a far greater problem. The feasibility of many of the alum treatment and disposal methods is limited by the fact that these sludges cannot be concentrated to high consistencies prior to disposal. Yet we know little about their thickening characteristics. Again, recent exceptions are the work by Neubauer and Gates and McDermott.

These same physical properties which prevent adequate thickening of sludges interfere with effective dewatering as well, and this has led to work on conditioning of sludges to alter their physical properties.

Freezing has been reported drastically to alter the physical nature of alum sludges. Indeed, these sludges have been reported to settle by gravity to 20 percent solids following freezing. Doe and his coworkers have recommended batch processes for freezing and emphasized the need for slow freezing. Recently, Bishop and Fulton have concluded that freezing was not economically attractive unless it could be done with natural cold. Work of of this type is being done in Copenhagen with dewatering of alum sludges by natural freezing.

Successful alteration of physical properties by heat treatment has been reported. The temperature and pressure conditions required are less drastic than those used in the Porteous process of conditioning waste treatment plant sludges.

A variety of results has been reported recently on conditioning of sludge with polyelectrolytes. Factors contributing to the inconsistencies in the reported results are: differences in the various polyelectrolytes, the reluctance of manufacturers to tell what their products are, and unknowns regarding the handling and mixing of polyelectrolytes.

Various means of dewatering sludges have been investigated. Many of the investigations have been conducted in Great Britain. Vacuum filtration generally has not been successful with alum sludges without ample conditioning or use or precoat filters. Filter presses have been favored in some British work, where various types of dewatering equipment were compared.

Neubauer reported that centrifugation of alum sludges was not attractive. Centrifugation, of course, is common with lime sludges. Neubauer recommended sand filters over all other types of dewatering devices for alum sludges. This was when the goal was to dispose of the sludge in land fill.

Little basic research has been done on lagooning. It seems like a simple enough process but the results reported in the literature are very divergent, and it would seem that this is an area in which basic research is needed.

The effects of the ultimate disposal of water treatment plant wastes on the environment needs to be considered. What is the effect of the disposal of wastes, from water treatment plants on the water environment? How about the land environment? For the most part, our efforts seem to have been to condition and treat the sludge so that we could fill holes with it, and little attention has been given to living in harmony with the environment.

There are numerous nebulous references in the literature to the fact that sludges are beneficial in wastewater treatment plant operation, that they somehow improve the quality of water receiving streams, and that they are beneficial in agriculture. However, little documented work has been done in this area. We really don't know much about their effect on land nor on water.

An exception to this lack of work in the ultimate disposal of sludges is in the area of sludge reclamation or the recovery of chemicals from sludges. Recalcination of lime sludges has become well known and is perhaps beyond the basic research stage. Reclamation of alum is being done, but it's an area that is also undergoing research at present. Work at Lake Tahoe indicated that alkaline methods of alum recovery were not usable whereas the acid method was.

A list of some of the current efforts on research aspects of the problem of disposal of wastes from water treatment plants will include the following:

In Illinois, a committee of the AWWA Illinois Section is surveying the characteristics of sludges produced and the treatment methods being used, and the effects on the environment of these disposal practices.

In Ohio, studies supported by the state deal with the treatment and ultimate disposal of softening sludges. At the University of Cincinnati work is underway on centrifugation of sludges from the Cincinnati Water Treatment Plant, using various chemical additives.

Work on the lagooning of sludges is underway at the University of Massachusetts. They are studying the rates of drainage and drying of sludges.

At the University of Illinois we are doing work on thickening of sludges from water treatment plants and some work on vacuum filtration of the sludges.

The effect of freezing by natural conditions is being investigated at the Shoremont plant at Rochester.

A study at Dayton is directed to the removal of magnesium in lime sludges by recalcining, and they are exploring possibilities for reclamation of magnesium.

At Atlanta work has been conducted on dewatering of sludges, with the conclusion that filter pressing is an attractive means of dewatering sludges.

As I indicated, much of the present work in this area is in the related area of advanced waste treatment. Mr. Dean is especially qualified to review these projects.

MR. DEAN: Research underway in the advanced waste treatment program relates to the removal of phosphorus, principally as the simple ortho-phosphate. Not very much condensed phosphate remains after adequate secondary biological treatment.

When alum is used for precipitation in tertiary treatment, it is used to bring down the phosphate, not just to clarify. To take out phosphates, you use a lot more alum than you do for clarifying. The resulting sludges are quite different, and yet they have facets in common, and I hope that we can learn a little from this use of alum.

We are doing some work on freezing. We find that freezing does make sludges settle better, but we have not found the dramatic effects that Doe reports. If we freeze a sludge, it may settle twice as fast as it did before freezing. But Doe report a tremendous difference between a "jelly" that would never dewater and "coffeegrounds", as he describes it, after freezing.

We have been looking quite seriously at the rates of freezing in cold climates, and it is obvious that if you want to freeze a lot of water, the way you do it is in thin layers. By putting down a layer of one or two inches of water each night in cold weather, you can freeze up several feet of water with no trouble at all. In central Alaska, the most freezing in a filled lagoon would be a four foot depth. By putting down two inches a night all winter for six months, the theoretical feet of ice would be so great that you would have trouble thawing it all out again during the summer.

The experience in Copenhagen, Denmark, has been that even mild frost will freeze sludge. We think of Copenhagen as being far north, yet only about half of the year does it have enough frost to make good skating on ponds. However, the City of Copenhagen very successfully freezes its sludges. Every little frost drops the sludge out as a sand. Then the water is decanted, and another thin layer of sludge is applied. The ponds are not operated in depth.

One further comment on the volatile content of the sludge. The "combustible matter" is not all organic. Aluminum hydroxide is extremely difficult to dehydrate, it does not dehydrate completely at 105 degrees C, and the rest of the dehydration takes place after it is put in the furnace. Most of the volatile content of these sludges is just plain water of hydration.

MR. DOE: In view of Mr. Dean's statement, I would like to comment on the effect of freezing sludge. I think one important point we must recognize today is that all sludges are different. It certainly is incorrect to say we can treat all sludges by a specific process and obtain similar results.

The particular sludge reported upon in one of my papers was from an upland catchment area in England. This was an alum sludge which showed a spectacular change after freezing.

I have recently tried freezing on two different sludges from plant in the U.S. These were frozen in the laboratory, and we got similar results. These samples had more suspended solids, whether due to the river turbidity or to the activated carbon used, I don't know. I am now quite willing to believe that not all sludges will freeze with such spectacular results as the upland catchment sludge on which I first experimented. But this is an effective process even although it may well be not very economical.

May I comment on the research report in another respect. I feel that this reports a series of isolated but nevertheless important incidents. Unfortunately, at the present moment, there is no central service to disseminate all this information. And, second, there is no coordinated program at all. Each investigation is an "ad hoc" project. This situation exists in all the countries that we are talking about.

Personally, I feel that we now have plenty of tools for the treatment of these wastes: vacuum filtration, freezing, pressing, and so on. I like pressing very much, and I hope this process will be discussed later.

I do think it is important that a continuing program be organized. In particular, I hope that a clearing house is created, preferably through the AWWA Research Foundation, to collect and disseminate new information.

MR. TCHOBANOGLOUS: I have two specific comments and a general comment dealing with the characteristics of sludges produced of water treatment plants.

First, attention should be directed towards defining the thixotropic properties of these suspensions as related to their dewatering. It is important that the relationship between the mineral and organic composition of the sludge and the property of thixotrophy be defined.

The second specific comment deals with the use of polymers. At present, the process of polymer selection can best be described as random. Characteristically, a number of polymers from various manufacturers are tried until one is found that seems to work. What is needed, however, is an ability to first define the properties of the suspensions and then to design or select a polymer that will produce the desired results. Based on conversations with polymer chemists it appears feasible to think in terms of specfically designed polymers.

As a general comment I would like to state that, after reviewing the literature on this subject as well as the conference status reports, it is painfully apparent that more systematic approach to the study of the disposal of sludge from water treatment plants is required. For example, although much data may be found in the literature on this subject it is of little value since it cannot be cross-correlated: in almost all cases the characteristics of the sludges were not defined. What in needed is for research workers to establish priorities in delineating the problem, so that we may begin to systematically gather meaningful data which can be used to optimize the design and operation of sludge disposal facilities.

MR. DICK: I would amplify the comment on the discontinuity in our approach to this problem and the need of a clearing house. Note that on the first page of the status report on research we referenced a number of previous reviews of this type which were made and essentially lost. This is an unfortunate thing.

We have been talking about thixotropy, and perhaps a definition is in order. The structure of thixotropic materials breaks down with time when they are sheared. For example, a lagoon filled with alum sludge may look as though you would walk across it. If a drag line is dropped into the sludge, the material changes into a thin "soup". That is thixotropy. We don't know very much about this property with regard to alum sludges.

MR. SHULL: First, I can confirm the comments on sludge freezing made by Mr. Doe. On a laboratory scale we tried freezing three different types of sludge: One of these was a straight alum sludge, another was an alum sludge developed from water containing high turbidity, and the third was an alum sludge containing activated carbon. On thawing, each of these sludges produced the "coffee grounds" form. The material filtered rapidly and the filtrate was clear.

I want to mention the use of polymers. In treating filter backwash water, the addition of alum will sometimes improve settling of the solids. Other times a polymer is needed. Apparently the best chemical to use is related to the zeta potential of the floc particles. When the potential is positive, an anionic polymer works best; when negative, either alum or a cationic polymer works best. Thus, in plant operation we have to vary the chemicals used from time to time as determined by jar tests and zeta potential determinations.

Finally, I want to say a few words about recent research carried out at one of our plants by representatives of the Sharples Division of Pennwalt Corp. This study, which ran from July 1, 1968, until November 19, 1968, involved the use of several types of centrifuges and it attempted to show the effect of centrifuging on sludge dewatering. The sludge contained alum and activated carbon.

A preliminary report just submitted by Pennwalt shows the following: Changes in raw water turbidity (and accompanying changes in pH) are reflected quite directly in the compaction characteristics of the solids both in the sludge clarifier and in the centrifuge cake. The clarifier is a Walker Process Clariflow, in which the sludge is removed continuously.

Centrifuge feed concentrations through the summer ranged from 0.2% to over 4% (by weight) suspended solids. Cake concentrations up to 18% were obtained, although 15% was a more normal limit for high feed concentrations. At lower feed concentrations, the concentration ratio between centrifuge cake and clarifier sludge was approximately 10:1 for reasonable centrifuge time cycles.

After several modifications to the centrifuge, recovery of sludge solids exceeded 95% with almost clear effluent obtaining much of the time. On all but two days (with usual turbidity conditions) centrifuge cakes met the "inversion" tests (viz., cake would not flow out of an inverted jar).

Two 50-hour continuous pumping tests as well as other operating data showed the sludge rates required from the clarifier for different values of raw water turbidity and the resulting feed concentrations. It appears that a centrifuge operating at 45 - 50 GPM should handle the clarifier sludge in most cases.

Under some conditions of low solids concentration, capacities up to 50% higher and occasionally to 100% higher might be needed for relatively brief periods. One 48" X 30" Tornado-Matic unit operating at 1300 G should meet the usual conditions.

Filter backwash samples collected over several washing cycles, twice during the summer, indicated a probable average backwash loading of 200 - 250 ppm suspended solids. Assuming the probable worst conditions for filter operation (backwashing every 10 hours), and a sludge which would settle in an auxiliary clarifier with alum addition to sometimes over 1% concentration, an additional 48" X 30" Tornado-Matic would be required to dewater the underflow sludge from the auxiliary clarifier, unless it were considered feasible to return this auxiliary flow to the head of the plant.

Some study was made of the effect of polymers on sludge dewatering by centrifugation. Most of the time the sludge was centrifuged without the use of conditioners. A solids recovery of 95 percent was obtained without conditioning. There was some improvement using a cationic polyelectrolyte, but not a great deal.

MR. DICK: Your comments show that it has been possible to rationally select a polymer on the basis of physical behavior - namely, zeta potential. You mentioned pH and other characteristics which influence compaction. These are reasonable influences, but they have not yet been explored.

MR. TCHOBANOGLOUS: We have tried process control through zeta potential measurement, and find a great variability amongst various polymers. There may be one polymer which reduces the potential with a 1 ppm dose, and another which requires a 30 ppm dose to get the same reduction in potential. We have found the best operational results occur when a slight negative potential exists.

MR. SHULL: These findings correspond with ours. In one particular case, where the zeta potential was slightly positive, an anionic aid (Rohm & Haas Primafloc A-10) did an outstanding job. Four milligrams per liter was the required dose. On the other hand, about 12 mg/l of another anionic aid would have been required.

When the zeta potential went on the negative side neither anionic aid was affective. In this instance, however, Primafloc C-7 (a cationic aid) did a tremendous job. So did alum. Actually, alum and C-7 were about equally effective.

Once again, when the zeta potential changed to positive, neither alum nor C-7 were effective and we had to change to the anionic aid.

MR. DICK: We have tried the use of various polymers for treating wastewater sludges. The results have been utterly frustrating.

MR. ADRIAN: We have done some work on freezing an alum sludge having a considerable content of activated carbon. In one test, the intrinsic permeability of the sludge decreased by a factor of 50 to 55; that is, from a value of 10.7×10^8 before freezing to a value of 0.17×10^8 per cm^2 after freezing. These solids, after freezing, exhibited the characteristic "coffee grounds" form.

It was noted that the duration of freezing seemed to have some effect. If the sludge was thawed immediately upon appearing frozen, then the change was of the order of 20 to 25 fold as measured by the intrinsic permeability.

MR. DICK: Mr. Neubauer, Do you care to comment on your experiences with centrifugation as opposed to those in Philadelphia. I think they are opposed, aren't they?

MR. NEUBAUER: No, I would say that they are quite comparable. We found that, with lab scale models, the best concentration we could get was close to 15 percent solids and more like 6 to 12 percent. We just didn't feel that this concentration could be handled for disposal by landfill. I would like to ask how Mr. Shull planned to handle sludge at that low a concentration.

MR. SHULL: We haven't gone that far. Ours is a pilot plant test, but it is definitely beyond the laboratory. In our experience, the centrifuged cake of 15 percent solids appeared to be a material which could be hauled

MR. NEUBAUER: We found that a centrifuge cake of 6 to 12 percent solids was a very greasy material. It appeared that hauling this material in a truck would present a lot of problems. We felt that a reduction to about 20 percent solids was needed before it could be handled readily.

Just one other point. On the question of freezing, while we didn't report on it, we did perform some laboratory tests on the Monroe County sludge, and obtained very similar results - a "coffee grounds" type of sludge solids.

MR. BISHOP: We have been working with the Monroe County Water Authority to develop a method for handling their particular sludge disposal problem. Since Monroe County lies in upper New York State and experiences cold winter weather for extended periods of time, freezing of their sludge appears to be an economical method for consolidation with resulting disposal of the dried waste as land fill.

Our first step was to freeze, in the laboratory, a sample of the sludge from their upflow clarifiers. The sample of sludge had thickened to about 3.5 percent total solids prior to freezing. After freezing, the sludge had consolidated to a 17.5 percent total solids concentration.

The results of these tests encouraged us to construct one test lagoon which was operated through the winter of 1967-68. This lagoon was filled to a depth of about 30 inches in January of 1968 with a sludge containing 0.3 percent total solids. The test was terminated on August 1 with a resulting sludge total solids concentration of 34 percent or about twice the results which were obtained from the quick-freezing method performed in the laboratory.

In analyzing the cause for this increase, there is a large increase in holding time, thereby allowing consolidation of the sludge. The supernatant in the test lagoon contained about 5 mg/1 of solids. The settled sludge in the bottom of the lagoon contained about 76 percent combustible material and about 24 percent ash. After decanting the supernatant liquid from the lagoon, about one week was required to dry out the sludge to allow ease of handling.

Presently, we have three test lagoons in service which have been operated through the winter season of 1968-69. Our approach at this time has concentrated on the disposal of sludge on a batch basis. The three lagoons were constructed with varying depths of 2 ft., 3 ft., and 4 ft. From these three test lagoons, we hope to obtain additional data relating to the effectiveness of varying lagoons depths. No results are available at this time.

MR. DICK: Will any individual studying freezing explain the mechanism to me? I think there is no explanation in the literature. Are there some ideas from the group?

MR. DEAN: Really, we don't know. However, slow freezing will form ice crystals. Water is removed from the sludge. In general, the information of ice is inhibited by a colloid. Normally the ice crystal grows at the expense of the water of hydration of the colloid around it.

The frost heave in clay soil is similar. Here, water migrates from the clay into the ice crystal and dehydrates the clay around it.

I think the same sort of thing happens in freezing aluminum hydroxide gel. In freezing, water moves into the ice crystals, leaving the aluminum hydroxide. When the ice is melted, there is no great force pulling the water back into the gel.

Now, the effectiveness of freezing decreases as the organic colloid content increases. If we freeze activated sludge, as we are doing in Milwakee, then slow freezing must be used. Fast freezing would not allow the water time to move out of the colloid into the ice crystal. No spectacular change takes place: the "coffee grounds" form does not result. The sludge, if very carefully handled, can be dewatered on a screen. If the sludge is pumped any distance, or run down a flume, most of the effect of freezing will be lost. What has been described is the extreme case of a sludge having a very high content of organics. We are now working with activated sludge containing alum.

The ultimate disposal of alum sludges is something I should have said more about. Thick layers of alum sludge will clog the soil, as Mr. Doe has described on the basis of his experience. We know that if alum is put on the soil and allowed to dry down, it will inhibit seed sprouting. We have made a little study of organic sludges containing alum. It doesn't take very much force to break up this crust. If freezing occurs, there is no trouble with alum.

Getting back to disposal of alum, Mr. Barth, in Cincinnati, has been studying the addition of alum or sodium aluminate to trickling filters and activated sludge plants. He report that the aluminum hydroxide has no effect on the biological operation of the activated sludge plants, and little effect on the trickling filter plant. If you waste alum sludge to the sewer at the rate it is produced, our evidence indicates that there will be no upset of the biological plant, and there may be some increased phosphate removal.

MR. NEBIKER: What is the effect of alum sludge on sewage sludge digesters?

MR. DEAN: The effect of aluminum hydroxide on digesters has been studied on only a small scale. We have small 15-gal. digesters that appear to operate very well with added alum sludge. No influence on digesters or on sludge drying was noted when 110 parts of alum equivalent was added to the activated sludge feed to the digesters.

MR. BACH: It is interesting to note that, in practically every instance, studies of freezing alum sludge give results similar to those reported by Mr. Doe. At Minneapolis we have made such studies and find that, on thawing, water separates readily and leaves granular solids.

We are not presently using alum as a coagulant except in our experimental plant. Our interest in research on alum sludge disposal is as a very practical problem - we have no space available to dispose of sludge as land fill. We have made some study of centrifuging and some of filter pressing. With each method, we found it necessary to use about 125 ppm of coagulant aid in order to remove 95 percent of the solids. We are very interested in some means of concentrating the sludge and drying it.

MR. KINMAN: One point has been made, and I think we need to emphasize it again: the fact that these sludges are different, even within the same treatment plant, and this may account for some of the variations in the research results.

Maybe one of our primary needs is to be able to characterize an alum sludge chemically. Some reports do not indicate what the chemical characteristics of the sludge actually were. I am referring to changes in the nature of the sludge which result from variations in the quality of raw water, and of chemical dosage which affect changes in the composition of the sludge.

MR. LACY: This comprehensive report would be much more useful if the authors could point out future research and development requirements as the participants see them, no matter how imaginative and far out the ideas might be.

Also, I think there should be some elaboration in this report on the possible industrial applications of the lime sludges, for example. I have no experience on sludge utilization to cite, but encourage studying this.

MR. BLACK: I can mention two recent reports on practical applications of lime softening sludges. One describes the use of such sludge to remove sulfur dioxide from a hot gas stream (Hawkins and Malina, 1969). The second describes phosphate removal characteristics of lime softening sludge (Emery and Malina, 1969).

These two references should be added to the excellent bibliography prepared by the AWWA Research Foundation as a part of this report. (Note: These references have been included in the bibliography.)

MR. DICK: The need for pointing out areas where research is needed is certainly an important contribution to be made by this Conference. We hope to do that in our Committee reports.

This concludes discussion of the status report on research.

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STATUS REPORT ON ENGINEERING

Walter K. Neubauer and Donald P. Proudfit

TREATMENT AND REUSE OF FILTER WASHWATER

In the past it has been common practice for washwater wasted from water purification plants to be discharged directly to the nearest stream as filters are washed. Recent emphasis on control of pollution sources and the fact that the water works industry is the major benefactor of this emphasis, has made direct discharge of the washwater unacceptable in most cases.

Characteristics of Washwater

Filter washwater may contain fine clay particles, hydroxides of iron and aluminum, iron oxide, activated carbon and other materials representative of the chemicals used in water treatment. The wastes will often include debris and chemical precipitates from the filter media and small portions of the media itself, and they may include a concentration of strainings of organic debris. Turbidities have been recorded in excess of 2,000 mg/l. Excessive chemical doses may change the character of the washwater (Dean, 1953, and Hall, 1947).

Typical 5 day BOD values for alum plant washwater are extremely low, ranging from 0 to 5 mg/l. COD values have been recorded as high as 160 mg/l. The pH values are reported to range from 6.9 to 7.8 (Russelmann, 1968).

The solids content will vary during backwash with peaks in excess of 800 mg/l (O'Brien and Gere Report, 1966) and average values ranging up to 400 mg/l for plants utilizing alum. Average values are cited as 1500 mg/l for plants utilizing iron and manganese removal (Russelmann, 1968). Approximately 1/3 of the total solids are volatile in most cases. Suspended solids range from 40 to somewhat in excess of 100 mg/l in alum plants, and up to 1,400 mg/l for plants utilizing iron and manganese removal. Average values of suspended solids are reported at approximately 800 ppm (Walton).

Reuse of Washwater

Many chemical coagulation plants reuse filter washwater. Since the washwater comprises 2 to 5% of plant flow, many plants practice conservation by recycling filter washwater, thus eliminating the washwater as a waste stream.

Wichita Falls, Texas, mixes the filtered backwash water with a lagoon overflow before recycling.

It is sometimes desirable to settle the backwash water before recycling. Colorado Springs has a 20 mg reservoir converted for reuse of washwater. At this plant, 97% of the turbidity and 79% of the total solids are removed in one hour after each backwash (Proudfit, 1968). Recirculation of filter backwash waters is practiced in some plants only during periods of low flow.

Direct Discharge of Washwater

The most common method currently utilized in the disposal of filter washwater is direct discharge to a watercourse.

In a survey of some 1700 plants, it was shown that 93% of the plants eventually discharged filter washings into streams or lakes without treatment (Dean, 1953).

When it is deemed necessary to discharge filter washwater directly to a watercourse, low flow augmentation can be utilized to offset the pollutional loading.

Treatment Methods

A small number of plants treat filter washwater before discharging them to stream. The most common methods of treatment include lagoons and settling basins. In the survey referenced above, this type of treatment was used in only 2% of all plants surveyed. Even when lagoons are employed, there are normally no facilities for removal of the sludge that accumulates and this is sometimes discharged at high water levels (Hall, 1947).

A substantial portion of the suspended solids may be removed by settling basins or lagoons. When these clarification basins are large in size, provision should be made for surface withdrawal of the supernatant and removal of sludge accumulation.

No papers outlining other forms of treatment were found in the literature searched.

COAGULANT SLUDGES

Sludge Characteristics

The water treatment plant wastes most difficult to treat are those resulting from chemical coagulation processes. Such sludges are likely to contain inert materials such as sand or silt, organics in solution or suspension, microscopic organisms of considerable variety, and constituents characteristic of the chemicals used in the process: aluminum or iron salts, polyelectrolytes, lime, soda ash, caustic soda, etc. (Russelmann, 1968). These constituents yield a chemical suspension or sludge of extremely high moisture content (over 98%). This sludge varies in color depending on the nature of the impurities and remains insoluble in a pH range of natural water. When discharged to streams of low velocity if may form sludge banks and, on occasion, has caused unpleasant odors.

Perhaps the most important parameter in discussing wastewater sludge is the solids content. Reported values for alum sludges range from 1,000 to 17,000 mg/l dry solids, with suspended solids usually accounting for 75 to 90 percent of the total (Neubauer, 1968; O'Brien and Gere Report, 1966; Russelmann, 1968). The volatile content ranges from 20 to 35 percent of total solids.

The biochemical oxygen demand (BOD) is relatively low, approximating that of secondary sewage effluent. In carrying the BOD test to its ultimate value it was found that a considerable amount of BOD was exerted after the initial 5 day period. In one instance, the 5 day BOD was less than 30 percent of the ultimate demand. Typical values of 5 day BOD range from 30 to approximately 150 mg/l.

The chemical oxygen demand (COD) is considerably higher. It

TABLE I

COAGULATION SLUDGE CHARACTERISTICS

From: Russelman, 1968

Plant	Treatment	BOD (5-day) mg/l	COD mg/l	pH	Total Solids mg/l	Volatile Solids mg/l	Total Suspended Solids mg/l	Volatile Suspended Solids mg/l
A	Alum Coagulation & Sedimentation	41 72 (1) 144 (2)	540	7.1	1,159	571	1,110	620
B	Alum Coagulation, Clarifier	90	2,100	7.1	10,016	3,656	5,105	2,285
C (3)	Alum Coagulation, Clarifier	108	15,500	6.0	16,830	10,166	19,044	10,722
D'	Alum Coagulation Clarifier	44	XXX	6.0	XXX	XXX	15,790	4,130
E	Diatomite Filter	105	340	7.6	7,466	275	7,560	260

(1) BOD after 7 days
(2) BOD after 27 days
(3) Activated carbon in sample

has been found to range anywhere from 500 to 15,000 mg/l, the higher value being due to activated carbon present in the sample.

Table 1 illustrates some typical values of coagulation sludge characteristics.

The dry unit weight of coagulant sludges ranges from 75 to 95 lbs/cu.ft. (Krasauskas, 1968). For purposes of disposal by landfill it is estimated that a 20 percent solids content is nesessary. Alum sludge at 20 percent solids was found to have a unit weight of approximately 73 lb/cu.ft.

Direct Discharge to Lakes, Streams, etc.

The most common method of disposal of coagulant sludges presently is by direct discharge to water courses. In a survey of 1,530 filter plants it was revealed that 92.5 percent discharged sludges directly (Dean, 1953).

The satisfactory disposal of sludge in streams or rivers is dependent upon flow for adequate dilution. Controlled discharge at high flow will help, but of course requires storage facilities. Filter plants at Bangor and Biddeford, Maine, and Lawrence, Massachusetts pump raw water from large rivers and disposal of sludge and washwater in these streams with ample dilution is reported to be a practical and economical method (Smith, F.E., 1948).

The City of Atlanta treats a most difficult water from the Chattahoochee River by coagulation with alum. The 30,000 lbs per day of sludge produced, together with the washwater, are returned directly to the river below the intake. Because of the polluted status of the Chattahoochee, the wastes from the water treatment plant have been regarded as of relatively minor importance. However, a major research project is now being undertaken by the Atlanta Water Department for more satisfactory methods of disposal (Doe, 1966-67).

The list of plants utilizing this method of disposal is almost endless. The growing emphasis on pollution control is turning what has been in the past a very economical method of disposal into one that is completely untenable. For many treatment plants adequate methods of disposal other than direct discharge simply have not been available.

Concentration of Coagulant Sludges

Of primary concern in disposal of sludges is the reduction of volume. In the case of coagulant sludges not only is the waste disposal problem reduced, but in many cases the supernatant from such reduction can by used to supplement the raw water source.

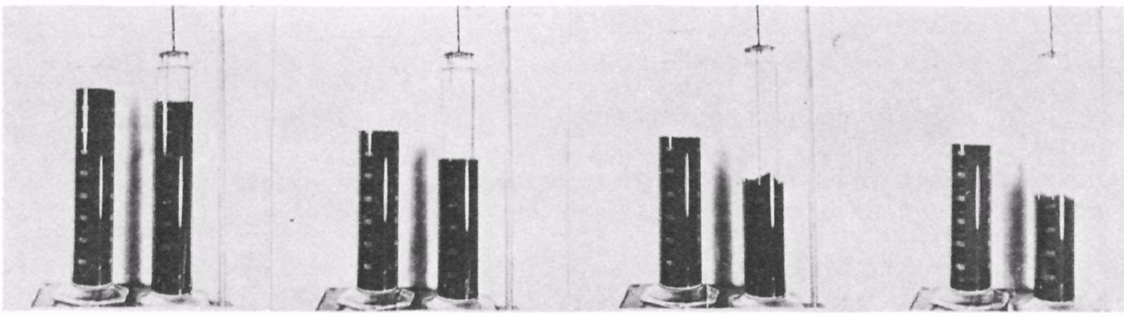
The simplest method of sludge concentration is plain sedimentation. Some preliminary design criteria for sedimentation of coagulant sludges indicate that a settling basin designed on a one hour detention time, above four months sludge storage, should suffice (Hall, 1947). Settling tests on alum sludge indicate that the sludge could be brought from 0.5 to 1 percent solids through sedimentation (McWain, 1968; Neubauer, 1968; O'Brien and Gere, 1966). Vertical flow tanks, by the very nature of their design, are usually desludged periodically as part of the operation of the tanks. On the other hand, horizontal flow tanks are usually emptied two or three times a year. Design considerations should include the volume and thickness of the sludge produced (Doe, 1966-67).

A promising new method of sedimentation titled Lamella Sedimentation has recently been developed at Chalmers University in Sweden. Its main advantages are that it greatly reduces the volume of the sedimentation tank and limits the problem of piping during de-sludging. The process consists of the upward flow of flocculated water at an angle of some 55 to 60 degrees from the horizontal, between a series of parallel plates spaced a few inches apart. The tanks are designed to have a throughput capacity of 3 cubuc meters per hour per cubic meter of volume, some five times that of conventional sedimentation tanks (Doe, 1966-67). The method is analgous to that utilized by Neptune Microfloc in the United States (Culp et al., 1968).

Sedimentation may be greatly enhanced by thickening whereby the sludge is stirred during the sedimentation process. The simplest and most widely used form of disposal of hydroxide and lime softening sludges in the United Kingdom involves collection and thickening by natural sedimentation and holding tanks prior to disposal in lagoons or drying beds (Young, 1968). The effectiveness of thickening for coagulant sludges is well documented in the literature.

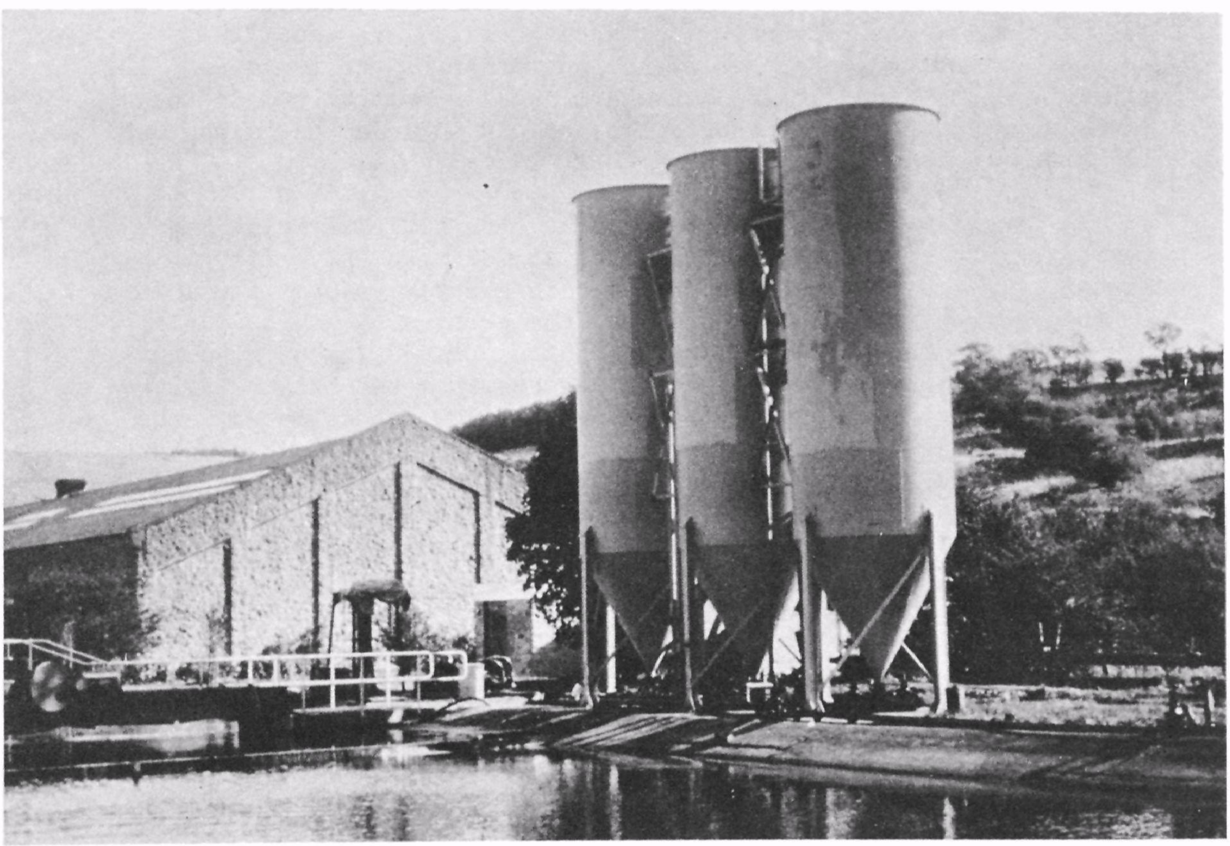
Detailed design and operating criteria for sedimentation and thickening are readily available in the literature on sewage treatment and industrial waste disposal.

SLUDGE THICKENING



1 hr 6 hrs 12 hrs 24 hrs

THE EFFECT OF SLOW STIRRING



Stocks Plant, Fylde Water Board, England

Left: 30-foot diameter Stirrer

Right: Three Sludge Thickening Tanks

TREATMENT OF COAGULANT SLUDGES

Discharge to Sanitary Sewers

An increasingly popular method of disposal of coagulant sludges is discharge to sewage treatment plants via sanitary sewers. In a survey of over 1,500 plants Dean found only four that used this method prior to 1953 (31). A number of large cities, such as Detroit, Wilmington, and Philadelphia presently discharge to sanitary sewers. There are no reported difficulties at the waste treatment plants involved caused by the addition of the sludge, with the exception of some initial problems in the vacuum filtration process at Detroit (Krasauskas, 1968). Some chalk sludges have been found capable of neutralizing acid wastes and actually provide a benefit to the sewage treatment plants (Anon., Civil Eng., 1949).

Depending on their nature, specific sludges may actually work as coagulant aids in the treatment of sewage. An example of this would be the use of sludges containing lime as coagulant aids for vacuum filtration.

A flow velocity of 2.5 fps is used to prevent settling of these coagulant sludges in Detroit sewers. The possibility of the sludge silting in the sewer must always be considered (Smith, 1948; Doe, 1966-67; Krasauskas, 1968).

Another major problem in the discharge of coagulant sludges to sanitary sewers is the possible slug load on the sewage treatment plant. Most sedimentation basins in water treatment plants are cleaned by completely unwatering and the sludge is pumped to the sewer as a slug.

Evaluation of the following considerations before discharge of a coagulant sludge to a municipal treatment plant is recommended (Smith, 1948):

1. Waste damage to sewer system.
2. Amenability of the waste to existing treatment processes.
3. Hydraulic capacity of sewage treatment facilities.
4. Strength of the waste in relation to interfere with the treatment processes.
5. The effect of waste on the final plant effluent.

The following recommendations have also been made (Doe, 1966-67):

1. Cross connections must be precluded, possibly by a water break, to insure that if the sewer backs up the raw sewage passes elsewhere.

2. Sludge should be discharged as an average flow over 24 hour period, not as a slug flow.

3. Fears have been expressed that an alum sludge would choke the bacteria in trickling filters; the activated sludge process, however, does not seem to have such drawbacks.

Use of Lagoons

The most common treatment method presently utilized at water treatment plants for handling coagulant sludges is lagooning. In areas where ample land is available, lagooning can be quite economical. It enables the utilization of natural temperatures (both drying and freezing) to aid in the dewatering of the sludge.

The major problem in many lagoons is that the sludge is not sufficiently concentrated so that it can be removed from the lagoon to land fill. Typical solids contents obtained by lagooning coagulant sludges range from 1 percent to as high as 10 percent. The detailed study of lagoons at the Monroe County Water Authority Shoremont Plant, in New York state, indicated that after three years of lagooning, the highest solids concentrations found anywhere in the lagoon was about 10 percent (McWain, 1968; Neubauer, 1968; O'Brien and Gere Report, 1966).

Lagoons may also be provided with underdrain systems. The British Water Research Association is proceeding to investigate such artificial drainage in lagoons (Doe, 1966-67).

Drying Beds

Sand drying beds are used extensively for the dewatering of sewage sludges. These beds usually consist of 6 to 12 inches of sand ranging in size up to 0.5 mm. The underdrain system includes graded gravel, varying in depth from 6 to 12 inches, and 6 to 8 inch drain pipes to convey the filtrate from the beds. A number of parameters affect the ability of the drying beds to dewater the sludge. These include air temperature and humidity, wind currents and viscosity of the sludge.

A Colorado Springs Plant is designed to treat basin sludge with drying beds. Sludge from the recovery basin will be discharged to drying beds and it is expected that only a small amount of clear filtrate will be discharged from the beds to the stream. After natural drying, sludge will be landfilled (Proudfit, 1968).

Bench scale tests performed on alum sludge indicate that a solids content of 20 percent can be obtained in 70 to 100 hours with 97 percent suspended solids removed from the filtrate. These tests indicate that a final filtrate containing suspended solids in the range of 200 to 450 mg/l could be expected, dependent on the sand size and the time required to reach the required solids content. A 1.0 mm sand was found too coarse to yield the necessary filtrate quality.

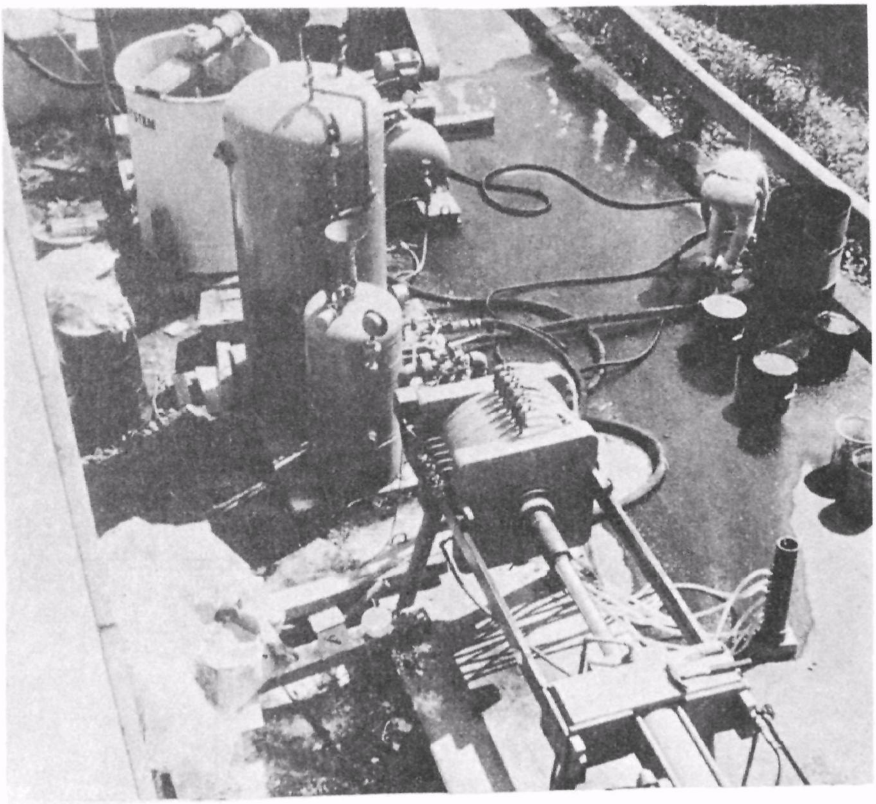
Another form of drying beds, termed wedge wire filtration, has been reported (Sankey, 1967). This utilizes mesh sizes ranging from 0.125 to 0.25 millimeters. An optimum depth for a 2 percent solids sludge is given at 6 to 12 inches. Beds must be covered for the first 7 to 10 days, and then can be left open for a 21 day draining and drying period. It is also possible to layer new sludge over the old. Beds should be designed in pairs with a traveling cover.

Vacuum filtration

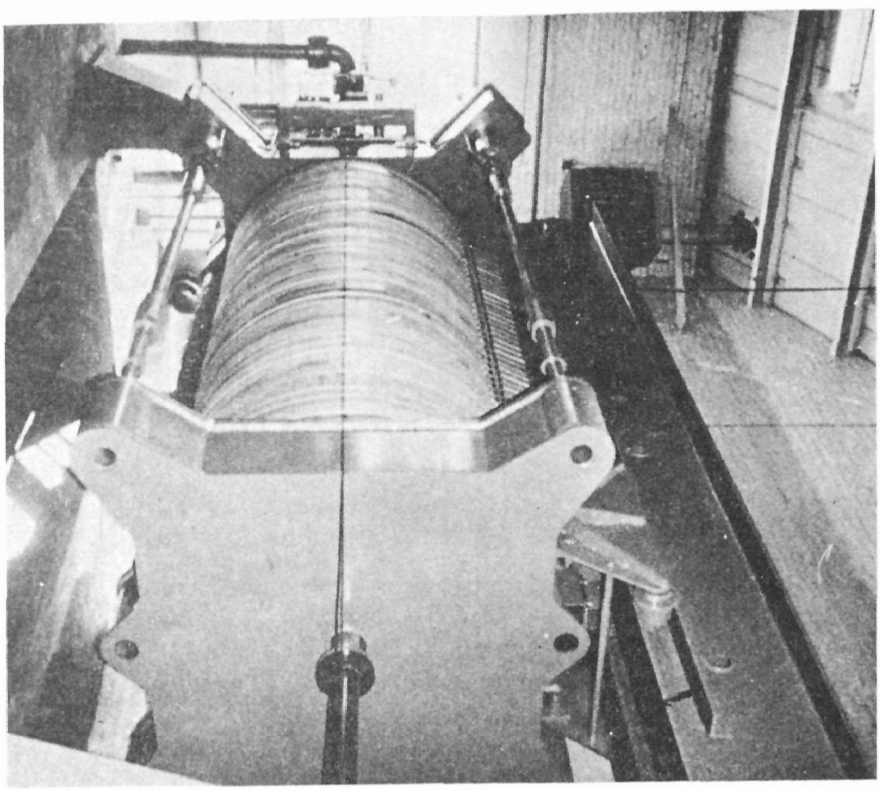
The vacuum filter has long been a popular method for dewatering sludges in the waste treatment and chemical process industries. Its application to coagulant sludges has, however, met with limited success. The Opel Car Works in West Germany has been listed (Doe, 1966-67) as making the only successful application of vacuum filters to alum sludges. The success is attributed to the tremendous amount of calcium carbide, readily converted to lime, available as a by product of the car works. Cake thickness varied from 2 to 20 millimeters and solids content ranged from 20 to 40 percent.

While vacuum filters are often used with lime sludges, a precoat is required with hydroxide sludges (Young, 1968). This was borne out in numerous bench scale tests where a pre-coat was required at 2 percent solids content, giving filter loadings of 5.6

SLUDGE PRESSING



Pilot Scale
Sludge Pressing
Equipment
(New Jersey)



Full Size
Sludge Press
Industrial Use
(USA)

gph per sq.ft. with a pre-coat of 1 pound per 10 gallons. Cake solids approximated 15%.

Tests of a rotary vacuum pre-coat filter at the Albany treatment plant by Johns-Mansville indicated successful dewatering of 1.25% solids content sludge to 32% cake.

In an unique application of an industrial waste, H. R. Peters of the Atlanta Waterworks reports that a combination of coagulant aids, alum sludge and a paper pulp filler yielded a loading rate of 5 lbs. per hr. per sq.ft. on a rotary vacuum filter.

Pressure Filtration

Pressure filters are used extensively in the chemical process industries for dewatering sludges. They have been utilized in England in the treatment of waste coagulant sludges, but their use in treatment of these sludges in the U.S. has not been extensive.

Pressure filters are utilized with dewatering of alum sludges at the Arnfield Water Works. A 1.8% raw sludge, after conditioning with lime, is pressed to get a cake thickness of 25% solids. Pressing time is normally eight hours (Doe, 1966-67).

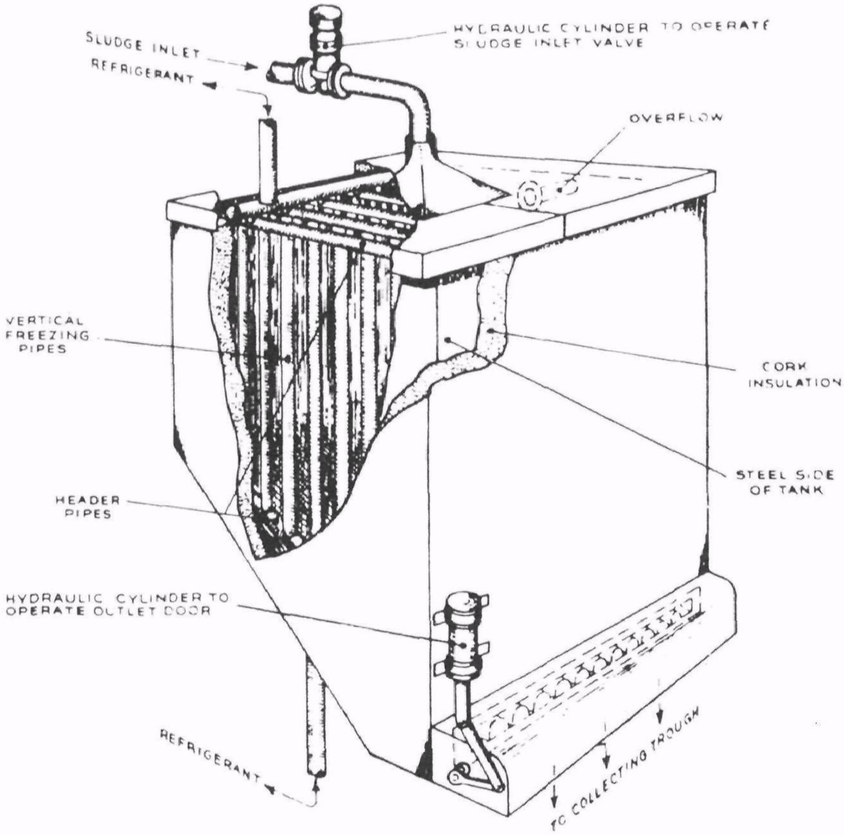
The Daer Water Works reports 18.3% solids in an alum sludge after 24 hours of pressing. Addition of a lime slurry to the sludge reduced the required pressing time to 6 hours (126). A number of other reports indicated success with pressure filtration of chemically pretreated alum sludge (Webster, 1966; Sankey, 1967; Young, 1968; Doe, 1958).

Centrifugation

The success of centrifugation in dewatering lime softening sludges has been demonstrated in many installations throughout the world, due to the relatively high ratio of solids weight to liquid weight. However, in the case of coagulant sludges, this ratio is very low.

A number of investigations have been conducted on the use of centrifuges for dewatering coagulant sludges and several full-scale installations have been built. At present, however, the process has been found to be unacceptable for this purpose.

SLUDGE FREEZING



Sketch - Typical Alum Sludge Freezing Unit

To thaw, flow of refrigerant (ammonia) is reversed

Doe, P.W., Report

British Waterworks Association

Used by permission

Doe, in 1966-67, published an review of water works waste disposal practices throughout the world. He found no successful examples of dewatering of alum sludge by centrifuging. Lab scale tests experienced difficulty in obtaining greater than 12% dry solids by this process although Peters, in 1968, reported getting 25-30% dry solids from recent experiments conducted at the Chattahoochie Water Treatment Plant. The latter results may be affected by the relatively high turbidity of the incoming raw water plus the addition of lime (along with alum), resulting in a sludge with approximately 5% dry weight of solids.

Freezing

Dewatering of sewage sludge by freezing was first studied and reported on by Clements, in 1950. Consideration of application of this method to alum sludge was given by Palin, in 1954, and again by Doe, in 1958. These early experiments on this process indicated that the freezing of a coagulant sludge would produce a physical change in the solids which is quite dramatic. The gelatinous consistency is dissipated and sludge particles become of a finite size, similar to grains of sand. Saturation with water does not produce any marked dissolution of the particles.

Based on this early experimentation, the Fylde Water Board in Blackpool, England, through Frank Law, Engineer for the Board, constructed a full-scale plant at the Stocks Waterworks for the freezing of alum sludge. This plant has operated successfully since 1961, and a second plant at Fishmoor has operated successfully since 1964. The design, construction and operation of these plants have been reported upon quite fully by Doe.

In Scotland, the Daer Water Works is in the process of constructing a sludge freezing and alum recovery plant for its water works. This plant was expected to be in operation in 1968. The basis for this process has been discussed (Webster, 1966) and further reported upon (Young, 1968). Other plants reported to be constructing facilities for the mechanical freezing of sludge are at Tokyo, Japan and Lippstadt, W. Germany (Doe, 1966-67).

In those climates where frost occurs frequently during the winter months, natural freezing of alum sludge is a distinct possibility. The only full-scale natural freezing operation concerning alum sludge is being practiced at the Søndersø Treatment Plant of the City of Copenhagen, Denmark. This process has operated very successfully since 1963 (Doe, 1966-67; Christensen, 1968). The freezing of the sludge takes place in lagoons with an effective height of one meter and having a drained gravel bottom. As a result of the freezing and thawing cycles, and drainage through the gravel, the sludge reduction is dramatic. The amount of sludge remaining after 2 years of operation consisted of a layer about 4 centimeters deep.

Experiments in natural freezing have also been conducted in the United States at the Shoremont Plant of the Monroe County Water Authority in Rochester, New York. Reports have indicated that natural freezing of the alum sludge from Shoremont in lagoons does produce a very marked reduction of sludge solids. Freezing also results in a change in the character of the solids which should permit of easy disposal (McTighe, 1968; Bishop, 1968).

Heat and Pressure

Very little is known about the treatment of coagulant sludges by heat, i.e., high temperatures applied to the sludge under pressure. Palin (1954) reported on experiments utilizing the Porteous process for dewatering sewage sludge. These experiments showed that coagulant sludge volumes were substantially reduced by application of heat and pressure at levels below that utilized by the Porteous process. Doe (1958) felt that heat treatment or "boiling the sludge under pressure" would be effective in destroying the gelatinous nature of alum sludge.

Chemical Recovery of Alum

Although it has been reported that attempts were made in the early 1900's to reclaim alum from water treatment plant sludge, the first definitive investigations seemed to have been made by Eidsness of Black Laboratories, Inc. for the City of Orlando, Florida (1952). Later studies were made by Palin (1954) and Vahidi (1960).

The first engineering investigation leading to full scale operation of a recovery plant was undertaken by Roberts and Roddy (1960) for the water treatment plant at Tampa in the late 1950's. Based on these experiments, a portion of the Tampa treatment plant was converted to recovery aluminum sulfate from the aluminum hydroxide sludge by the addition of sulfuric acid. The full scale plant operated for a short time and then the process was abandoned, according to Doe (1966-67), because of the rapidly changing water quality and the fact that at times softening was required, resulting in no production of hydroxide sludge. In addition, the high color residual could not be eliminated except by high doses of chlorine, and the entire process required constant and skilled supervision.

At the Daer Water Treatment Works near Hamilton, Scotland, an ambitious pilot plant program reported by Webster (1966) and commented on by Doe looks to a combination of the mechanical freezing of sludge with subsequent recovery of alum by treatment with sulfuric acid. One of the important aspects of the pilot plant study has been to be certain that there is no build-up of color or iron over a period of time. This problem has been experienced in other attempts at alum recovery. The full scale plant at Daer was expected to go into operation in 1968.

DIATOMITE FILTER SLUDGES

Description of Sludge

The nature of the diatomaceous earth process is such that the amount of filter aid is usually twice that of the impurities removed from the water. This means that the filter cake, which is removed from the filter element and disposed of periodically, has characteristics similar to the diatomaceous earth itself. This material is the fossil skeletons of microscopic water plants and is composed almost entirely of pure silica. It has a dry density of about ten pounds per cubic foot and the specific gravity is approximately 2.0.

Direct Disposal

As in most other types of waste from water treatment plants, the filter cake which is removed in diatomaceous earth filtration has, in most cases, been discharged directly to a water course. Because of the relatively high ratio of the solids weight to the liquid weight, settlement takes place relatively rapidly. In deep, quiet waters, the wastes settle out quickly and the nuisance is of a minor nature. In shallow, swift moving bodies of water, the waste can be carried considerable distances and deposited in areas where it can become a nuisance.

Treatment

The only method of treatment of diatomaceous earth sludges in common use today is lagooning. As noted earlier, the ratio of solids weight to liquid weight promotes fairly rapid settlement of the solids in the sludge. Although no specific date are available, observations indicate that a detention time of 2 to 4 hours is adequate to settle out a majority of the solid particles. This relatively short detention time permits construction of small lagoons and the method is thus an economical one.

An installation which has been very successful is at Massena, New York, where a small lagoon treats the waste from a 5 mgd diatomite filtration plant prior to discharge of the supernatant to and old canal. Another plant in Newark, New York, utilizes a small detention basin with equal success prior to discharge of the waste effluent into a very small stream.

BRINE WASTES

Description of Wastes

Brine wastes are principally those resulting from regeneration of ion exchange softening units utilizing sodium zeolite as the resin. These wastes constitute from 3 to 10% of the treated water volume (Haney, 1947; Haney, 1949) and contain substantial quantities of the chlorides of calcium and magnesium with small amounts of various compounds of iron and manganese. Haney in 1949 reported the analysis of a waste brine shown in Table 2.

Russelmann (1968) described the waste effluent of an ion exchange softener near Albany, New York, as containing over 20,000 mg/l of total solids and almost 12,000 mg/l of chlorides. Very little suspended solids are present in waste brines.

The most troublesome component of the waste is the chloride ion derived from the salt used for regeneration. Chlorides cannot be removed by any reasonably economical method.

TABLE 2

ANALYSIS - WASTE BRINE FROM ION EXCHANGE SOFTENER

Item	mg/1
Calcium	1,720
Magnesium	600
Sodium and Potassium	3,325
Sulfate	328
Chloride	9,600
Total Dissolved Solids	15,656
Total Hardness	7,762

Direct Disposal

Direct disposal to streams, lakes and other bodies of water has been practiced to a large extent by many water works operating ion exchange softening units. If the dilution is sufficient to very quickly reduce the concentration of chlorides below an acceptable level, this method may be tolerated. However, if dilution is not adequate, excessively high concentrations of chlorides can create not only a nuisance but problems of a toxic nature, affecting aquatic and fish life and livestock (Haney, 1947; Haney, 1949; Russelmann, 1968).

The U.S. Public Health Service has set a limit of 250 mg/1 of chlorides for potable water. However, lesser concentrations can be harmful to certain life forms. The Federal Water Pollution Control Administration has indicated the hazards of excessive salts, particularly sodium, to irrigation waters.

Sewage Treatment Plant

In some cases, brine wastes have been discharged to a sanitary sewer system and ultimately treated in a sewage treatment plant through dilution. However, if the concentration is high, these wastes may cause corrosion of equipment as they pass through the plant and piping system. If such wastes reach the treatment plant as a slug, they can cause an upset of biological balance of the plant.

Lagoons

Lagoons or evaporation ponds have been used with mixed success, according to reports by Haney (1947, 1949). Because of the lowering of the vapor pressure of the water by the dissolved salts, evaporation from lagoons may be substantially less than for fresh water in a particular area. Haney notes, that, as evaporation does occur, the concentration of dissolved salts is increased with further lowering of the vapor pressure and retardation of evaporation. Even if evaporation is successful, there remains a problem of disposing of the residual salts.

If the soil is porous, brine seepage from a lagoon may result in mineralization of nearby surface streams or ground water. Many instances of pollution of this nature have been reported. The use of a lagoon for temporary storage and then subsequent release to a watercourse has also been reported. This type of operation is suitable where an adequate watercourse is available at certain periods of the year. A method such as this requires careful control of discharges to avoid undue contamination of the receiving stream.

Brine Disposal Wells

In certain geological formations, the use of deep wells for the disposal of brine waste has proven satisfactory. This has been particularly true in the oil fields where large quantities of brine have been disposed of in wells from 400 to 5,000 feet in depth. However, Haney points out that the danger of contamination of aquifers supplying potable water supplies is great. Care must be taken to investigate the geological formation into which the brine will flow and extensive testing must be undertaken from time to time to determine the effects of the brine flow on adjacent water supplies. Care must also be taken that the formation into which the brine is disposed does not become plugged with the products of corrosion. Prevention or removal of these products and suspended matter in the brine before injection into the well is essential.

TABLE 3

IRON AND MANAGANESE SLUDGE TREATMENT

Process	Sludge Form	Sludge Disposal	Comments
Oxidation with or without chemical assist. Slow sand filtration.	Retained on filter media	Physical-mechanical removal from filter media, hauled to disposal site.	Primarily used in older plants. Considered ultimate disposal; no further study needed
Coagulation and clarification. Rapid sand filtration.	Clarifier sludge; retained on filter media	Removed with clarifier and/or filter backwash sludge	Usually combined with coagulation and/or softening sludges. Additional disposal study needed.
Oxidation with chemicals. Pressure or gravity filtration.	Retained on filter media	Removed with filter backwash sludge	Disposal problem same as for other filter backwash sludge
Aeration with pH adjustment. With or without chemicals. Detention. Pressure or gravity filtration.	Retained on filter media	Removed with filter backwash sludge	Disposal problem same as for other filter backwash sludge
Manganese zeolite.	Precipitation on filter, generally anthracite	Removed with backwash sludge. Regenerant brines removed with rinse water	Additional study needed on effects of brines on receiving vehicle
Ion-exchange	Insignificant, predominately and regenerant brines	Removed with rinse water	Additional study needed on effect of brines on receiving vehicle

IRON AND MANGANESE SLUDGES

Processes for removal of iron and manganese from water are categorized in Table 3. Variations of each process are in use but disposal of any sludges would be the same as listed for the basic process category. With the exception of regenerant sludges as referenced under the manganese zeolite and ion-exchange processes, no sludge disposal data were found in the available literature.

MICROSTRAINER SLUDGES

Microstrainer sludges consist primarily of algal growths and larger particles of turbidity. The sludges produced by microstainers are not considered a waste disposal problem by some authorities; however, this is moot and depends on circumstances in a given installation. The Recommended Standards for Water Works (10-State Standards) (146) requires that provisions be made for the proper disposal of washwater. Table 4 summarizes available data on a number of microstrainer installations.

Additional investigation of the installations listed in Tables 3 and 4, such as definitive information on raw water characteristics, special provisions, amount of waste, and its characteristics would be helpful.

PRESEDIMENTATION WITHOUT TREATMENT

Description of specific installations and factual data on controlled tests or nature of presedimentation sludges are not found in available literature. In general, the literature expresses only the author's opinion regarding the degree of pollution to the receiving stream. It is the apparent consensus that pollution is not produced if sufficient dilution of the sludge is obtained in the receiving stream. By controlling the time and amount of sludge discharged to the stream, it is contended proper dilution can be effected. The implied criterion to judge pollutional effect is the formation of sludge banks in the receiving stream. The more recent literature implies that states increasingly classify presedimentation sludges as sources of water pollution along with other types of sludges, and that better methods of disposal must be found.

TABLE 4

MICROSTRAINER SLUDGE TREATMENT

Installation	Raw Water	Special Provisions	Sludge Disposal
Fontana System San Gabriel Water Co.	Lytle Creek 0-3 ppm turbidity	Bypass screems when turbidity is greater than 25 ppm. Treat screens with hypochlorite and ultraviolet radiation	1.6% waste water - no information on disposal
Kenosha, Wisc.	Lake Michigan 5-15 ppm turbidity	Treat screens with hypochlorite ea 6 wks, oxidizing agent ea 4 mo. to remove iron bacteria	4.1% washwater pumped, 2.7% wasted - returned to Lake Michigan
Denver, Colo.	Surface-Marston Lake. 3-5 ppm avg. turbidity	Add Cl_2 to waste. Treat screens with hypochlorite	1% waste, returned to Lake Michigan
Colorado Springs, Colo.	Snow melt, less than 3 JTU turbidity	Microstrainers used only for peak loads	Returned to Monument Creek downstream from plant
Boulder, Colo.	Snow melt		To sludge ponds, then drained off to Boulder Creek
Baker Metro, Colo.			To sewage treatment plant
Palisade, Colo.			To irrigation ditch and used for irrigation
Glenwood Springs, Colo.			Returned to No Name Creek

TABLE 4 (Contd)

Installation	Raw Water	Special Provisions	Sludge Disposal
Loveland, Colo.			Returned to river
Estes Park, Colo.			To sludge pond, supernatant drained off to sewage treatment plant
Grand Junction, Colo.			To irrigation ditch
Durango, Colo.			To washwater pond and water reclaimed
Golden, Colo.			Returned to Clear Creek
Ft. Collins, Colo.		3 units; third unit for reclaiming waste water from others	No data
Greeley, Colo.			Returned to Boyd Lake
Fort Collins-Loveland W.D., Colo.			To irrigation ditch
Little Thompson Valley W.D., Colo.			Returned to Dry Creek
Evergreen, Colo.			Returned to Bear Creek
Danvers, Mass.	Middleton Pond 4.0 ppm avg. turbidity		1% to 5% net waste water. No information on disposal

TABLE 4 (Contnd)

Installation	Raw Water	Special Provisions	Sludge Disposal
Belleville, Ontario	Lake Ontario	Treat screens with sodium hypochlorite and ultraviolet radiation	1.5% to 2.7% net waste water
Haweswater, Great Britain	Low turbidity	Pilot plant	No information on waste water. Reference does not consider this washwater as a sludge disposal problem
Turret Water scheme of the Loch Turret Water Board	Low turbidity		Returned to Turret Burn. Reference considers waste water beneficial to animal life

SLUDGE LAGOON

City of Minneapolis, Minn.

Water Department

Research regarding the characteristics, magnitude and disposal methods for presedimentation sludge is indicated.

LIME SLUDGES

Discharge to Surface Waters

Presently, most lime sludges are disposed of in the nearest watercourse as the most expedient and least expensive method, and because there has not existed legislation or other prohibition against such disposal. With recent state and federal legislation, the emphasis on pollution abatement is directed primarily to those areas where nuisances are created in the receiving waters. It can be expected that greater pressures will be exerted in the future by legislative authority as problems increase and public opinion requires action.

Lagooning

1. Continuous - fill Lagooning. This disposal means is suitable where large areas of land are available within reasonable distance of the treatment plant site. The words "suitable", "large areas", and "reasonable" can be defined only after studying of each treatment plant situation, and making engineering, economic, and esthetic evaluation for alternative methods of disposal.

In instances where the sludge must settle through ponded water, a consolidation of only 40 percent maximum by weight of dry solids can be expected. In several instances, a consolidation of only 20 to 30 percent was reported. In lagoons where the supernatant is allowed to flow off the site without ponding, an upper limit of 50 percent dry solids has been obtained. In either case, the effluent usually can be reclaimed if desired, as was done at Lompoc, California (Scolari, 1968).

Mace (1953) reports that odor problems with lime sludge lagoons are rare, and are temporary and insignificant when they do occur. Generally odors are from plankton or algae growths.

When the lagoons are completely filled with lime sludge, the next problem is how to reclaim the large lagoon area. Low land

TABLE 5

SLUDGE LAGOON CAPACITY REQUIREMENTS

City	Acre-Feet of Sludge/yr/mgd/100ppm Hardness Removed	Assume Moisture %
Cedar Rapids, Iowa	0.62	50
Columbus, Ohio	0.52	50
Sandusky, Ohio	0.66	50
Lansing, Michigan	0.65	50
Hinsdale, Illinois	0.45	50

around the Miami, Florida, water treatment plant was filled with sludge and subsequently covered with 1 to 2 inches of soil and sown with grass (Dittoe discssn. 1933). Dean (1953) states that fills have been made by continuously applying sludge without pre-drying in some cases, but cautions that heavy loads should not be applied for several years.

Rules of thumb for determining the storage capacity of lagoons have been used in the past, in some cases based on scant information. Lagoon requirements at several locations have been reported by Howson (1961) as indicated in Table 5.

The 10-State Standards (1968) recommend a minimum lagoon depth of 4 to 5 feet, a capacity of 3 to 5 years solids storage, with multiple cells and adjustable decanting devices. Criteria for design of sludge drying beds are:

1. Minimum of one year's total storage at a depth of 12 inches

2. Multiple beds

3. Two ppm of sludge for each 1 ppm of hardness removed

4. Assume accumulated sludge will air dry to 75 percent moisture

5. Sludge density will be 120 pounds per cubic foot.

Aultman (1947) reported that Hoover estimated lagoon capacity to be 0.00211 acre-feet for each million gallons of water softened. The sludges from different treatment plants vary widely in settleability, specific gravity, amount of consolidation, and other characteristics. Nelson (1957) pointed out that sludge characteristics and settleability cannot be predicted with any measure of accuracy. Because of the unpredictable nature of water plant sludges, application of rules of thumb can result in inadequate lagoon capacity.

Additional engineering studies of continuous fill lagooning should be made to determine: (1) Better guidelines for sizing lagoons; (2) Ultimate uses of lagoon sites after filling; (3) Costs of construction, operation, and maintenance.

Fill and Dry Lagooning. This disposal requires that a landfill site be available within economic hauling distance of the lagoon. Usually, two or three lagoons are necessary for alternate filling, drying, and subsequent removal of the dried sludge. Lagoons are sized depending upon sludge production rates, characteristics of the sludge, average air temperature, etc. Except as cited in the Ten-State Standards for continuous fill lagoons, specific design criteria for sizing fill and dry lagoons are not found in the literature. However, Howson (1961) and Savage (1954) do state that lagoons should be of such dimension that dried sludge can be removed readily by dragline or other conventional equipment.

Additional engineering studies of fill and dry lagooning should be made to develop the same information desired for continuous fill lagooning.

Recovery of Lime by Recalcination

The literature discusses existing lime recalcining plants individually rather than on a comparative basis. Regardless of the type of recalcining equipment utilized, each process comprises the same steps as follows:

a. Sludge thickening and or blending. In some cases, recarbonation is utlized in this step.

b. Dewatering by centrifuge or vacuum filter.

c. Flash drying of dewatered sludge by use of off-gases.

d. Recalcining of high temperature; i.e., converting calcium carbonate to calcium oxide.

e. Product cooling, where required.

Types of recalcining plants. The two predominant types of recalciners in present use are the rotary kiln and the fluidized bed reactor. As indicated by recent installations, fluidized bed reactor plants appear to be gaining favor. It is contended that the latter system: (1) operates more economically; (2) produces less dust; (3) produces a harder CaO product, less susceptible to airslaking; (4) requires less installation space; and (5) is capable of faster start-up and shutdown.

Other types are variations of multiple hearth furnaces as the plant at Lake Tahoe, Nevada (Moyer, 1968); flash drying furnaces, as plant at Salina, Kansas, and Pontiac, Michigan (Swab, 1948); and at Marshalltown, Iowa (Pedersen, 1944)).

Existing recalcining plants. Table 6 summarizes available data on existing recalcining plants or plants under construction.

Sludge Characteristics. Sludge from the water treatment and softening process consists primarily of calcium carbonate with hydroxide precipitates of coagulants. It may also contain hydroxides of dissolved iron, manganese, aluminum, and magnesium as well as silicates, clay or silt particles and organic matter.

As excess of hydroxide precipitates in the sludge will soon render the recovered lime useless due to their build-up during recycling through the water plant. These precipitates must be removed prior to recalcination. The separation can best be accomplished by centrifuging, either by separate classification or as the sludge is dewatered. Recarbonation of the sludge prior to centrifugation will return the insoluble magnesium hydroxide to the soluble magnesium bicarbonate. The magnesium is subsequently removed with the centrate which must be wastes.

Also, when tastes, odors, or color occur in the water, the centrate must usually be wasted. Where build-up of minor constituents

TABLE 6

RECALCINING PLANTS

Location	Approximate Construction Date	Rated Capacity Product Output (Tons/Day)	Type of Dewatering Equipment(1)	Type of Recalciner (2)	Heat Requirement (Mil Btu/Ton Output)	CO_2 Recovered	Lime Plant Cost $	Water Plant Rated Capacity (mgd)	Lime Fed (lb/mg)	Sludge/ Lime Ratio
Marshalltown, Iowa	-	4.2	C	FC	9.66	-	-	3.5	-	-
Pontiac, Michigan	-	-	C	FC	-	-	241,000	10	2,200	2.50
Miami, Florida	1948	80	C	RK	8.5	Yes	856,000	180	1,800	2.20
Lansing, Michigan	1954	30	C	FB	8.0	-	-	20	2,200	2.27
Salina, Kansas	1957	-	C	FC	-	-	-	-	-	-
Dayton, Ohio	1960	150	C	RK	9.0	Yes	1,500,000	96	2,140	2.47
San Diego, California	1961	25	C	RK	9.0	-	534,000	-	-	-
S. D. Warren Company(3)	1963	70	VF	FB	7.2	-	-	-	-	-
Merida, Yucatan	1965	40	C	RK	-	Yes	-	24	-	-
Ann Arbor, Michigan	1968	24	C	FB	-	-	-	-	-	-
Lake Tahoe, Nevada(5)	1968	10.8	C	MH	7.0	Yes	-	7.5	-	-
St. Paul, Minnesota(4)	1969	50	C	FB	8.2	Yes	1,750,000	120(6)	990	2.40

(1) C - Centrifuge; VF - Vacuum Filter
(2) RK - Rotary Kiln; FB - Fluidized Bed; FC - Flash Calcination; MH - Multiple Hearth
(3) Paper mill owned by Scott Paper Company
(4) Now under construction
(5) Activated sludge disposal plant
(6) Lime recalcining plant designed to accommodate future water treatment plant capacity of 170 mgd.

is not detrimental, or where tastes, odors and color are not present, the centrate can be returned to the water treatment plant for reprocessing.

The effect of silt and clay particles in the sludge has not been fully investigated or reported in the literature. However, the recalcined product may take on the characteristics of cement rather than lime if the amount of particulate matter is sufficient.

It is reported by Aultman (1939) that, in extreme cases, it could be necessary to remove the silt and clay in a pre-sedimentation basin before application of softening chemicals. For existing plants where recalcining of lime is being considered, this factor may be insurmountable due to plant layout.

Sludge Conditioning. Conditioning of softening sludges may involve thickening, blending of sludges from several clarifiers, recarbonation for magnesium removal, or combinations of the three functions. Thickening to reduce the amount of water processed may be undesirable where magnesium removal is required. Removal efficiency is reduced as the solids content of the sludge increases. Consequently there are limitations to the amount of thickening permitted. Where recarbonation is contemplated, pilot plant tests are recommended by Nelson (1957). Where several clarifiers or basins are used, all sludges should be blended.

Sludge Dewatering. Dewatering of softening sludges is accomplished by means of vacuum filters or centrifuges. Aultman (1939) reports that vacuum filters commonly produce sludge of 45 to 50 percent dry solids by weight. Sowden (1941) reports sludge of 62 percent dry solids, and Dloughy (1968) reports 75 percent.

As reported by Nelson (1944), centrifuges regularly produce sludges of 60 to 65 percent dry solids, and higher solids content in some instances. As shown in Table 6, use of centrifuges predominates. This is attributed to their smaller space requirement, higher solids concentration, and their dual capability of magnesium classification and dewatering.

Flash Drying. Flash drying of the sludge is accomplished following dewatering by injecting the sludge into the stream of hot offgases from the recalciner. The dried sludge is subsequently removed in a cyclone separator and the stack gas is scrubbed of particulate matter before being discharged to the atmosphere.

Recalcination. Dried sludge is fed to rotary kilns by means of screw conveyors or similar devices at the upper end of the sloping, rotating kiln. The kiln operates at a temperature of approximately 2,000°F. The product may be in a powdered form of irregular pebbles.

Calcium carbonate sludge is fed by an air conveyor system to the fluidized bed reactor where it is instantly transformed to calcium oxide. The calcium oxide adheres to previously calcined and crushed "seed" pellets which are also fed into the calciner.

Pellet growth is promoted by the addition of soda ash to the dewatered sludge prior to flash drying. The soda ash fuses at the calcining temperature of 1,600°F forming a molten nucleus to which the calcium oxide particles and seed pellets adhere. The pellets grow in this manner to a size which can no longer be suspended by the fluidizing velocity of the gases in the calciner, and at that point are discharged from the reactor.

Carbon Dioxide. The stack gases contain 15 to 27 percent CO_2 depending upon the amount of excess air used in fuel combustion. The bulk of the CO_2 contained in the stack gases is liberated from calcium carbonate as it is reduced to calcium oxide.

The CO_2 in the stack gas can be used to recarbonate the softened water and/or the sludge before dewatering. Sheen and Lammers (1944) suggests that the CO_2 may be recovered and marketed as "dry ice". Liquid CO_2 recovery may also be economically feasible as this process requires less energy than does the manufacture of dry ice.

Additional Study and Research. Recalcining plants are purportedly feasible only above 20 ton per day product capacity for fluidized bed reactors and 50 ton per day for rotary kilns. Development by manufacturers of economically packaged units for water treatment plants producing sludge in lesser amounts is indicated. Also indicated are additional studies of methods for obtaining higher efficiencies. Finally, economical liquid CO_2 recovery should be investigated as a means to reduce costs where sale of the CO_2 is practicable.

Discharge to Sewage Treatment Plants

The discharge of waste lime sludges to sewage treatment plants has been considered and used at Daytona Beach, Florida (Russell, 1955). The plant employing the "Daytona Beach Process" was constructed in April, 1949, after pilot plant studies. The addition of 15,700 pounds of sludge (dry solids weight basis) to the sewage treatment plant designed for 70,000 people removed 45 percent of the BOD and 75 percent of the suspended solids. Sewage sludge and waste lime sludge were removed from the upflow clarifier and dewatered by vacuum filter.

On the strength of the successful application of this process at Daytona Beach, Florida, a similar plant was constructed at Ocala, Florida. In view of the successful reports at Daytona Beach, it is curious that in 1961 the disposal of lime sludge at Ocala was reported as a problem, and a new sewage treatment plant was constructed to replace the plant constructed in 1949.

Garland (1969) reports the process was abandoned at Ocala because: (1) the state regulatory agency now requires secondary treatment, and (2) the plant was poorly maintained, and would have required replacement of much of the mechanical equipment which was not considered justifiable.

A similar project is in the planning stages for the City of Dallas, Texas by Black and Veatch (1968). Spent lime from the City's Bachman Creek Water Treatment Plant will be used to treat overflows from the sanitary sewer system. The interceptor sewer receives infiltration which causes flows exceeding its capacity. A point of diversion of flocculation and sedimentation facilities is planned, permitting diversion and treatment of all flows above the capacity of the sewer.

The project has received an offer from the Federal Water Pollution Control Administration for a supporting research and development grant. It is anticipated that the plant efficiency will exceed that of plain sedimentation.

Disposal as Agricultural Lime

Dloughy (1968) and Fleming (1957) cite instances where water softening plant sludge has been air-dried in lagoons and offered to local farmers. These plants were relatively small in capacity An increased need for agricultural lime, particularly in conjunction with nitrogen fertiliziers, has been cited. However, local needs and marketability will determine its success. This method is probably not applicable to medium or large sized plants.

Mechanical Dewatering and Disposal of Cake in Landfill

This method of disposal has been suggested in the literature, but no actual American installations are known. Young (1968) describes the Pitford, United Kingdom, plant. Unpublished research bases on the St. Paul, Minnesota project indicated that sludges can be dewatered by either vacuum filtration or centrifugation. A dry solids content by weight of 60 percent and higher can be obtained from centrifugation as contrasted to about 50 percent maximum from vacuum filtration in most installations. Dloughy (1968) states that 75 percent dry solids has been obtained at Boca Raton, Florida.

Freshly dewatered sludge is difficult to handle and haul as it is extremely sticky. In transit, water may tend to separate further from the sludge and, unless the truck is watertight, a nuisance may be created along the hauling route. The main problem is in removing the sticky sludge from the vehicle. One suggested mean is to line the truck bed with polyethylene film or other liner and dump the liner with the sludge. Italiano (1968) attempted this method of disposal but abandoned it because of handling difficulties.

Reliable cost data are not available except those developed in the St. Paul study, and these indicate that hauling is considerably more expensive than pumping the sludge at a higher water content.

A review of additional treatment plant experiences would be helpful in assessment of this disposal method.

Modification or Selection of Treatment Process

In order to simplify sludge disposal problems, Doe (1966-67) proposed modification or changing water treatment processes. He cites the Broughton Treatment Plant of the Fylde Water Board, England, as an example. The design of this treatment plant was revised to incorporate contact reactors in lieu of conventional equipment. This is the "Contact Reactor Process" in Europe and the Permutit "Spiractor Process" in the United States.

The "reactor" is a cone-shaped, bottom apex, vertical tank. The raw water and chemicals enter the tank tangentially at the apex, flow spirally upward, and discharge over a weir near the top. The raw water and chemicals mix with a sand catalyst admitted at the top of the tank, and the mixture suspension is maintained by the upward spiraling flow of the water.

The calcium carbonate plates out on the sand catalyst or nuclei, forming small hard pellets which grow in size until the vertical flow of water can no longer maintain suspension. The pellets drop to the apex of the tank and are periodically discharged to a sump for dewatering. It is contended the pelletized sludge will contain only 5 to 10 percent water by weight.

Although the pellet form is attractive from the standpoint of sludge handling, the process is reported to have several limitations in application. These are:

1. Minimum water temperature is 55°F
2. Magnesium content in raw water should not exceed 85 ppm (as $CaCO_3$)
3. Turbidity should not exceed 10 ppm
4. Tri-sodium phosphate must be added to retard and control plating action of calcium carbonate on the sand nuclei
5. In cold climates the reactors must be enclosed in heated structures, thereby adding to the cost of installation.

Excessive magnesium will form magnesium hydroxide which will not plate out on the catalyst. Instead, it will remain in the water and will quickly clog filters. The process will not remove excessive suspended solids, which will remain in the water unless removed on the filters.

Doe (1966-67) cited an instance where a choice of raw water source was made largely to reduce the waste sludge. In the case cited, the softer of two waters was selected to reduce the amount of sludge requiring disposal.

Burd (1968) reported that San Diego, California no longer softens its water and lime recovery is no longer practiced.

DEFICIENCIES IN ENGINEERING

The major deficiency that exists in the design of adequate facilities for the disposal of wastes from water treatment plants is the lack of full scale operating facilities from which design parameters for successful installations can be established.

With few exceptions, most of the work done to date has been in laboratory investigations and pilot plant studies. While these are necessary as an initial step, proper engineering design cannot proceed without the benefit of operating data on full scale installations.

Of particular concern are those facilities which might be utilized in the disposal of coagulants sludges. The majority of large plants utilize coagulations, sedimentation and filtration processes for water purification. Coagulant sludges are produced in the largest quantities, and also are the most difficult of the sludges to treat.

Cost Data on Engineering

Very little cost data is available today because of the lack of full scale plant operations for the disposal of sludges. The one exception to this would be in the area of lime-softening sludges where numerous full scale operations have produced rather good cost data.

In the case of diatomaceous earth sludges, microscreening sludges, manganese sludges and brines, there are so few installations which practice sludge disposal on a major scale that costs are not normally available.

In the disposal of coagulant sludges, a few costs have been developed, mostly from plants in England where several full scale facilities have been erected. These costs are for specific installations and have been difficult to translate into American dollars.

Another factor which makes it difficult to establish cost guidelines is the varying circumstances which substantially affect the cost of the process. A basic unit cost should be established. Modifications of costs would then be made for any particular circumstance.

(Note that a report on current technology and costs for 15 waste treatment plants in the U.S. is included in this report.)

* * *

DISCUSSION OF STATUS REPORT ON ENGINEERING

MR. NEUBAUER: Discussion of the status report on research has made very evident the overlapping interests between research and engineering aspects of this waste disposal problem. I am sure similar interests will be evident in the report on plant operation aspects.

With regard to engineering aspects of the problem, our discussion should relate especially to identifying gap areas in which information is inadequate. A great deal of information remains to be filled in to make the engineering details complete.

In the case of filter washwater, for example, its reuse at some plants is more for economy than it is to provide waste treatment. Little study has been done in this area, and more is needed.

The most information is available on coagulant sludges. Substantially more needs to be known about the coagulant sludges, starting with their properties.

The concentration of sludges is important. Just the difference between half of one percent and one percent dry solids content means a reduction of 50 percent in volume. Better methods of concentration of coagulant sludges can make the process of dewatering and disposal more economical. They will result in handling fewer solids, with less volume. As to the treatment of coagulant sludges, there are many possibilities.

We find even less information available concerning diatomaceous earth sludges. Our report includes a few references, and I am hopeful there will be more reported in the discussion.

Brine wastes are almost impossible to treat, and must be disposed of in a manner which will render them innocuous. The salts cannot readily be removed from the waste. Disposal methods used to date include evaporation, brine injection wells and direct discharge to surface waters. The use of ion exchange softeners is widespread throughout the country, and brine wastes are becoming a critical problem.

Finally, I wish to refer to Mr. Peter Doe's fine comments, in his most recent paper. He urges that the agency responsible for determining the type of water treatment process should give serious consideration to the type of wastes that will be generated, and to the disposal of the wastes. In many cases there may be no choice. But, in others, there are means by which the process can be varied to make the waste more easily handled. I believe this consideration is generally overlooked today, but recommend that it should be more generally emphasized.

MR. PROUDFIT: In preparing our status report on engineering, my part covered pre-sedimentation, iron, maganese, microstrainer, and lime softening sludges. Additional comment on several of these items is justified.

Microstrainer sludges are constituents strained from water, and generally returned to the water source. There is very little information available in the U.S. on microstrainer sludges.

In Colorado, many microstrainers have been installed and are considered as a water treatment process. These units are simply strainers which remove some organisms and turbidity; these are returned to the raw water source, except in some instances where strainings and wash water have been used for irrigation. Microstrainers are used at Kenosha, Wis. to strain algae from Lake Michigan water.

I believe microstrainers have a place in pre-treatment but should not be considered as complete treatment. The return of microstrainer sludge containing large concentrations of algae to the raw water will increase algal populations and compound the original straining problem. This problem could be acute where the raw water source is a limited impoundment.

Pre-sedimentation basin sludge is in the category of microstrainer sludges. My area of familiarity is primarily the Missouri River, where water treatment plants settle out sand and silt and return it directly to the stream. There is very little design or engineering information available on pre-sedimentation basins. In general, they are designed on an empirical basis to perform over a wide range of turbidity loadings. It can be argued that pre-sedimentation basins, if used without chemical coagulation, do not contribute any additional stream pollution. Additional research should be done on these basins.

The treatment of lime sludges has already been discussed. One of the important aspects of lime sludge recalcination is the need for more research and information on small plants. It is my experience that lime recalcining may be uneconomical in small water softening plants.

MR. HARTUNG: I don't believe that Mr. Proudfit intended to minimize the problem of iron and manganese waste disposal. There are a large number of iron and manganese removal plants which remove only iron and manganese after aeration or oxidation with potassium permanganate. The disposal of these sludges constitutes a tremendous problem because of the discoloration they cause when disposed of on the ground, and because they kill vegetation. I think this waste also should be considered as one of our major problems.

MR. PROUDFIT: I did not intend to minimize the specific problem you have discussed. Your comments are correct. I referred only to the removal of small quantities of iron and manganese with other products of sedimentation, and not to processes primarily for iron and manganese removal.

MR. TCHOBANOGLOUS: In terms of both engineering and operation, attention should be given to the problem of developing methods for estimating the sludge quantities and characteristics, especially reliable methods that can be used in the field.

MR. NEUBAUER: That problem was one of the first considered by the AWWA research committee on sludge disposal. We have not yet developed standard methods of analysis by which quantity and quality characteristics could be determined in plants throughout the country.

I wish to call attention to several significant items not included in our status report. These are summarized from reports prepared by Gauntlett for the British Water Research Association, and included in the reference bibliography.

Gauntlett noted that a small particle size and high gelationous metal hydroxide content in the sludge tend to give low settling rate, large settled volume and low permeability to water. He also reports that alum clarification sludges are not significantly improved (as regards settled volume and permeability) by chemical means.

He concluded that alum sludges can be drained since a significant proportion of the water is physically and not chemically bound. He recommended that the beds should be designed to provide maximum drainage rate without floc breakthrough; to permit a shallow sludge depth and to provide protection from rain until drainage is complete.

MR. NEBIKER: In our plant visits, we encountered wide fluctuations in the amount of sludge discharged from sedimentation basins. This is less so in sewage treatment. In sewage treatment, there is emphasis on minimizing the amount of sludge, because it is recognized the sludge must be disposed of. In water treatment, where sludge is generally discharged to surface waters no attempt is made to minimize quantities.

This is an area of research and engineering study that should be emphasized; the removal of sludge from clarifiers to minimize the quantity of the sludge. If this need was emphasized in plant design and operation, the sludge disposal problem would be substantially reduced.

For example, the solids content of sludge recorded at Moline, Illinois, is 1.0 percent. Ann Arbor reports solids of 25 percent. Similarly, the figures for tons of solids removed per million gallons exihibit tremendous variation. I believe this is due to the fact that operators have not emphasized maximizing the solids content. In sewage plant operation, equipment, manufacturers and the operators are concerned both with the overflow rate and the underflow rate. This is not the case in water treatment.

I would say the variation in the water softening sludge and the alum sludge is about the same, with differences several magnitudes of between minimum and maximum.

MR. RUSSELMANN: In New York State, there are three microscreen installations. Although they discharge only what has been removed from the waters, the effect of the waste upon receiving waters is variables - depending upon the receiving waters, the amount of waste, and the manner of disposal. These installations take waters from lakes and returns the wastes to the lake or to an entirely different stream which may have a very low flow. The wastes cause undesirable conditions because of the concentrated loadings of organic materials. Where the washwater is returned to a cove in the same lake from which the water is taken, excessive fertilization takes place and creates algae problems.

We should bear in mind that handling wastes from water treatment should be part of the entire design of the water treatment plant. Waste disposal is an engineering project from the very beginning to the very end. Unless we do this, even though we may not contravene standards for receiving waters, we may degrade the quality of that resource as a source of water supply or for other uses.

MR. TCHOBANOGLOUS: On reading all these status reports and looking at the various proposed regulations, I am almost convinced that the disposal of waste solids may eventually become the limiting or controlling factor in the design of water treatment plants.

MR. RUSSELMANN: It becomes increasingly obvious that the selection of any water treatment project for communities must be determined in considerable part by the methods for waste disposal and the location of the plant.

MR. DICK: I am pleased to hear the comments regarding the need for incorporating waste disposal considerations into the overall design. Our present water treatment practices stem from optimization of the various unit operations and processes that go into normal treatment - with total disregard for wastes. As the report on current technology suggests, when we put in waste disposal the economics will shift. The entire scheme of water treatment could conceivably change as a result.

For example, depending on the treatability of clarification sludges and backwash sludges, it might be desirable to minimize clarification process and maximize removal on the filters, or vice versa. We might want to emphasize plain sedimentation, where applicable, if this gives the better sludge for treatment.

Perhaps radical changes in our approach to water treatment technology are indicated when waste problems are considered. We should not attempt to solve only those problems that have been created by present practices. Instead, we should look to the source of the problems and, if preferable, change the treatment scheme.

MR. DOE: May I amplify those remarks by referring to the Fylde Water Board softening plant in England which, about ten years ago, provided a perfect illustration of this. The plant is designed to treat an underground water of some 250 mg/l calcium carbonate hardness, and about half the amount of magnesium.

The problem from the very start was waste disposal. We thought initially of a straight lime precipitation process. but we were well aware of the difficulty of disposing of this particular waste material. We then considered ion exchange process but we met the same problem of waste disposal. The plant location was about 20 miles away from the sea, and we actually investigated the route for a nine-inch diameter pipeline to carry the waste to the sea.

The third alternative considered was to produce a neutral effluent by mixing the two wastes together. Again we had the same problem of disposing of the effluent. The plant as eventually designed was our original conception of precipitation with hydrated lime.

When this plant was actually under construction, we learned of the contact reactor process, in the status report on engineering. The entire design of the plant was changed with, I think, great courage on the part of the chief Engineer, Mr. F. Law; and great loss of hair on my part as I was in charge of the plant construction. We installed a contact reactor plant. The practical result is that we make a maximum of 30 tons of pellets per day and we sell these. We made about $2,000 profit last year.

We have not found evidence of the limiting factors affecting the contact reactor process referred to in the engineering report. In our particular case, we found that minimum water temperature had little effect as long, of course, as it did not go down to 32 degrees Fahrenheit. We operated at temperatures somewhere between 40 degrees and 60 degrees Fahrenheit, mainly of course, because we treated underground water. And we didn't find operating problems at this low temperature.

We had been told that it was necessary to operate under a pressure of two atmospheres, but when we tried the process at atmospheric pressure it still worked exactly the same. We then designed three additional reactors without covers of any time.

Two of these were made of concrete and the third of steel; they all worked perfectly well. We didn't find the magnesium content to be a limiting factor; in this water, the ratio was about two calcium to one magnesium. A paper is being written by the chemist of the Fylde Water Board, Mr. M. A. Hilson, and when it becomes available I will try and arrange for him to bring it to the attention of the AWWA.

Finally, as far as Calgon is concerned, or the trisodium phosphate referred to here, some form of phosphate control apparently is necessary to prevent after-precipitation. This did cause us a little trouble because the reaction continues beyond the reactors. Precipitation occurs in the sedimentation tanks and could reach the filters. The reaction must be stopped. Perhaps Dr. Black will comment on this chemical problem.

One final point. The bottom of our reactors is not in the form of an apex. Our tanks end with a cylindrical portion something in the order of three and one-half feet in diameter.

There appears to be a minor disadvantage which is inherent in this process. The large beads, as has been stated, cannot drop right to the bottom of the reactor, because of increasing velocity due to the tapering shape of the reactor. They are suspended perhaps ten to 15 feet above the bottom. It is at that level that the beads must be removed.

The problem is this: The process should be controlled to form the fine beads, because they have the greatest surface area for a given weight. Fine beads are the ones on which the plating is done. But the big beads come down and mix with the small ones, and in debeading the small ones are removed as well as the large ones. When this problem has been overcome, the contact reactor process will be improved.

MR. BLACK: I think you will probably find that you are selectively softening that water and removing only the calcium hardness. The process of selective softening is applicable only to waters very low in magnesium, and from which no magnesium will be removed in the softening process. Almost all of our Florida waters are of that type. This treatment is discussed in a paper now in press in the Journal of AWWA. These waters are also warm - which, of course, promotes the softening reaction.

Several such plants are successfully operating in Florida. One of our major cities has just converted an ion exchange, sea water regeneration, plant to this new process employing selective lime softening.

I shall report to the Conference Committee on Research Needs that the problem of disposal sludge resulting from softening of high magnesium waters has recently been solved in one American city. The solution involves:

"A process whereby all calcium values are recovered as high quality quicklime; all magnesium values as very pure $Mg\ CO_3$, $Mg\ (OH)_2$ or both; all sludge water is recycled and recovered; and all liquid and solid wastes eliminated. This is accomplished in one installation serving two major softening plants,one 100 mgd and one 50 mgd, separated by a distance of approximately four miles."

MR. PROUDFIT: The remarks by Mr. Doe are very interesting. I think the contact reactor reference in the report emphasizes the dangers of generalization. This information is primarily from the manufacturer of these units. I have no firsthand knowledge of them.

MR. NEUBAUER: I would like to know from Mr. Doe, since he said this waste is being sold at a profit, just what use is being made of it?

MR. DOE: At the present moment, the British Government gives a subsidy to farmers for certain types of fertilizer. The word "fertilizer" is here used in a very loose sense. Anything which will give benefit to the land may generally be called fertilizer. Fo pH correction of the clays in this area, the pellets are spread on the land by the farmer. Large dumps must be provided to store the pellets, so that they are available for spreading on land at the times that they are required. These pellets are very attractive to chickens and birds.

MR. DEAN: I emphasize what was said about looking at the disposal of the sludge. Let's take the specific example, water softening. Lime softening or ion exchange processes can be ocean, brine softening, by which I mean ion exchange with brine regeneration, is impractical.

The salt content in many of our waters, is already too high, and there isn't an economical way of getting rid of brine.

So this fact can change the process, and it has very definitely influenced the decision as to whether or not to use ion exchange or lime softening.

MR. DICK: I think this discussion emphasizes the need for keeping the whole picture in perspective. For instance, it would be very unfortunate if we create an impression that lime sludges are a problem and, as a result, ion exchange softening seems more acceptable. Actually, ion exchange is not an acceptable treatment except on a seacoast.

MR. AULTMAN: We must, indeed, look at the overall problem. As Mr. Doe indicates, going to the pellet type of sludge, there was no problem with disposal in that particular area. But in an area where there is alkaline soil, there may be just as great a problem with disposal of the pellets as would exist with normal lime sludge. There is no one answer to the problem.

MR. FAHY: I might comment on experiments with the use of lime softening sludge as a soil conditioner. The City of Grand Forks, North Dakota, attempted to use the sludge in order to stabilize the soil in certain alleys, Initially, sludge application in the first several blocks was highly successful. The sludge was spread in the alleys, rototilled in, and no traffic was allowed while the sludge settled.

However, later in the fall when more sludge was spread, quite an extended period of rainfall occured. It was then neccessary to block those alleys off for several weeks. The soil became veritable a quagmire. There is much need for study in using lime sludge for soil stabilization.

Grand Forks proved that soil stabilization could be done successfully when there was an extended period of warm weather. This is not an approach to use if there is a chance of an extended period of rainfall shortly after the sludge is applied.

MR. ADRIAN: Lompoc, California, had an interesting experience in trying to find a use for sludge. The Los Angeles Times published an article on the availability of Lompoc's lime softening sludge - free of charge, if anyone wanted to take it.

A manufacturer considered the use of sludge as a paint additive, but found other material was commercially available at a cost lower than that of transporting sludge. Other inquiries were received, but no good use for sludge was developed.

MR. PROUDFIT: On the subject of various uses of lime sludge, I would like to add a few comments. We have done research and had discussions regarding various methods of disposal.

In one instance, a contractor thought he could reclaim and dry lagooned lime sludge and use it as filler in asphaltic concrete for paving. He learned that handling and drying the sludge was more costly than commercial filler, such as cement or other inorganic material.

In another area, it was concluded that lime sludge could be spread in cattle feed lots to prevent or alleviate hoof and mouth disease. Whether or not this application would be effective, feed lots are limited. This use could not accommodate disposal of large continous volumes of sludge.

I believe one of the most important applications for lime sludge may be in sewage treatment plants which must remove phoshates. This will be a beneficial use, and should not increase the final sludge disposal problem.

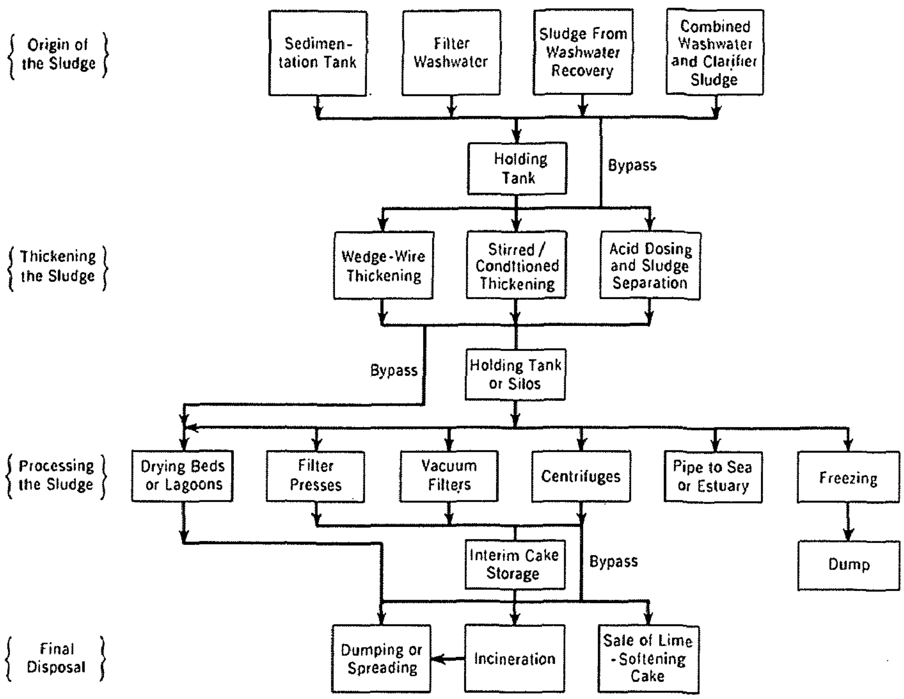
Land disposal appears attractive, but land costs are increasing. In many instances, when water treatment plants are located in highly populated areas, land for sludge disposal is not within economic reach - either because of cost or distance.

Engineers should recognize that a water treatment plant design must now include positive means for disposal of sludge. At the same time, engineers should consider economy as a basic consideration in the selection and design of disposal methods.

This concludes discussion of the status report on engineering.

* * *

SLUDGE DISPOSAL PROCESSES



Alternative Successive Stages in Sludge Disposal

Young, E.F. J.AWWA, 60:717 (1968)

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STATUS REPORT ON PLANT OPERATION

J. W. Krasauskas and Lee Streicher

The disposal of water treatment plant wastes has, up to the present, posed no real problems of plant operation - because the majority of water treatment plants in the United States discharge these wastes to surface waters. In most instances, plant managers have not considered discharge of these wastes to surface streams as pollution.

Recent actions have been taken by the Federal Water Pollution Control Administration to implement the Water Quality Act of 1965, and stricter State regulations have been developed which apply to the discharge of such wastes to surface streams. Thus, water production officials are required to critically review their current methods of disposal, and to actively seek practical solutions. The majority of water treatment plants in the U.S. do not have the capability of conducting applied research, but must depend upon governmental agencies, equipment manufacturers, consulting engineers, and the larger water treatment plants to supply practical answers to this vexing problem.

Types of Water Treatment Sludge

It has been estimated that water treatment plant alum coagulant sludge production in the U.S. amounts to over one million tons annually. Since the majority of water plants in the U.S. use alum as the prime coagulant, the disposal of this type of sludge should receive primary consideration. Other sludges which must be considered from the use of coagulants such as, sodium aluminate, potassium aluminum sulfate, ferric sulfate, ferric chloride, copperas, chlorinated copperas, and sometimes lime.

Another consideration is the increasing use of coagulant aids such as, bentonite clays, activated silica, and various polyelectrolytes. Other miscellaneous chemicals contributing to sludge volume or influencing sludge composition are: copper sulfate used for plankton control; activated carbon for taste and odor control;

and potassium permanganate for color, iron and manganese removal.

The other types of plant waste discharges which must be considered are the calcium carbonate sludges and brines resulting from water softening processes.

DISPOSAL OF ALUM SLUDGE

An Alum sludge consists of aluminum hydroxide plus loam and clay particles, color colloids, microorganisms including plankton, and other organic and inorganic matter removed from the water being treated. The sludge is usually bulky, and gelatinous in consistency. It has a high moisture and a low solids content. It varies in color from a light yellow to a black depending upon the character of the source water and the chemicals used for treatment.

Plant operations for disposal of alum and other coagulant wastes may include:

1. Direct discharge to surface waters
2. Lagooning
3. Discharge to sanitary sewers
4. Freezing
5. Centrifuging
6. Vacuum filtration
7. Sand bed and wedge wire drying
8. Filter pressing
9. Barging to sea
10. Pipeline transport
11. Alum recovery

The discharge of water treatment plant wastes directly to surface waters is, obviously, the most economical method of disposal. This method is becoming impractical in many locations. Almost all states now have pollution control laws or regulations to limit such discharges. State and interstate regulatory agencies increasingly require the installation of waste control facilities.

Operation of Lagoons

Lagoons for disposal of waste sludge require suitable land areas. As has already been pointed out in the engineering report, these are not generally available adjacent to large urban water treatment plants. In the case of rural water treatment plants, where cheap land is available, lagoon disposal is simple and economical.

While operational costs of lagoons are low, factors such as climate, intermittent or continuous input, percentage of sludge solids, and the availability of one or more alternating lagoons, will have a bearing on the land area required. Generally, at least two lagoons are needed. They can serve as settling basins or as thickeners preceding some other process.

Problems exist with insect breeding. Lagoons serve as attractive nuisances to children in inhabited areas, which may add increased cost of fencing to the total overall costs. Lagoons create wasteland which should be inclosed by tamperproof fences to prevent injury or drowning of persons or animals.

It is known that alum sludge is difficult to dewater by lagooning: some sludges have not thickened beyond 9 percent solids, even after years of settling. An alum sludge of 6 percent solids cannot be easily handled, nor does it make good landfill if pumped to a disposal site.

An alternative method of lagooning which combines freezing as part of the process has worked well in cold climates. It produces an end product which can be disposed of readily. Freezing results in a decrease to one-sixth of the original volume, and an increase to 17.5 percent of the total solids. After the sludge is thawed, the sludge solids are in the form of small granular particles ("coffee grounds") which on drying become a brown powder. Again ultimate disposal sited must be provided. Where the sludge remains in place indefinitely, unsightly spoiled land areas are produced.

Discharge of Wastes to Sanitary Sewers

A disposal method which deserves more study is the discharge of wastes to the sanitary sewer. Four large U.S. cities discharge sludges and washwater to sanitary sewers; Detroit, Michigan; Philadelphia, Pennsylvania; Wilmington, Delaware; and Washington, D.C. Primary wastewater treatment plants in these cities have not experienced treatment difficulties from these discharges.

In one city, where the sedimentation basin wastes were released as a slug, difficulties with vacuum filtration were experienced. When the waste discharges were spaced over several days, the difficulties ceased. Continuous removal and discharge of sludge reduces the possibility of interference with the wastewater plant processes.

Settling basin sludges and waste water can be discharged into sanitary sewers if large fast flowing sewers are available and primaary settling is a part of the waste treatment plant process. In one large city, a 100 gpm pilot activated sludge plant has received a proportionate share of the water plant sludge discharged to the primary plant without experiencing any difficulty in handling the combined wastes.

Waste Treatment by Freezing

In the United Kingdom, a freezing process for treatment of alum sludge has been sucessfully operated. Pre-thickening, to reduce the volume and thereby the cost, is a primary step. In the process, water of hydration is removed from the gelatinous aluminum hydroxide, changing the character of the sludge to small granular particles which settle rapidly, and the final volume to one-sixth of the original volume.

Although the original freezing process for sewage sludge was developed in 1950, use of this method for treatment of water plant sludge was first initiated in England in 1963. Capital costs for construction in England generally approximate $17,000 per 1,000 gallons of sludge frozen per day. Power costs in England vary between 180 KWH and 230 KWH per 1,000 gallons of sludge frozen, depending upon the ambient temperature of the sludge.

Waste Treatment by Centrifuging

Wastewater treatment plants have used centrifuges for dewatering primary and activated sludges with some degree of success, but their use in water treatment plants has been very limited. It has recently been shown that alum sludge, removed continuously from a conventional sedimentation basin (1.0 to 1.5 percent total solids) can be concentrated in a centrifuge (to about 17 to 18 percent solids). A solids concentration of at least 18 to 20 percent is considered necessary if the material is to be handled with mechanical equipment and hauled to a disposal site.

Advantages of the centrifuge method are the low space requirements, complete process automation, and ability to handle either dilute or thickened sludges. Disadvantages are relatively high maintenance costs and scarcity of disposal sites for the dewatered sludge.

Waste Treatment by Vacuum Filtration

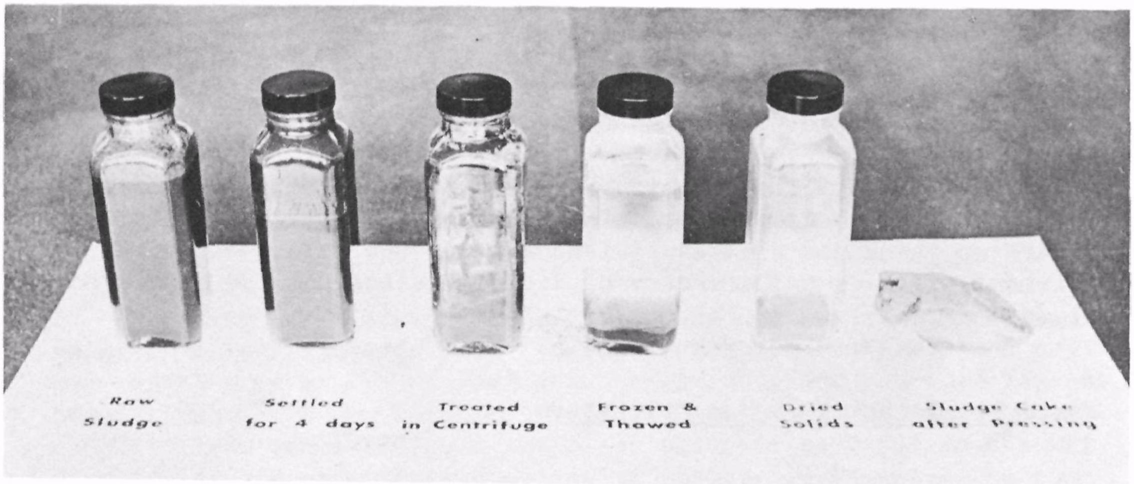
Vacuum filtration equipment is extensively used for dewatering wastewater treatment plant sludges, but its application to water treatment plant sludges has been limited. This method utilizes a cylindrical drum covered with a porous fabric made of metal mesh, steel coils, wool, cotton, nylon, saran, or one of the newer synthetic fiber cloths as filtering media.

To obtain optimum results with this method it is necessary to chemically condition the sludge with polyelectrolyte, diatomaceous earth, or lime, to prevent clogging of the filter cloth and to improve the dewatering qualities of the sludge.

The advantage of this process is that a product suitable for direct disposal on land may be produced.

The disadvantages are that vacuum filters are unable to filter dilute sludges, such as those obtained from basins having continuous sludge removal devices. A disposal site for the dried sludge is still needed. Vacuum filters are particularly applicable to large treatment plants producing substantial quantities of sludge.

SLUDGE DEWATERING



Samples of Alum Sludge from Various Dewatering Processes

1. Raw Sludge
2. Settled for 4 days
3. Treated in Centrifuge
4. Frozen & Thawed
5. Dried Solids
6. Sludge Cake after Pressing

Waste Treatment by Sand Bed and Wedge Wire Drying

Sand drying beds are probably the method of choice in rural areas where land is readily available and relatively cheap. However, since large land areas are generally required and sand is expensive, cost is a factor not to be ignored. The sand beds may be open or covered.

Disadvantages of this method are the poor dewatering of sludge in cold or rainy climates, high labor costs for collection of dried sludge and hauling to disposal site, and the long time needed to adequately dewater the sludge. Mechanical devices can be used to expedite the collection of dried sludge but their use results in loss of sand and causes increased operation costs because new sand must be purchased for replacement.

It is reported that in England, where large land areas are available, the cheapest method of drying water plant sludge has been in lagoons and on sand drying beds. A modification of sand drying was developed using wedge wire as the filter media. Wedge wire required an initially high capital outlay, although maintenance costs were low. In England, this method was rejected in favor of the filter press.

Waste Treatment by Filter Pressing

The filter press has not been used extensively in the United States for dewatering of alum sludges. However, pilot studies have been conducted recently in several large U.S. water and waste treatment plants with reported success. One water treatment plant in Great Britain has pressed sludge containing 1.5 to 2.0 percent solids and obtained a wet cake containing 15 to 20 percent solids.

The original objections to the use of this method have been the short life of filter cloths and lack of automation. However, the use of snythetic fibers has increased cloth life, and recent modifications have provided complete automation for the feeding and pressing cycle. Short shutdowns required for cake removal.

Disadvantages of this process are reported to be initial high costs for equipment, relatively high maintenance and operation costs, operation not completely automatic, and after discharge of cake the filter cloth must be inspected to prevent operating difficulties.

Barging To Sea

Barging water plant sludge to sea may be advantageous where the plant is located on a river, close to the sea. To reduce costs the sludge should be thickened before hauling to the disposal site which may be 400-500 miles, round trip. This disposal method should be closely evaluated with other disposal methods for cost, flexibility of operation, and ease of handling.

Pipeline Transport

Pipeline transportation of sludges for long distances to lagoons or to the ocean for disposal is simple and relatively inexpensive. Asbestos cement pipe of 4 to 6 inches in diameter is adequate and can be constructed at low cost.

Advantages are relatively low original cost, low maintenance costs, flexibility in handling plant sludge loads, and combining sludge from more than one operation.

Alum Recovery

Recovery of alum from alum sludge through treatment by sulfuric acid results in reduction in sludge volume to less than 10 percent of the original volume, and concentrates the sludge to 20 percent solids by weight. In recent pilot plant tests, during which a filter press was used to dewater the acidified alum sludge, alum recoveries of 80 to 93 percent were attained and the residual cake contained 40 to 55 percent solids.

Disadvantages of alum recovery from sludge are the high cost of sulfuric acid in certain areas, need for increased alum dosage when the recovered alum is reused, concentration of undesirable chemicals, and operating costs of the treatment process. When comparing costs of recovered alum with that of purchased alum due credit must be given to capital investment, interest, and depreciation as well as the cost of acid used for recovery.

DISPOSAL OF FILTER WASHWATER

Filter washwater can be lagooned, and the settled water pumped back to the plant intake or discharged to a sanitary sewer. In some plants, washwater has been pumped back to the rapid mix unit without settling, but this practice has been reported to adversely affect coagulation. Where washwater is lagooned, the clear supernatant may be drained off and the sludge dewatered.

Some plants have installed small auxiliary water treatment units specifically for treatment and recovery of their filter washwater. The capacity of these units is about 2 to 3 percent of the capacity of the main plant, and the treatment process is similar to that used in the main plant. That is, alum (with or without a polyelectrolyte coagulation aid) is flash mixed with the dirty washwater. Passage through a conventional mixing and settling basin follows.

The clarified washwater flows by gravity to the main plant filter influent channel where it is mixed with the clarified water from the main plant settling basins. This method of washwater recovery has been found to be efficient and economical, and the amount of washwater used in filter operation has been reduced to less than one percent.

DISPOSAL OF SLUDGE FROM SOFTENING PLANTS

Methods for disposal of softening plant sludges have, in general, been similar to those used for disposal of alum or iron sludges from coagulation treatment processes. Discharge to surface waters (where dilution permitted), and lagooning, have been by far the most common practices for such waste disposal. In some instances disposal into sewer systems has been allowed. A few plants have installed facilities for lime reclamation.

The major constituent in the sludge produced at lime or lime-soda softening plants is calcium carbonate, which generally falls within the range of 85 to 95 percent of the dry weight of the solids in the sludge. Other constituents which may be present include: magnesium hydroxide, the hydroxides of iron and/or aluminum, insoluble inorganic matter such as clay, silt, or sand, and organic matter such as algae or other plankton removed from the water being treated.

The quantities of calcium carbonate produced during lime treatment are quite substantial, as one pound of pure quicklime (calcium oxide) when added to water will react with the calcium bicarbonate in the water to precipitate 3.57 pounds of calcium carbonate. As commercial quicklime usually contains only 85 to 95 percent calcium oxide, and as the lime also reacts with some of the magnesium, iron, and aluminum that may be present, the amount of sludge produced during lime treatment is generally assumed to be about 2.5 pounds, dry basis, for each pound of quicklime added.

The use of lime and soda ash together, in proper proportion and dosage for the water being treated, can effect the removal of practically all the magnesium and most of the calcium from the water to leave a residual hardness of only about 25 parts per million.

Softening Sludge Characteristics

The physical characteristics and wet volume of the sludge produced during lime or lime-soda treatment may vary very widely, depending upon the ratio of calcium carbonate to magnesium hydroxide in the sludge, whether or not alum or another coagulant (with or without a coagulant aid) was used, and the nature and amount of foreign material (inorganic or organic) that may be present in the water being treated. The calcium carbonate particle sizes are quite small, usually falling between 5 and 15 microns. Solids in sludge collected in the settling basins of lime and lime-soda softening plants have been reported to range from 2 to 33 percent. Similarly, the volume of sludge discharged from such plants has ranged from 0.3 to 6 percent of the water softened.

Most of the large softening plants have been built adjacent to their source of supply of raw water, usually a large river, and it has been very simple and economical to discharge their waste sludge to a point downstream from the plant intake. As this sludge consists mainly of inorganic matter which has no oxygen demand and contributes essentially no disagreeable tastes or odors to the water, its primary nuisance qualities have been the production of turbidity and the formation of sludge banks. Nevertheless, more and more States are classifying such sludge disposal as water pollution and are enacting legislation regulating or prohibition this practice.

Lagoon Treatment of Softening Sludge

Discharge into impoundment basins or lagoons has also been a relatively simple and inexpensive method for disposal of softening plant sludge. Where sufficient land is available at low cost, this practice can offer a long term solution to the sludge disposal problem. Unfortunately, with continued urban development and population growth, land for sludge lagoons becomes increasingly difficult to find; at the same time, the volume of sludge produced is increased, due to the need for more and larger plants to provide the water for urban communities.

The lagoon capacity required for disposal of the sludge is dependent upon the physical characteristics of the material and the extent to which it is dewatered during impoundment. Where the sludge has been dewatered to about 50 percent moisture content, the lagoon capacity requirement has been reported as about 0.5 acre-foot/year/mgd/100 ppm hardness removed. Lagoon depths usually vary from 3 feet to 10 feet ore more, but may be much deeper where a canyon or gully can be dammed to form a suitable impoundment area, or where worked-out gravel pits are available.

Successful operation of sludge lagoons requires that they be divided into several independent ponds or pools so that each section in turn may be permitted to dry while the others remain in use. Generally, the supernatant from the sludge ponds is decanted and diverted into a natural watercourse or pond, or is permitted to percolate into the underground. As the decantate is of essentially the same quality as the water being treated at the plant (except that it is softer and usually lower in bacterial population) its addition to the surface or underground water should not prove objectionable.

The dry sludge, when accumulated in sufficient quantity in the dewatered section, may be hauled away to a more remote disposal area, may be used in landfill operations or for soil conditioning, may prove useful as a neutralizing agent for acid wastes produced in some industrial processes or, if it is sufficiently pure calcium carbonate, may even serve as an inert filler in some industrial products or as a pigment in inexpensive whitewash coatings.

In the operation of sludge lagoons, measures are usually required to protect the public from potential nuisance or hazard. As the ponds may be an attraction to children and animals (and even to adults if someone has planted fish in the ponds or if ducks land there), it is usually necessary to enclose them with an adequate fence. Mosquito and fly abatement measures may be required. If organic matter is present in sufficient quantity to cause odors upon decomposition these must also be controlled, and periodically it may be necessary to cut down or otherwise restrain the growth of pond weeds and grasses.

Sewer Discharge of Softening Sludge

Disposal of softening sludge to a sanitary sewer is used only in a relatively small percentage of water softening plants. Calcium carbonate sludge may be sufficiently dense to settle and plug the sewer lines unless adequate dilution water and high velocities are maintained to keep it moving freely.

Softening plant sludge is also reported to have caused problems in the operation of sludge digestion units in sewage treatment plants, possibly due to a mixture containing a disproportionately high percentage of sludge over a period of time with consequent inhibition of biological activity.

Reclaiming Lime from Softening Sludge

As regulations to control stream pollution become more stringent, the practice of reclaiming lime from softening plant sludge may become more widely accepted. Theoretically, it would be possible to recover from pure calcium carbonate sludge twice as much quicklime as had been used in the water treatment process to produce that sludge.

Thus, a plant practicing lime reclamation would produce sufficient lime to meet all of its needs and have a surplus to sell to other users. Actually, impurities in the sludge and less than 100-percent efficiencies in the reclamation process reduce the amount of lime recovered. Nonetheless, it can produce substantially more than is used for softening the water.

The reclamation of lime from softening plant sludge has been slow because most plants used the simple and inexpensive methods of lagooning or discharging sludge into a nearby watercourse. Additionally, the adaption has been retarded by: (1) constantly changing quality of the river water being treated, with resultant variations in sludge quality and complications in the calcining process; (2) the difficulties occasioned by the accumulation of magnesium in the reclaimed lime; (3) lack of fully satisfactory calcining equipment, especially for small plant installations; and (4) the reluctance of small communities to adopt a procedure which had not been completely proven and widely accepted.

The City of Miami, Florida, put an 80-ton per day rotary kiln lime recovery installation into service in 1949. The process includes thickening of the calcium carbonate sludge to 20 to 30 percent solids, dewatering by centrifuge to about 67 percent solids, followed by calcination at a temperature of 2,000 to 2,200°F in an oil-fired rotary kiln. Original operating difficulties were all overcome, and satisfactory and economical operation of the lime recovery plant is reported. Excess lime produced was shipped to Tampa and Gainesville, Florida.

Recovery of lime from softening plant sludge has been practiced in Lansing, Michigan, since 1957. The process used includes recarbonation (to improve the settling rate and aid in separation of magnesium hydroxide from calcium carbonate), dewatering by centrifuge, and calcining in a fluidized bed furnace. Production was about 25 tons per day.

Dayton, Ohio, has also been reclaiming lime, but from a larger plant rated at 150-tons per day capacity. Here the sludge is recarbonated, dewatered by centrifuge, and burned at 2,000°F in a rotary kiln to produce a high quality pebble lime (91 to 92% available CaO). Excess lime produced is sold to nearby communities.

San Diego, California, recovered lime in a 25-ton per day plant until the process was abandoned because softening of the water was discontinued. The calcium carbonate sludge was dewatered by centrifuge and then calcined in a gas-fired rotary kiln at 2,000°F. Enough lime was produced at the one recovery plant to provide for the needs of three water treatment plants in the city.

Because pollution control regulations will sharply curtail the practice of discharging softening plant sludge to surface waters, lagooning will probably remain for the near future the simplest and least expensive way of disposing of such sludge.

The reclamation of lime from calcium carbonate sludge will gain much wider acceptance as improved recovery systems are available, and as markets for excess lime are developed. The increasing cost of land, and its decreasing availability will also lead to that development.

DISPOSAL OF BRINES FROM SOFTENING PLANTS

Cation-exchange softening materials, as well as equipment and procedures for their efficient use, have been greatly improved in the past 20 years. However, no significant advancements appear to have been made in methods for disposal of the spent brines from such softening operations. Perhaps this is due to the fact that the greatest increase in cation-exchange softening has occurred in the use of small units designed for industrial, commercial, or residential use.

From small units, the spent brine and rinse water are almost always discharged directly into the local sewer system. Although collectively the quantities of waste brine so discharged are very substantial, individually the discharges are relatively small and widely scattered, so no more practicable solution to the disposal of the brine from these units could be offered.

Disposal of brines from water treatment plants utilizing cation-exchange softening still follows the long-established patterns of:

1. Dilution (controlled or uncontrolled)

    a. Directly to stream
    b. To stream via sewer system

2. Discharge to ocean

    a. Directly
    b. Via sewer system

3. Discharge into wells

4. Evaporation

The chemical composition of waste brines from softening plants may vary over a wide range, with total dissolved solids concentrations approximating 15,000 to 35,000 ppm. Major constituents are sodium, calcium, and magnesium chlorides. A representative range of the major constituents in softening plant brines is shown in Table 6.

TABLE 6

Waste Brine From Cation-Exchange Softening Plant

Major Constituent	Concentration (ppm)
Calcium (Ca)	3,000 - 6,000
Magnesium (Mg)	1,000 - 2,000
Sodium (Na)	2,000 - 5,000
Chloride (SO_4)	9,000 - 22,000

The quantities of brine and rinse water used for regeneration of softening units may vary over a wide range. The total waste water generally varies from less than two percent to about five percent of the amount of water treated, although values as high as 10 percent have been reported.

Due to their salinity, regenerant brines cannot be permitted to come in contact with growing plants; nor can they be discharged underground at any point where they might possibly percolate into an underground fresh water aquifer.

Discharge of these brines directly into a river or other watercourse has been permitted where flows are sufficient to afford the dilution necessary to protect the quality of the water for downstream users and for aquatic life. Where normal stream flows are insufficient to meet unregulated dilution requirements, controlled discharge of waste brines may be permitted. This entails the use of a holding reservoir for collection of intermittent high-rate brine discharges, and subsequent releases of the stored brine at regulated rates to correspond with the dilution capability of the stream flow. If the receiving stream is subject to extended periods of low flow, relatively large and expensive holding reservoirs may be needed for this method of disposal.

Discharge of brines into sewers which ultimately deliver the wastes into a flowing stream may be subject to the same controls as prescribed for direct discharge into the stream itself. If sewage reclamation is practiced and the reclaimed water is returned underground for groundwater replenishment, even greater limitations are set on discharge of brines into the sewer system.

For those softening plants favorably located close enough to the coastline to permit direct discharge into the ocean, or via a sewer system directly to the ocean, the problem of brine disposal is greatly simplified. Furthermore, if the softening plant can be located close enough to the ocean to use sea water instead of purchased salt for regeneration, substantial savings in the costs of plant operation may be effected.

Apparently, only relatively few softening plants use brine disposal wells to dispose of waste brine. These wells must be located in an area where there is no possibility of brine intrusion into the groundwater supply and where the underground formation is porous enough to disperse and store the brine received.

The brine must be essentially free of suspended matter to preclude plugging of the well, and also free of any soluble constituents which might form precipitates upon oxidation or upon reaction with other mineral matter in the subsoil formation and thereby cause plugging. Any need for treatment of the brine before disposal would add to what could already be a relatively high cost of the injection well itself.

Storage of brine in unlined impoundment basins is not acceptable in many locations due to the danger of infiltration of the brine into the underground water supply or into a nearby stream. If evaporation is considered as a means of brine disposal, properly sealed or lined pits must be developed to avoid seepage from the storage area.

A vital consideration in the design of these basins is whether the rate of evaporation exceeds the precipitation in the area, particularly in view of the fact that the rate of evaporation of a brine decreases as evaporation progresses and the concentration of the residual liquid rises. The problem of disposal of the precipitated salt also may be a difficult one to solve, even though evaporation may be feasible. Evaporation, therefore, may be one of the less practicable methods of softening plant brine disposal.

Precipitation of the calcium as a high quality calcium carbonate and of the magnesium as relatively pure magnesium hydroxide is possible if the concentrated portion of the spent regenerant brine is collected separately from the rinse water which follows it during the regeneration process. This would, at the same time, leave a substantial portion of recovered sodium chloride brine for reuse. Equipment, chemicals, and process control would be required for such an operation, and it is questionable whether this procedure could be economically justified.

It appears, then, that discharge to the ocean, either directly or via the local sewer system, is the best method for disposal of water treatment plant brines where the geographical location permits. Controlled or uncontrolled dilution by way of discharge into a nearby watercourse is used in inland areas when stream flows are adequate for the purpose. Discharge into injection wells or evaporation in seepage-free impoundment basins may be the only recourse where neither of the preferable methods of waste brine disposal is feasible.

PLANT OPERATION REQUIREMENTS

Improved techniques needed to solve the problem of waste disposal from water treatment plants are suggested below:

To reduce the volume of sludge, improved methods of solids concentration should be actively researched and practical applications developed.

Improved dewatering techniques for water plant sludge should be developed. Wastewater sludge dewatering methods should be considered for possible adoption to water plant wastes, and research conducted on newer methods.

Research is needed to develop new chemicals, and extend the use of present chemicals, to condition sludge for more effective dewatering.

Continued study should be made of reclaiming by-products of sludge such as alum, lime, or other chemicals, and to make sludge more suitable for soil conditioning or other practical uses.

Economic evaluation of current methods of sludge disposal is needed.

More detailed study of heat, freezing, pressure cooking, and other physical means for altering sludge structure is desirable. This could reduce the bulk and improving handling characteristics of sludge, and result in lower disposal costs.

Develop improved means of sludge transfer which will improve upon present methods of mechanical handling.

Mechanical dewatering methods should be compared on the basis of efficiency, cost and final product.

Development of laboratory methods of sludge processing which will simulate actual plant conditions.

Finally, there is an outstanding need for a continuing survey of current plant operations, research, and demonstrations. The information developed should be coordinated and widely distributed.

* * *

DISCUSSION OF STATUS REPORT ON PLANT OPERATION

MR. KRASAUSKAS: The item which impressed me most in each status report was that it has not been possible to develop cost figures applicable to the operation of plants for the disposal of water treatment wastes. Each plant has differerent problems.

The availability of land appears to be an especially important problem. Where lagoons would be applicable to one installation, they might not be in another. In Washington D.C., our plant is located just below Spring Valley, which is one of the most exclusive residential areas. Land isn't available and lagooning cannot be considered.

The most significant operating problem stems from the fact that no matter which process is used, the end product must be disposed of, whether it contains 20 percent solids, 30 percent solids, or 50 percent solids. Since water treatment plant wastes cannot be destroyed, they must be placed ultimately on land of sufficient size to handle the waste. The Washington D.C., water treatment plants have a maximum capacity of about 270 mgd, and produce approximately 45 tons of sludge to dispose of each day. We can drive in any direction up to 50 miles from the city of Washington without finding cheap land.

One alternative is possibly alum reclamation, because we have about 16,000 tons of sludge on a dry basis, of which 5,000 tons is alum.

If 70 percent recovery of alum is possible, we can reduce the total tonnage to be disposed of. Even then, we must consider where to haul it, and what the cost will be.

Hence, even though possible methods of disposal are identified in our reports, we have not really solved the problem. If we could incinerate our sludge like wastewater sludge, so that the end product is ash, our problem would greatly reduce in scope. But water plant sludge, being inert, is not amenable to incineration. As a plant operating problem, considering ultimate disposal, we don't really know the answer.

MR. STREICHER: I shall report on our own operating experience and on of the research and investigations that we have conducted.

We have had experience in washwater recovery. In fact, we have built, at each of our two 400 mgd plants, special washwater reclamation units. Each plant has two units which together have a rated capacity of about 12 mgd. We handle filter washwater as if it were a turbid water coming into the plant. The washwater is treated with alum, flocculated, settled, by gravity, and the clarified water flows back and mixes with the water from the main plant settling basins, thereby becoming a part of our process water. We have left for disposal from the washwater reclamation units only a small increment of alum sludge which we dispose of by lagooning, in the same manner as the sludge from the main plant settling basins.

In the early years of plant operation, we used lime and accumulated considerable lime sludge in our impoundment basins, located about a mile and a half from the plant. The surface water was decanted and flowed into a flood control reservoir which was also used for recreational purposes. It settled and consolidated to about 50 percent solids. Since we had the impoundment area divided into four sections, each section was permitted to dry alternately. Incidentally, this sludge was about 93 percent calcium carbonate.

In about 1949-50, we sold most of our lime sludge to a manufacturing concern in Los Angeles for use in neutralizing an acid waste which was disposed of into the sewer system.

With reference to odors, we had none from lime sludge. The sludge we have today, (mainly organic and inorganic matter from our main plant settling basins without coagulant, and the alum sludge from the washwater reclamation unit) has some odor at times as it is dumped into the lagoon. But once the sludge is covered by water, there is no noticeable odor.

We have also had experience in brine disposal. We have the largest ion exchange softening plant in the world, producing 5 mgd of brine for disposal. As was mentioned earlier today, disposal of brine is a real problem unless you are fortunately situated. In our case, we discharge the waste brine into our wastewater disposal line which joins with the Los Angeles County sanitation system, about 22 miles from the plant. By that means, we dispose of it to the ocean.

When an ion exchange softening plant is far from the ocean, the only means of brine disposal may be discharge into deep wells or into evaporation ponds, provided that this can be done without contaminating the underground supply. In our location, we are not permitted under any circumstances to discharge brine anywhere except to the ocean.

We haven't had any significant experience with alum sludge other than that produced in the washwater reclamation units, a very small operation representing about three-quarters of one percent of the main plant flow. However, we will be faced with the problem of alum sludge handling and disposal from a new plant now in the early stages of construction and scheduled to be completed in 1971.

In the new plant area we are not as fortunately situated with regard to lagooning ponds, as in our existing plants. True, there are some gravel pits about 12 or 14 miles distant from that plant site. It would be expensive to construct a sludge line for that distance but, in addition, the gravel pits themselves are valued at 1 million to 5 million dollars each.

We are hoping to work out an agreement with the city of Los Angeles Bureau of Sanitation to accept sludge from the new plant in their sewer system for ultimate delivery to their sewage treatment plant. If we are not successful in this, we have two other courses left.

We started out by considering about seven different plans for sludge disposal, and reduced then down to three. The first choice is disposal to the sewer system as I have just described. The second choice will be either disposal to a gravel pit or the operation of an alum reclamation plant.

To evaluate alum reclamation, we visited a few plants in Japan where that is being practiced. Interestingly enough, water treatment plants in Japan have been forced by their pollution control agencies to discontinue discharging alum sludge into streams. A number of plants are operated for alum reclamation,but do not recover alum all the time. In fact, more than half the time - when the flow is sufficient in the streams - the old practice is used of discharging the alum sludge directly into the surface waters. Apparently this practice is permissible during very high stream flows. Obviously, the discharge of sludge is considerably cheaper than alum reclamation.

I might mention that as a part of alum reclamation they are using vacuum filters, and are not particularly happy with the drying they accomplish. The solids content of the filter cake is about 28 or 30 percent. The cake is very sticky and rather hard to handle.

Sludge cake is presently dumped into a ravine which is filling rapidly. I don't know what they are going to do when the ravine is filled with alum sludge.

We ran some tests of our own on the recovery of alum from sludge, not being satisfied with 59 or 60 percent alum recovery, nor with 28 to 30 percent solids in the alum cake. In Japan, the acid treated sludge is put into a settling basin, permitted it to settle out, and the alum is decanted for recovery. To the residue, which contains a mixture of insoluble material and alum, lime is added and the mixture is filtered.

In our pilot plant tests, we treated the residue with acid and filtered the mixture at a pH of 1.5 to 2.5. The filtrate is clear and of good quality.

Because of the poor experience reported with vacuum filters, we made studies with a small filter press. With this, we were able to obtain a cake of 40 to 45 percent solids, and in one run over 50 percent solids. This cake is quite dry. With filtration of an acid residue, and using a filter press, we were able to attain recoveries of alum from 80 up to 93 percent and produce a very dry cake at the same time.

MR. KRASAUSKAS: The cost of sulfuric acid is now very high, about $27 a ton in our area and expected to increase. At present, we purchase a grade 2 alum which has about ten percent impurities; it's very similar to alum we used to manufacture. We manufactured alum from 1928 until 1964 in Washington D.C.; approximately 5,000 tons a year.

If we purchased sulfuric acid to manufacture alum today, we would be meeting the price of the alum that we buy. In fact, it might even cost us more to recover alum than we originally paid for it.

MR. DEAN: It might be possible to dissolve the precipitate with less hydrochloric acid than three mols. In England, one mol basic, aluminum chloride is used for sludge conditioning.

According to the literature, if alum is not exhausted as a precipitant, it should be possible to recover a soluble aluminum chloride with only one mole of hydrochloric acid. Three moles of sulfuric acid would probably be needed.

There could be a cost saving, plus the fact that you would put less sulphate into your water, which is also a consideration. This might be a research possibility.

MR. STREICHER: In our pilot tests, we found that when the ratio of aluminum hydroxide to other suspended matter was high, considerably less than stoichiometric amounts of sulfuric acid were required to get almost complete alum recovery. As the other insoluble matter increased in proportion to the aluminum hydroxide, more and more sulfuric acid was required. If the ratio of other insolubles was high, compared to aluminum hydroxide, it took more than stoichiometric amounts and the alum recovery was reduced. So it depends on the ratio of aluminum hydroxide to other suspended matter, according to our tests, just how much alum can be recovered.

MR. KRASAUSKAS: There is another benefit in the recovery of alum. The volume of the sludge is reduced to approximately one-sixth of the original volume. Do you find this to be true?

MR. STREICHER: Yes, but the recovery of alum would be much more attractive if the disposal problem disappeared entirely. When you have any residue left to dispose of, a treatment process loses some it its attractiveness.

MR. KRASAUSKAS: This is the trouble with all methods of sludge treatment. We still have an end product which must be disposed of.

MR. LAMB: I'd like to ask a question of the plant operating people present. The next topic which we will discuss is regulatory aspects. It would be interesting, I think, to know the attitudes and philosophy of operating people toward the whole question of waste disposal from water treatment plants. What do you think is the general attitude of operating and management officials in the water works industry concerning this problem?

MR. STREICHER: I think that they would rather be able to just shrug it off, but obviously it isn't possible now. In the present day I think we are going to be guided by the regulations more than anything else.

We have enough room for disposal for the next 50 or 100 years, so we are not concerned at this time. What would happen if we could not dispose of sludge on our own land, I don't know.

MR. KRASAUSKAS: To comment further on Mr. Lamb's question: the water treatment sludge presently discharged to the Potomac River in Washington is equivalent to about six-tenths of one percent of the load of silt which is carried by that river.

In the past, we have considered that the return of solids removed from the river do not add pollution. We do recognize that we will have to conform to pollution control requirements.

MR. WEBER: The net effect of returning removed impurities to a lesser quantity of water must degrade the quality of water.

MR. WEBBER: The City of Toledo is under proscription from two pollution agencies to cease discharge of wastes to the river.

MR. SHULL: It is the philosophy of our management that we have a moral obligation to get rid of settling basin sludge and filter washwater. I realize that a little nudging from the State regulatory agencies perhaps has had some bearing on this. Since we have always been very much concerned about what other people put in the stream above us, so we now feel obligated to do something for water users below our plants. We are doing everything possible to provide for adequate waste disposal.

MR. HENRY: Deep well disposal has been mentioned several times. Can anyone report on the use of deep wells for disposal of regenerant salt brines?

MR. STREICHER: I am not familiar with that operation, but it is mentioned in the literature. I believe there are examples of this practice in Kansas, where brine taken from salt wells is used for regeneration. The waste brine is then reinjected into other wells. This can be done only where aquifers can be definitely isolated from each other.

MR. DEAN: We are beginning to worry about the disposal of brines put down into wells. If the pressure of recharge is higher than the normal pressure, there is a very real danger of breakthroughs, thus getting salt into good aquifers.

This has happened at a number of places in Texas, not documented. It might be done safely in some geology situations.

But it's not the general answer. It's a special case like discharging in the ocean is a special case.

MR. KRASAUSKAS: Disposed of waste sludge into the sanitary sewer has been mentioned as a preferred method. We considered that method in Washington.

However, our Department of Sanitary Engineering already has such a serious problem disposing of wastewater sludge that they are not interested in adding the sludge from our water treatment plant. We must find some other method of disposal.

Our Department of Sanitary Engineering is considering barging sludge to sea, which would involve a distance of about 200 miles. They still haven't decided. If they do select that method, then it will be possible to dispose of our sludge in this manner.

MR. STREICHER: That's a long way to move sludge.

MR. KRASAUSKAS: Yes, but we simply have no land nearby to dispose of a large volume of sludge. We have a real problem.

MR. ADRIAN: Lompoc, California reclaimed the decant from their dewatering and drying beds. The decant had been added to the sewer when the beds were first installed and had problems with solids building up in the sewer line.

Apparently, solids built up would discharge suddenly, then would be received as a slug at the sewage treatment plant. The problem was solved by reclaiming the decant water and having no discharge into the sewer. There may be a problem, adding water treatment waste to the sewer, wherever the flow rate is low.

MR. STREICHER: I can report that, some years ago, the City of Los Angeles put in a test plant to study the treatment of sewage with alum. As I recall, an excess of some 50 ppm of alum, above the coagulant dosage, was added. The effluent from this plant discharged to a sewer line and caused clogging of that line.

Apparently, when the excess alum combined with the greases in the fresh sewage, a thick deposit was formed and the clogging problem was serious. That experience made the City reluctant to accept our sludge.

We told then that we could not afford to overtreat water with alum, and planned to have no unreacted alum left in the sludge at the time it was discharged. Additionally, we would pay for added capacity of the sewer system to provide a larger line.

The Los Angeles Bureau of Sanitation laboratories tested the alum sludge from our washwater reclamation unit, also sludge samples from the Livermore Plant on the South Bay Aqueduct. We will be treating the same type of water at our new Balboa plant. Their tests indicate that the sludge should not give them problems in sewers or in the sewerage treatment plant, except for increasing the bulk of sludge to be digested.

MR. JOHNSON: In the reclamation of your filter washwater, you mentioned that you coagulate the water and let it settle?

MR. STREICHER: Yes, we treat it just as if it were raw water.

MR. JOHNSON: Have you ever tried recycling the washwater back through the plant without this treatment.

MR. STREICHER: Yes. That's the way we started to reuse the water, but it caused problems in the settling basins and filters. In the original 100 MGD plant we had no washwater reclamation unit, and we recycled the washwater from the filters back to the plant influent channel.

In the early years, we used lime treatment and no problems were encountered. Then we abandoned lime treatment and, in fact, coagulation entirely (because our plant influent water is usually so good that we don't have to use any coagulation). We then found that as a result of returning untreated filter washwater, our clarified water contained about four times as much turbidity as the raw water.

It was necessary to use intermittent alum treatment of all of the water in the plant, just to remove this returned suspended matter from the washwater. This is the reason we installed a special washwater reclamation unit. We reduced our washwater from about two and one-half percent to three-quarters of one percent. We are continuously treating only this three-quarters of one percent with alum, rather than intermittently treating 102.5 percent. This is much cheaper, and more efficient procedure.

MR. TCHOBANOGLOUS: What effect would improved plant operations have on the total waste disposal problem, in your estimation?

MR. STREICHER: There is always room for improvement in plant operation. For example, by washwater reclamation, we never have washwater going to waste. Additionally, we have reduce the amount of chemical treatment required, have produced a better water, and reduced the amount of sludge.

MR. TCHOBANOGLOUS: Although there are large cities that can afford the manpower required to look into these matters there are many small cities that barely have enough personnel and facilities. I was wondering if anyone has looked into the effect of improved plant operations.

MR. HARTUNG: I don't understand the question with regard to improved plant operations. Certainly if you are more efficient in the operation of your plant, you will reduce operating costs. But in the last analysis you must dispose of any solids taken out of the water, efficiently or inefficiently. If you are efficient in handling it, then obviously you are going to reduce operating costs, but the problem of how to dispose of the sludge remains the same.

The preparation for disposal and the disposal of solids, which have been withdrawn from a clarifier, is the same kind of problem whether the solids are withdrawn at 0.1% solids or if withdrawn after concentration to about 10% solids. The cost of handling and preparation for disposal are different, but the amount of solids for disposal and what to do with these solids is the same in either case.

MR. ADRIAN: I'd like to comment on another aspect of efficiency with regard to plant operation. The City of Minot has a serious water shortage during the summer. The plant is operated very well, but the washwater was not reclaimed, and is discharged to a nearby stream. Apparently this was an oversight in plant design, that no attempt was made to recover this water which would be helpful in aleviating the summer shortage.

MR. PROUDFIT: Just in defense of the engineers I'd like to comment that there are many well designed plants that are not properly operated.

MR. NEBIKER: Since washwater already has chemicals added, for pH adjustment, etc., the reclamation of this water will not only save water but save on chemicals also.

Regarding the problem of land disposal of sludge. The disposal of a solid sludge is not as difficult as frequently thought. Many studies have been made to locate sanitary landfill sites. A survey in Boston showed that about eight percent of this strictly urban land was not used, predominantly because of the new highways. Cloverleafs could serve as sites for solid waste disposal. I think that in many cities one can find small sites for disposal solid sludge.

The cities of Chicago and Cleveland are studying the pumping of sewage sludge considerable distances for land disposal. It would appear that this method is practical for many communities that have a shortage of available land nearby.

After land has been filled, it can still be used. Removal of the dewatered sludge may be required, but this temporary solution for disposal may be more reasonable in cost than other methods. Land dewatering will reduce the volume of sludge to be rehandled.

MR. HARTUNG: With regard to the return of washwater to the plant influent: Most of us who have tried the recovery of washwater, by returning it to the incoming flow into the plant, have had about the same kind of experience. We find that the return of washwater often places a load on the plant out of proportion to the value of the water saved, unless the water is treated before it is returned. In analyzing who this is so, we have concluded it is because of the way washwater is handled prior to recovery.

As the backwash water falls into the washwater troughs and then flows through a sewer, the floc and coagulated material which it contains is pulverized and broken. It is then almost impossible to resettle the washwater in a settling basin, or to re-coagulate it with the same amount of coagulant being used in the plant for the raw water being processed.

My company has one plant in which the filter unit is located within the settling basin. When we backwash the filter, the water merely rises up out of the filter unit and then flows back into the settling portion of the basin. That water is readily reusable and refilterable. In an adjacent plant, treating almost the same type of water, the washwater spills into wash troughs, flows through a sewer, and is not usable.

MR. DOE: I have comments on several items in the status report on plant operation.

As sources of applied research on the sludge disposal problem, the report suggests: "governmental agencies, equipment manufacturers, and the larger water treatment plants." I believe the greatest future contribution will be in the form of feasibility reports prepared by consultants, and of research conducted in universities. Some good reports of this type have been prepared in New York State.

The status report lists eleven methods of sludge disposal. We should be careful not to give laymen the impression that "any method is excellent; which one shall we choose?" In fact, there may be only one or two methods applicable to a specific location.

On the question of sludge pressing the report refers to limited possibilities for automation of this treatment process. There are presses on the market in which the entire operation is completely automatic. My own firm has been operating a completely automatic pilot press this summer. This operation will put pressing in a rather better light. Maintenance is generally rather low on these presses.

MR. STREICHER: In one plant I visited in Japan they have filter presses designed for automatic discharge of sludge cake. Because of the nature of the material, they still have a man standing by with a scraper to remove sludge solids that don't come off freely. I understand that the better filter presses are almost completely self-cleaning.

MR. DOE: Especially the pre-coat ones.

MR. KRASAUSKAS: How are these presses arranged to take the creases out of the cloth automatically?

MR. DOE: We do not have the problem of creases in the cloth, with the filter press we are studying. In certain presses I have seen in England, it is necessary to rearrange the cloths and take the creases out.

There is a new type of press in which the cloth is caulked into a groove around the circular plate, and there is an additional rubber "O" ring going all the way around as a sealer. There is no leakage whatever of sludge. Unfortunately, these presses are not yet in operation on an alum sludge, but it is anticipated that there will be one soon.

MR. PETERS: As for the filter press being fully automated, it is our desire to have a remote-manual system to maintain quality control. The batch-mix may need adjusting, due to variation in solids content, to insure a firm cake from the filter press.

The filter cloth must be inspected for pinholes and wear, but according to consultants, the cloth should last for several thousand hours of operation. This information is based on pilot plant studies and not on full plant operation.

A question to Mr. Streicher. If it is acceptable in Los Angeles to discharge water plant sludge to a sewer, what type of treatment will be provided at the sewage plant?

MR. STREICHER: The sludge will go to the Hyperion activated sludge plant. This plant is in the early stages of construction, and will not be in operation for over two years.

If the water plant sludge is accepted, it will add a relatively small increment to the total load of sewage solids handled at the sewage plant. The final effluent from the plant will be discharged to the ocean.

MR. PETERS: By discharging water treatment sludge solids to sewers, we place the burden of disposal on the sewage treatment plant. Atlanta's sewage treatment plant is overloaded at the present time and passing approximately 50 percent raw sewage into the river.

From laboratory tests, we have found that river pollution is greater during high flows than during low flows. This is mainly due to the sewage plants bypassing their flow to the river during times storm waters enter the sewage systems.

MR. KRASAUSKAS: This is an important point. The only time we have real pollution in our Potomac River water intake is when we have runoff. Normally, the raw water has an mpn of about 50, which is extremely good water. At the time of a heavy runoff, the mpn increases to 250,000 or higher.

To answer the question of the effect of sludge on sewage plant operation, I visited Detroit. Dr. Shannon, is in charge of both the water plant and the sewage plant. That city discharges water treatment sludge to the sewer, maintaining a velocity of flow of about two and one half feet per second. There is no deposition of solids in the sewer.

When sludge solids were released from the clarifiers as a slug, the small county sewage treatment plant receiving it had trouble with vacuum filtration. When sludge was discharged over a period of about a week, there were no problems with vacuum filtration.

Detroit also has a pilot activated sludge plant, treating 100 gallons per minute. I was advised that a proportional discharge of alum sludge into the activated sludge treatment had no plant deleterious effect.

MR. RUSSELMANN: It is important to consider that in proper water treatment operation there is an accounting for water quality, from the raw water to the delivered water. Any discussion of plant operating practice should encourage an accounting for the wastewater, so that water treatment operations apply the complete management concept or accountability.

There are many water treatment plants that do not have adequate facilities for waste disposal. They should immediately be encouraged to provide operating reports, observations, and measurements of wastes, just as they do now for operating data on producing finished water. Such observations and measurements should also be made of land or water receiving areas. Useful data will then be available when the time comes to provide waste treatment or disposal.

This concludes discussion of the status report on plant operation.

* * *

STATUS REPORT ON REGULATORY ASPECTS

Edwin C. Weber

A status report on the disposal of wastes from water treatment plants, in order to be complete, must include information on regulatory aspects of the problem. To obtain this information, the AWWA Research Foundation made a survey of regulatory agencies by means of a questionnaire sent in December 1968.

Summary Report

A period of 15 years has elapsed since Dean, in 1953, reported on the status of federal and state laws prohibiting the discharge of water treatment plant wastes into surface waters.

At that time, Dean pointed to a definite trend toward the enactment of these laws. He also stated: "In the future the disposal of such wastes is likely to be a matter of increasing concern to designers and operators of water purification plants."

The 1968 survey by the Research Foundation shows that, since Dean's report, a dramatic change has indeed taken place in the enactment of laws. The technical literature, in recent years, also demonstrates increasing concern by designers and operators with problems of water treatment plant waste disposal.

The Federal Water Quality Act of 1965, requiring states to set standards for interstate waters in order to enhance water quality, has given states the authority to order the treatment of water plant wastes before discharge to surface waters.

Dean, in 1953, reported that 19 states did not consider the discharge of filter washwater or sedimentation basin sludge to surface waters constituted a violation of their pollution laws or regulations. Only 5 states did consider the discharge of these wastes to be a violation. The remaining 24 states controlled discharge of the wastes as needed, but did not have specific laws or regulations.

Responses to the 1968 AWWA Research Foundation survey indicate how completely the regulatory situation has changed. Instead of only 5 states having laws or regulations to control the discharge of these wastes, there are 5 states reporting they do not now have laws.

SURVEY OF REGULATORY AGENCIES

The Research Foundation questionnaire was sent to the 50 states, the District of Columbia, Quam, Puerto Rico, and the Virgin Islands. The questionnaire was also sent to eight interstate agencies.

Response to the questionnaire was excellent. Replies were received from 49 states, the District of Columbia, Quam, Puerto Rico, Virgin Islands, and six interstate agencies. The one state not replying was Nevada.

The survey form included ten brief questions requiring "yes" or "no" answers. The form first provided a definition, and thereafter each question referred to "these wastes."

> DEFINITION: Wastes from water treatment plants include those resulting from filter backwash; coagulation, softening, iron and manganese removal processes; diatomaceous earth filtration; and ion exchange brines.

The ten questions in the survey form related to Regulatory Information (5 questions); Statistical Information (3 questions); and Research Information (2 questions). Respondents were requested to supply special comments and to elaborate on their replies where appropriate.

SUMMARY OF REPLIES

A summary of questionnaire replies, and of special comments made by respondents, is provided on the following pages.

SUMMARY OF QUESTIONNAIRE REPLIES

REGULATORY INFORMATION

Question 1

"This Agency considers discharge of these wastes to surface waters a violation of pollution control laws or regulations."

Reply Yes: 43 States, Virgin Islands, 6 Interstate Agencies

Reply No : Alaska, New Mexico, Tennessee, Wyoming

No Reply : Florida, Montana, South Carolina

Question 1 - Comments

Alabama. "Such discharges could be a violation of pollution control laws if they result in contravention of water quality standards."

Arizona. "Depending on type of waste and size of receiving stream."

Delaware. "Depends on the stream."

Kansas. "Only lime-soda softening sludge, and ion exchange brines are now a problem. Wastes from filter backwash, coagulation, and iron and manganese are presently considered to be problems."

Kentucky. "Depending on volume in relation to stream flow."

Minnesota. "There is no violation per se unless the waste is discharged without a permit and violates the standards of water quality and purity for the receiving waters."

Missouri. "Depends on location. Must comply with Water Quality Stream Standards."

Montana. "Montana has two lime-soda softening plants. The wastes have not been of sufficient quantity to create a problem, since the discharges are to Yellowstone River where the river is already turbid."

New York. "We do not presently take any action against existing waste discharges unless there is a contravention of stream standards. This is in accordance with our Public Health Law. We do require plans and construction of waste disposal facilities for the waste effluents from new or expanded facilities."

Question 2

"This Agency has laws or regulations requiring control or treatment of these wastes before discharge to surface waters."

Reply Yes: 42 States, 3 Interstate Agencies

Reply No : Alaska, Arizona, Hawaii, Nebraska, Wyoming

No Reply : Florida, Montana, South Carolina

Question 2 - Comments

Alabama. "Alabama's pollution control law provides authority to control all pollution-causing wastes without reference to specific sources."

Alaska. "Because there are just four communities in Alaska with metropolitan populations of 10,000 or more and water supply comes from ground water sources, the State Agency has not considered it urgent to control the disposal of wastes from water treatment plants."

Delaware. "Controls all pollution."

Maryland. "Regulation 4.4 lists the requirements that the waste water must meet prior to discharge to waters of the State. Section 1.31 of Regulation 4.8 states that the waters of the State shall at all times be free from substances attributable to sewage, industrial waste, or other waste that will settle to form sludge deposits that are unsightly, putrescent or ordorous to such degree as to create a nuisance, or that interfere directly or indirectly with water uses."

Massachusetts. "The Massachusetts Clean Waters Act gives the Division of Water Pollution Control authority to require treatment of all wastes."

Minnesota. "Regulations of water quality and purity for the surface waters of the state have been adopted under the Minnesota Pollution Control Act, Chapters 115 and 116."

Nebraska. "We are now requiring retention or treatment of water and swimming pool filter wash and settling basin discharges."

New Hampshire. "Control by virtue of Surface water classification and discharge permit system."

Oklahoma. "State Health Laws requires that plans and specifications be submitted for a permit prior to construction. Also Water Quality Standards prohibits the discharge of wastes causing sludge deposits, turbidity, color or floating debris in surface water."

South Carolina. "Have not had to be concerned with this problem. Most of water treatment plants are small and the water takes low coagulant doses."

Tennessee. "Do not have separate specific regulations on water treatment plants."

Delaware River Basin Commission. "Wastes from water treatment plants are considered to be industrial wastes. Discharge of such wastes to Basin streams must meet all appropriate requirements of the Commission's Water Quality Regulations."

New England Interstate Water Pollution Control Commission. "Individual states have rules and regulations and/or laws regarding control."

Orsanco. "With regard to the discharge of water purification plant wastewater to the Ohio River, the State pollution control agencies will establish treatment requirements in conformance to the following policy:

1. "Installation of waste-control facilities will be required as a part of the initial construction of new water purification plants;

2. "Installation of waste-control facilities will be required at existing water purification plants whenever substantial improvements or enlargements are made at these plants;

3. "Installation of waste-control facilities will be required at existing water purification plants when the discharge of untreated waste results in obvious pollution or in quality levels that do not meet established criteria. In these cases time schedules for the installation of waste-control facilties shall be established in conformance with the State's plan of implementation."

Question 3

"This Agency plans future laws or regulations for control or treatment of these wastes before discharge to surface waters."

Reply Yes: Alaska, Arizona, Nebraska, Oregon, Tennessee, Virginia, Washington, West Virginia, District of Columbia, Virgin Islands, one Interstate Agency

Reply No : 36 States

No Reply : 6 States

Question 3 - Comments

Alaska. "As population grows and as implementation of water quality standards begin some form of regulation will be desirable."

Maryland. "The Department of Water Resources is of the opinion that the provisions of Regulation 4.4 and of Section 1.31 of Regulation 4.8 are adequate to control the waste discharges from water treatment plants to waters of the State. However, the Department is prepared to recommend additional law and regulation, should the results of research and study indicate this to be desirable."

Question 4

"This Agency has encountered pollution problems attributed to the discharge of these wastes to surface waters."

Reply Yes: 28 States, 2 Interstate Agencies

Reply No : Alabama, Alaska, Arizona, Arkansas, Colorado, Georgia, Hawaii, Iowa, Nebraska, Nevada, New Hampshire, New Mexico, Oregon, South Carolina, Texas, Vermont, Virginia, Washington, Wyoming

No Reply : Delaware, Florida, Montana

Question 4 - Comments

Idaho. "Has 10 small water treatment plants in the State which discharge backwash water without removing settleable material which is considered a violation of regulations. All plants have been notified to take whatever action is necessary to remove the settleable solids from the backwash water. We have not taken any legal action."

Illinois. "Adequate waste treatment is obtained."

Indiana. "Four plants discharging lime sludges to surface waters causing sludge banks. Required correction and discharge was abated."

Louisiana. "Siltation in lake, sludge banks in small streams."

Maine. "Sediment from backwash left noticeable deposits on channel beds, as a result, new construction precaution against this and other items were taken. Statue requires permit for new discharges."

Massachusetts. "Filter backwash and sludges discharged to river."

North Carolina. "Fort Bragg, North Carolina - Sludge from water plant sedimentation basin discharged to Lower Little River during period of low flow, resulting in small fish kill. Since the plant is owned and operated by a Federal Agency, the matter was investigated and referred to the Federal Water Pollution Control Administration for investigation and corrective action."

Oklahoma. "Downstream property owners complain of increases in turbidity and sludge deposits."

Tennessee. "Many new problems are being found each year on small streams and recreational waters. The City of Johnson City discharged waste from water treatment plant into a small mountain rainbow trout stream and killed the trout. Have also had problems with West Wilson Utility District's water treatment plant discharge of wastes from the coagulation basin and backwash of the filters into a recreational embayment on Old Hickory Lake."

Utah. "Salt Lake City Water Works Department's City Creek and Big Cottonwood water treatment plants discharge wastes to streams."

Question 5

"This Agency has taken official or unofficial action to discontinue the discharge of these wastes to surface waters."

Reply Yes: 32 States, 2 Interstate Agencies

Reply No : Alabama, Alaska, Arizona, Colorado, Delaware, Hawaii, Mississippi, Nebraska, New Hampshire, New Mexico, North Carolina, Texas, Virginia, Washington, Wyoming; 4 Interstate Agencies

No Reply : Florida, Montana, South Carolina

Question 5 - Comments

Illinois. "Demanded corrective action."

Indiana. "New water plants or major construction for existing plants are required to provide plans for acceptable waste disposal before the project is approved by the Board of Health. This is not in the true sense of the word, discontinuing the discharge of wastes to surface waters."

Iowa. "Motion for discontinuance of softening sludge discharges."

Kansas. "Lime-soda softening sludge is a serious problem. A section of one of our major rivers was ruined by softening sludge."

Louisiana. "Issued orders to offenders to correct situation."

Massachusetts. "The Division of Water Pollution Control has placed several municipalities on 'Implementation Schedules' to provide adequate treatment before discharge."

Maryland. "The Department of Water Resources has contacted officials of the following water treatment plants and requested that information be provided to the Department regarding any plans that they may have for avoiding recurrence of the objectionable conditions caused by the discharge of waste sludges from the water treatment plants to State waters:

a. "Anne Arundel County Department of Public Works - regarding the Pines Water Treatment Plant discharge of iron sludge to Chase Creek, a tributary of Severn River."

b. "City of Bowie - regarding the Bowie-Belair Water Treatment Plant discharge of iron and filter backwash sludge to a small tributary of the Patuxent River."

c. "Washington Suburban Sanitary Commission - regarding the Patuxent Filtration Plant discharge of filter backwash and alum settlement to Walker Branch, a tributary of the Patuxent River."

Michigan. "Generally, a minimum restriction is placed on quantity of suspended solids in the discharge."

New Jersey. "As an objective of the Potable Water Program, pressure is being brought against all water purveyors to install corrective treatment methods where applicable. This will be followed up with formal orders to insure compliance."

Ohio. "It is planned to continue to place more plants under permit by requiring a permit where stream water quality and minimum conditions criteria are not met, where new plants are constructed, or old plants altered, and where disposal facilities are now existing."

Oklahoma. "Construction of holding and settling lagoons or pumps installed for returning water to treatment plants. New plants required to install proper control."

Oregon. "There are 50 domestic water treatment plants located in Oregon. Eight of these 50 plants are impounding the wastewater before discharge of the partially clarified water to nearby stream."

"Oregon operates under a system of Board of Health Review of proposed work construction. Approval is required before construction begins. When new construction is planned, provisions are required for wastewater treatment which usually amounts to holding the water until most of the settleable solids are removed."

"All water treatment plants that chemically alter the water and discharge wastewater back to the stream will eventually require a discharge permit."

Pennsylvania. "The Sanitary Water Board requires the submission of an industrial waste application for the treatment of such wastes at all modifications of existing plants and at all new water treatment plants in addition to taking enforcement action at existing discharges where pollution exists."

South Dakota. "Cities discharging water treatment plant wastes have been or are being notified that continued discharges will not be permitted."

Tennessee. "Correction was made at Johnson City by constructing a lagoon and supernatant discharged to the stream at a controlled rate. At West Wilson Utility Control Board, issued Order for correction and outfall was extended 200 feet from shore."

Utah. "Salt Lake City Water Department was requested and did provide the necessary corrective measures."

Delaware River Basin Commission. "The Commission, under Section 3.8 and Article 11 of its Compact must approve all projects involving water treatment plants before they can be constructed."

STATISTICAL INFORMATION

Question 6

"This Agency has available reports on data on the quantities and characteristics of these wastes."

Reply Yes: Connecticut, Idaho, Kentucky, New York, Texas ORSANCO

Reply No : 43 States, Virgin Islands, 5 Interstate Agencies

No Reply : Florida, Montana

Question 6 - Comments

Idaho. "Has information on quantity and characteristics of most backwash water; but has not compiled these results in any type of report."

Maryland. "The Department of Water Resources has not attempted to collect reports or data from all the water treatment plants in Maryland."

Minnesota. "Regulations of the Agency require that all interstate wastewater dischargers submit operational reports to the Agency. This information has not been compiled."

Oklahoma. "Quantities of solids and liquid are estimated by design engineers with extra storage capacity to allow for drying and cleaning."

Interstate Sanitary Commission. "Discharges of wastes from water treatment plants are rare as all Interstate Sanitary Commission waters are tidal (no potable water)."

Question 7

"This Agency can identify water treatment plants having facilities for control on treatment of these wastes."

Reply Yes: 29 States, Puerto Rico, Virgin Islands, 2 Interstate Agencies

Reply No : Alabama, Alaska, Arkansas, Colorado, Hawaii, Idaho, Iowa, Kentucky, Louisiana, Michigan, Minnesota, Mississippi, Nebraska, New Mexico, North Carolina, South Carolina, Washington; District of Columbia; Guam; 4 Interstate Agencies

No Reply : California, Florida, Maine, Nevada

Question 7 - Comments

Idaho. "At the present time, plants have not installed facilities for the control of these facilities."

Indiana. "Have knowledge of the plants and disposal methods used by some plants; a listing is not maintained."

Kansas. "Do not believe a satisfactory method of disposing of lime softening sludge has been developed. We have many sludge lagoons that are preventing serious pollution but they are very difficult to operate and design criteria is not well established." Submitted listing of 20 towns having facilities for either lagooning or hauling softening sludge."

Massachusetts. "Billerica Water Treatment Plant, Billerica, Massachusetts."

North Dakota. "Indicated twelve water plants treating wastes."

Ohio. "Listed 52 water plants notified or placed under permit for waste sludge disposal and listed 35 water plants having lime softening process sludge disposal facilities.

Oklahoma. "Listed six plants having treatment."

Pennsylvania. "Listed 45 water treatment plants having sanitary Water Board Permits for Wastewater Treatment Facilities."

South Dakota. "Listed six water treatment plants."

Utah. "Listed eleven water treatment plants providing control of wastes discharges."

Vermont. "Tri-Town Water District plant discharges filter backwash water to a lagoon for sediment prior to discharge into Lake Champlain. There are ten municipally owned water plants in Vermont."

Virginia. "Surveyed 148 plants; only seven provided any form of waste treatment other than discharge to the nearest available water course."

Question 8

"This Agency can identify water treatment plants discharging these wastes to sewage systems."

Reply Yes: Arizona, Connecticut, Delaware, Georgia, Indiana, Kentucky, Missouri, Montana, New Hampshire, New Jersey, North Dakota, Ohio, Oklahoma, Texas, Virginia, Wisconsin, Wyoming; District of Columbia; Virgin Islands; Interstate Agency

Reply No : 28 States; 5 Interstate Agencies

No Reply : California, Florida, Maine, Nevada, South Dakota

Question 8 - Comments

Idaho. "None of the water treatment plants discharge to sewerage systems."

Indiana. "Know that certain plants do discharge to the sewers, a listing is not maintained."

North Dakota. "Indicated nine water plants discharging wastes to sewer system."

Ohio. "Indicated three water plants discharging wastes to sewer."

Oklahoma. "Only one - Tecumseh, not a desirable situation."

South Dakota. "For most larger installations, this method has been found unsatisfactory."

Tennessee. "There are a number of plants that discharge into municipal systems."

Virginia. "The Town of Berryville and Selma discharge wastes to municipal sewerage systems."

RESEARCH INFORMATION

Question 9

"This Agency has previously conducted or supported research on the treatment of these wastes."

Reply Yes: New York

Reply No : 46 States; Virgin Islands; 6 Interstate Agencies

No Reply : California, Florida, Maine

Question 9 - Comments

New York. "New York State Health Department has completed Research Report No. 14, "Characteristics of and Methodology for Measuring Water Filtration Plant Wastes" prepared by Cornell University; and Research Report No. 15, "Waste Alum Sludge Characteristics and Treatment" by O'Brien and Gere, Consulting Engineers."

Question 10

"This Agency is currently conducting or supporting research on the treatment of these wastes."

Reply Yes: Ohio, West Virginia

Reply No : 45 States; Virgin Islands; 6 Interstate Agencies

No Reply : California, Florida, Maine

Question 10 - Comments

Maryland. "On November 23, 1966, the Maryland Water Resources Commission, at its regular meeting, discussed the periodic discharges by Maryland water treatment plants of filter backwash and of sedimentary deposits from settling basins."

"At this Commission meeting, a motion was unanimously approved to request the Washington Suburban Sanitary Commission to explore the possibility of a demonstration project for the purpose of controlling and disposing of filter backwash and the discharge of sedimentary deposits from settling basins of water treatment plants."

Ohio. "Ohio entered into contract July 1, 1968, with Burgess and Niple, Ltd., Consulting Engineers, Columbus, Ohio, to study methods of handling lime softening plant wastes from water plants under 10 M.G.D. capacity. Five or six plants are being studied. The report on this study is due on July 1, 1969."

West Virginia. "West Virginia has been studying and requiring the recycling or reuse of filter washwater when new plants are constructed, in order to control sediment to the streams."

ADDITIONAL SURVEY INFORMATION

Kansas reports lime-soda softening sludges and ion exchange brines to be serious problems. Lagoons to retain these sludges are difficult to operate, and a satisfactory method to dispose of these sludges has not been developed. At present, Kansas has 20 municipalities using lagoons or hauling sludges to disposal sites.

Tennessee and North Carolina reported fish kills caused by the discharge of sludge from settling basins during periods of low stream flow.

Six Interstate Commission Agencies reported that they consider the discharge of wastes from water treatment plants a violation of pollution control laws and regulation.

Delaware River Basin Commission, ORSANCO, and Interstate Sanitary Commission have laws and regulations to control or treat these wastes before discharge to surface waters. New England Interstate Water Commission plans future laws and regulations for control or treatment of these wastes.

Delaware River Basin Commission, Interstate Sanitary Commission and ORSANCO have encountered pollution problems attributed to the discharge of these wastes and have taken action to discontinue the discharge of these wastes to surface waters.

* * *

DISCUSSION OF STATUS REPORT ON REGULATORY ASPECTS

MR. WEBER: We consider the response to our questionnaire was excellent. Replies were received from 50 states, and also from the District of Columbia, Guam, Puerto Rico, the Virgin Islands, and 6 interstate agencies.

I believe the summary of replies to the ten questions constitutes a very good status report on current regulatory aspects of the water treatment plant waste disposal problem.

When we compare the information obtained in this survey with that reported in the 1953 survey, it is evident that the states have recognized the need for control of these wastes, and have promulgated laws and regulations. Fifteen years ago, 5 states had laws to control the discharge of these wastes to surface waters - and now, only 5 states do not have laws.

It is possible that the Federal Water Quality Act of 1965 has significantly affected this change. The Act requires states to set water quality standards for interstate waters in order to enhance water quality, and gives states authority to order the treatment of wastewaters before discharge to surface waters.

Finally, I wish to emphasize that the problem of water treatment plant waste disposal is a very real problem. Our survey data demonstrate this point clearly.

Note that:

28 states report they already have encountered pollution problems from these wastes, and

32 states report they have taken action to discontinue discharge of these wastes. (Even though no pollution problems were recognized, the State of Idaho issued an order on all of its ten water treatment plants.)

MR. LAMB: As a member of the AWWA research committee on disposal of sludge, I looked at the replies to this survey for evidence of research. It is apparent that the states are not doing much.

Only one state reported that it has supported research, and two states indicate that they are supporting some now. This is an interesting situation, which does not speak well of our approach to the problem. The need for research or investigations is certainly made evident by the responses to question 4, which indicates that 26 states have encountered pollution problems in the discharge of these wastes.

MR. RUSSELMANN: It is true that New York state is not presently supporting research on this problem. Two projects were supported at a time when the State Health Department became concerned with the problem, and money was available. Unfortunately, it isn't possible now for the State to commit funds for this kind of activity.

MR. DICK: I remember that a major bond issue in New York state supports a program of construction grants for pollution control. It seems there is some disparity in supporting construction of new plants, but not supporting attempts to develop new means of improving water quality or to make construction dollars more effective.

MR. RUSSELMANN: The State's construction grants are for sewage treatment works, and are not applicable to water treatment plants.

I would like to repeat my suggestion discussed earlier. The resource for gathering data and measuring the problem we are dealing with exists in all water treatment plants. We are not doing much about it. This is an activity which can be done without financial support.

MR. HARTUNG: Several speakers today have mentioned that it is advisable to collect data so that we can measure the scope and the kind of problem with which we are dealing. I agree.

I would also like to say that, in conjunction with that problem, we need some kind of measure as to when the discharge of waste into a surface water supply actually is detrimental to that water supply. It has been emphasized that when waste discharge affects the raw water quality standards, then there should be abatement. My question is: How can we measure whether or not the disposal of these wastes into a river in any way affects the quality of that water as measured by the raw water quality standard which has been set?

An answer by one state to the questionnaire is that they are requiring abatement or the treatment of washwater wastes before such are dumped into the river, even when there is no possibility at all of measuring the effect upon the river. In one instance I know about, there is no change in turbidity from the discharge of wastewater. There is no change in BOD, or in appearance, and no sludge deposits. But yet the state has asked for the treatment of the wastewater before it's discharged to the river. Perhaps we ought to be practical in terms of the data we are collecting, in solving the problem.

When does the disposal of the waste in a body of water really cause a problem?

MR. COULTER: You have opened a subject on which I have strong thoughts. Very dramatic changes are taking place in water pollution control, and the water works industry is directly affected.

I think that we are playing a game called "water quality standards" in which we are trying to identify impacts on beneficial uses. We cannot except for some outstanding cases, really trace the impact back to any particular wastewater discharger and say, "Here is the polluter causing the damage that we are talking about."

In the State of Maryland, we have very strong feelings about the quality of water in the Chesapeake Bay and even in the polluted Potomac River. The Potomac is cleaner than any river that goes through a town of a million or more, but it still is considered polluted. We are moving towards the attitude that those waters are the property of the state. To discharge anything into those waters is a privilege accorded by the state, and to discharge anything into them that is not necessary is an abuse of the privilege.

I think that this kind of philosophy will be adopted more and more. It is important that we think this way in Maryland, because in the next 25 years the State's increase in population will be equal to the level of population reached in the first 200 years.

If we are to keep the waters clean for recreational purposes, if we are to continue to harvest shell fish and eat them raw, if we are to have the much higher quality of water that people talk about, if we are to make whole stretches of streams into parkland, then it seems to us that the strategy is to remove every bit of contaminant that we possibly can from every capturable source of wastewater.

Mr. Krasauskas reported that during high flows the Potomac River had bacterial counts up into the hundreds of thousands. During low flows, the counts are down to around 50.

This illustrates the point that a tremendous amount of pollution comes from uncontrolled and uncontrollable runoff. If we are to offset the pollutional aspects of that uncontrolled runoff, it becomes more and more incumbent on us to clean up all water that we can capture before it is discharged.

Waste treatment might appear to be a large cost to the water works industry. It has been pointed out that "the effects of wastewater might be beneficial," or that "the effect of wastewater discharge cannot be measured." This is temporizing. The elimination of waste discharges will have a cost, but it will have a beneficial effect.

For example, in the Patuxent River Basin we have recently requested several communities to go through the engineering work and come up with plans and specifications for removal of nitrogen and phosphorous from their wastewater discharges. We haven't seen the results of those engineering reports, but I would guess that the cost is going to be about 25 cents a thousand gallons to remove those contaminants from the wastewater.

I cite this to illustrate the point that tremendous investments are about to be made in water pollution control. It is going to become absolutely incumbent upon us to remove impurities from waste discharges to the maximum extent possible, whether we can demonstrate whether or not individual instances of removal are going to have a beneficial effect.

MR. KINMAN: I would like to have individuals representing states comment on the question, "Do you know of any actual enforcement proceedings taken against a water treatment plant or water utility to clean up its wastes?

MR. WEBER: Several years ago in Maryland, the City of Laurel brought a court case against the Washington Suburban Sanitary Commission for the discharge of wastewater. The City lost the case. At that time, the Commission obtained permission, or an easement, to discharge sludge to Walker Branch and to the Patuxent River.

The State of Maryland brought the matter of water treatment plant waste disposal before its Water Resources Commission. Mr. McLeod, Chief Engineer of the Washington Suburban Sanitary Commission, at that time called upon the AWWA for assistance.

MR. EAGLE: About going to court: I think we have tools equally effective, if not more effective than going to court, in our respective state water pollution control Boards. In the case of Ohio, I think we reported in the survey that some 35 water utilities were under permits. There are now some 55 under permit or in the process of being placed under permit. Every one of these permittees has orders or conditions issued by the Water Pollution Control Board that they small meet within specified periods of time.

To me, permits, orders, and conditions are official legal actions. In Ohio we try to stay away from court action, which is another way to stall. You will find that the Board is much more effective than the courts.

MR. COULTER: I might say one other word about research. In Maryland, I have attempted to promote research with the General Assembly, the Appropriations Committee, and others, and have had no success whatever.

If our state is any indication of the mood in the state legislatures at the present time, money for research on the disposal of these wastes will be very hard to come by. It is pointed out to me that the Federal Government can support research programs, so that each one of the 50 states will not have to provide laboratories and conduct research themselves.

MR LAMB: With respect to research, I believe we should not fail to point out that there is responsibility for supporting research at the plant level. If we were speaking about a different industry today, there would be some question concerning the extent to which the Federal Government should support research to solve the industrial problem.

I think that none of us would question that an industry should support a substantial amount of the investigation relating to the specific plant which stands to benefit from the research; for example, to demonstrate that they must or need not do something; if so, what need be done; and most economical ways for solving industrial waste problems at that plant.

If we are to look at the water treatment plant discharge as an industrial waste, why should the plant not also carry some of the financial load? I realize that these are practical problems involved, but repeat that if we were talking about any other industry, we would be looking to the industry to help. I see no reason why we shouldn't look to the water works industry in the same manner.

MR. WEBER: Some states do consider wastes from water treatment plants to be industrial wastes. Their regulations apply equally to do any type of industrial waste.

MR. LAMB: Frequently, Federal support of industrial waste studies is available only for categorical types of investigations which apply to a rather broad spectrum of some industry, or perhaps group of industries. There is another type of research, which the Federal Government and the States usually are not involved in. This deals with the solution of specific problems at specific plants. In these instances, the industry usually has to carry substantially the whole load.

I think that we in the water field will have to view our situation in somewhat the same light. In research or investigations which apply to a broad spectrum of the water industry (for example softening sludges and other categorical wastes), we might look to the Federal Government or the States for help. To solve the problems of specific water treatment plants, we should look to the plants themselves to come up with design parameters for construction of facilities suitable for treating their wastes.

MR. LACY: I will augment references to Federal support for research. The Federal Water Pollution Control Administration, through its Office of Research and Development, can award grant funds to do exactly what Mr. Lamb pointed out. Under out Industrial Waste Treatment grant program, we can support projects which have industry-wide application. These grants can provide up to 70 percent of the project cost, with a maximum of $1 million.

If a project is limited to solving the problem of a specific water treatment plant, it is obvious that the plant must solve its own problem. However, almost every problem does have some industry-wide application. I suggest that you come to us with demonstration projects you would like to implement. We will work out with you the degree of our interest in the project, and its applicability to the industry.

Our support of a project may not be 70 percent, but might be 50 percent. But we do have funds, and it is to your benefit to discuss your proposed demonstration projects with us.

MR. LAMB: For purpose of clarification, could you tell us what the situation is with respect to funds which do not require as much matching - such as projects for preliminary investigations not involving demonstration.

For example, do you have grant or contract funds which would be available for research studies with rather broad implications?

MR. LACY: In 1968, our funds for industrial waste treatment grants are a little more than $10 million, and for contracts about $300,000.

Research grants are our third type of grant. These grants support studies for basic or applied research preceeding the demonstration phase. These grants do not support the full cost of a project.

Under our research grant program, we are providing partial support for the AWWA Research Foundation's study of water treatment plant waste disposal, and the Foundation is providing the remaining support.

Let us assume that, following this study, pilot scale projects are developed which could be conducted at an AWWA member's laboratory or treatment plant. We would be favorably inclined to accept the recommendation of the Foundation and its advisory committee, and fund pilot scale development projects.

From that work, one or two processes might be developed which would be applicable industry-wide. Then we would welcome and encourage full scale demonstration of the process or processes at a specific plant. We invite you to come to us directly or through the Research Foundation with projects to demonstrate technology for treating these wastes.

MR. BISHOP: This question is directed to Mr. Doe. Who supports the Water Research Association in England?

MR. DOE: It is supported in part by means of a levy on those water undertakings in England who are members, and in part by Government funds. Some 75 percent of all the water undertakings, public or private companies, contribute to the Association.

Many industrial research associations in Great Britain are partly supported by the Government and partly by the industry. Perhaps one-half of a research association's funds represent a Governmental subsidy.

MR. BISHOP: The cast iron pipe industry of the United States supports its own research organization. The paper industry supports its own national council which conducts research on problems of that industry. Could research support be provided by the water works industry in this country?

MR. FABER: The AWWA Research Foundation was not organized on the same basis as the British Water Research Association. The Water Research Association does provide an excellent example of how water utilities and Government can together contribute to the cost of research.

I anticipate that the AWWA Research Foundation will develop the interest and support of water utilities for specific projects. As we identify applied research projects that are of wide interest to water utilities, I believe we can anticipate that support will be forthcoming from the industry.

MR. AULTMAN: The State of California has, in the past, not established regulations until a definite problem exists. As a result of the Federal Water Pollution Control Act, the State's Water Pollution Control Board has established standards.

I expect that the Board will undoubtedly sponsor investigations and reports on the problem of water treatment plant waste disposal. The Board has supported and published excellent reports on other problems.

MR. TECHOBANOGLOUS: The California Water Quality Control Board has been interested primarily in waste discharges, but is now beginning to look at water treatment discharges. I expect they will support research in this area. They have supported numerous studies in the wastewater field, and have published some 20 or 25 reports.

MR. RUSSELMANN: Regulatory agencies should at least fix some responsibility by requiring existing water treatment plants to observe the effects of their discharges upon receiving streams. When a new plant or extension of an existing plant is contemplated, the agency could require the community or the consulting engineer to evaluate the impact of wastes on the receiving stream.

MR. HENRY: Under the West Virginia water pollution control law, we do not have to prove pollution to require permits. Our permit system requires that anyone discharging water - carried waste into a stream must have a permit.

The last session of our legislature increased the criminal penalties for violation of the law which formerly was on a three-part basis: first offense, second offense, and third offense. Now it is on a one time basis. It costs up to $1,000 for the first offense, with, a minimum of $100. The cost is $10,000 if we can prove deliberate pollution.

We have, so far, been quite lenient with the water industry in our state. Almost two years ago, we encouraged the water industry to correct its pollution problems. We agreed to cooperate in the development of workable solutions. We are now doing this with a committee of the State AWWA Section.

MR. ADRIAN: Massachusetts has a state-wide fund for supporting research on waste treatment and disposal. This fund amounts to some $1 million per year. We find that, to date, the agency in charge has not been very receptive to supporting work on water treatment plant sludge disposal.

MR. STREICHER: The state of California is divided into nine regions, each of which has a regional water quality control board. Each regional board sets standards for surface or ground waters within its jurisdiction, and exercises control over waste discharges which might affect the quality of the surface or ground waters.

As waste discharges in basins at higher elevations may often degrade the quality of the waster moving into a lower basin, the lower basin users have an opportunity to voice their objections to such discharges or proposed discharges at regularly scheduled meetings of the regional water quality control board having jurisdiction.

MR. SHULL: In Pennsylvania no new permits for water treatment plants will be issued by the State Department of Health or the Sanitary Water Board unless provisions are made for the disposal of filter washwater and settling basin sludge.

Problems at existing plants are handled as complaints are received. If a complaint is received from someone downstream, the particular plant involved is cited and given a specific deadline to construct waste treatment facilities. All new plants must have waste treatment facilities incorporated in their plans. As I recall, the suspended solids discharged are limited to about 25 or 30 ppm.

MR. EAGLE: I believe that Ohio is not quite as arbitrary as Pennsylvania in this matter of filter washwater. We do require that adequate provision be made in the design of new or remodeled plants for taking care of the waste. If the engineer can show to our satisfaction that the waste discharges will not cause pollution to the waters of the state, then treatment facilities are not required.

This concludes discussion of the status report on regulatory aspects.

* * *

Section 2

REPORT ON CURRENT TECHNOLOGY AND COSTS

D.D. Adrian and J.H. Nebiker

The AWWA Research Foundation report on the disposal of wastes from water treatment plants was designed to include studies of current technology and costs. These studies were made, under a contract with the Research Foundation, by Messrs. Adrian and Nebiker of the Department of Civil Engineering, University of Massachusetts, Amherst, Mass. Their report follows.

INTRODUCTION

The authors of this report have made detailed studies of selected water treatment plant waste disposal practices currently in operation. The following report included a description of the process employed, its efficiency, accomplishments, and costs. The details are based upon literature reviews, questionnaire returns, and visitations to 15 operating plants. In addition, model studies were developed for three types of sludge dewatering.

ACKNOWLEDGEMENT

This report could not have been prepared without the active cooperation and help of many individuals. The authors have attempted to recognize those plant operators and superintendents who provided assistance by including their names in the Appendix on Plant Visitations. In addition, the assistance of Fred Eidsness and A.P. Black of Black, Crow and Eidsness; Peter Doe and Fred Menzenhauer of Havens and Emerson; and Robert Curran of Curran Associates (Northampton, Mass.) is gratefully acknowledged. The assistance of members of the AWWA Research Foundation Advisory Committee should also be given recognition.

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REVIEW OF TECHNOLOGY

I. SUMMARY OF CONCLUSIONS

Neither the disposal of filter washwater nor softening brines appears to be a major engineering problem. Coagulation sludges, particularly those resulting from alum treatment, are not presently dewatered by mechanical means in the United States. Where space is available, drying on sand beds is a feasible method for dewatering alum sludges in the few examples found that are in use today.

Pressure filtration of alum sludge is technologically feasible, but is not yet in use in the U.S. and costs are unknown. Freezing and thawing substantially alters favorably the dewatering and settling characteristics of alum sludge, but cost considerations suggest that only natural outdoor freezing in lagoons or drying beds will be economically attractive. In some instances, the disposal of alum sludge to the sewer is not considered a problem, either because of undesired sedimentation in the sewer or deleterious effects on the sewage treatment process.

Lime softening sludges are capable of dewatering by land methods or, in certain instances, by centrifugation or vacuum filtration. They can generally not be disposed of to the sewer owing to problems of sedimentation, both in sewers and in digesters. Recalcination of lime softening sludge can be of significant economic benefit, but the process is limited to date to sludges from larger plants, treating water low both in turbidity and magnesium.

II. OBJECTIVE OF REPORT

This report seeks to provide detailed information on various water treatment waste disposal practices, including descriptions of these processes; data on process efficiency; evaluation of process accomplishments; and analyses of capital, operating, and maintenance charges. Visits by the authors to a number of treatment plant were made to directly ascertain the information.

III. METHODOLOGY

Initially, there was little information available to identify operating plants which could provide good examples of current technology.

A straight-forward approach was used to obtain and evaluate information:

1. Review of the literature to ascertain the various disposal methods used in this or other countries.

2. Contact with state regulatory agencies to locate plants with disposal methods which met with their water quality standards.

3. Preparation of a questionnaire to aid evaluation of performance by the various methods during plant visitations.

4. Selected plant visitations.

5. Compilation of data, including cost analyses.

6. Preparation of a preliminary report, which was submitted to the Foundation's Advisory Committee for comment.

7. Preparation of this report, including comments received from the Advisory Committee and plant officials.

IV. TREATMENT AND REUSE OF FILTER WASHWATER

An increasing number of state regulatory agencies now identify the discharge of untreated filter washwater as a violation of their stream pollution regulations.

Boca Raton, Florida, practiced re-cycling of their washwater with apparently a slight profit. A washwater recovery basin served to reduce the impact of the large washwater flows on the upflow-clarifiers, and to some extent clarify the washwater, though this was unintentional. Since this was a lime softening plant for groundwater there were no difficulties with algae re-cycle and buildup. Similar situations were found at Lansing, Michigan, and Miami, Florida, but recovery basins were not needed due to the larger capacities of the plants and the numbers of filters.

The Rinconada Water Treatment Plant in Los Gatos, California, and the Sunol, California, plant utilized washwater recovery basins, with periodic washwater sludge removal. Both plants were designed for alum treatment of surface water, and no problems were noted. It should be emphasized, however, that the value of water in this area is high, and thus incentive for recovery is greater than in water rich areas.

Willingboro, New Jersey, and New Britain, Connecticut, treatment plants sent their washwaters to sludge thickening lagoons, and the decants from these were sent to a stream and to the reservoir, respectively. Both plants used alum for coagulation. It is questionable whether this method is sound, for the quality of the decant is not clearly superior to the quality of the washwater, and the addition of washwater to the sludge merely aggravates the sludge problem.

Overall, it would appear that washwater recovery is economically feasible for water-scarce regions, or in instances where ground water is softened, for the washwater will not create an algal buildup problem, and the recovered water has the added value of being, in fact, softened water.

V. DISPOSAL TO SEWERS

An example of diatomaceous earth filtration backwash water disposal to the sewer was found at Point Pleasant Beach, New Jersey. Since surges of washwater could not be handled by the sewer, a holding tank was used to distribute the flow over longer time intervals. Neither deposition in the sewer nor adverse effects on the primary sewage treatment plant were noted.

Washbrine from a zeolite water softening plant was disposed of to the sewer at South Orange, New Jersey. The capacity of this water treatment plant was far smaller than the capacity of the regional sewage treatment plant to which the brine flowed. In most instances it is doubtful that brine could or should be disposed of to the sewer unless, as here, significant dilution took place.

Disposal of alum sludges to the sewer has not been found to cause deposition problems. However, the same cannot be said of lime sludges. And whereas the addition of alum sludge to the sewage treatment processes may cause little problem beyond that of creating greater sewage sludge volumes, lime sludges would cause, in addition, sedimentation problems in the digesters.

Disposal of water treatment wastes to the sewer must be considered an intermediate step, placing final disposal into the hands of the sewage treatment plant operator. If the plant is large compared to the water treatment plant, a satisfactory solution is available (with the possible exception of lime sludges). Costs can be based on the charge structure set for inclusion of other industrial wastes into the sewerage system. If the sewage is discharged into the ocean, larger volumes of brine may be accepted.

VI. LAGOONING OF SLUDGE SOLIDS

Lagooning remains the most popular and acceptable method of disposal of water treatment sludges. Yet lagooning is in fact frequently not so much a disposal method as one for dewatering, thickening, and temporary storage.

One should clearly differentiate between lagoons and drying beds: lagoons are generally built solely by enclosure of a land surface by dikes, or by excavation. Drainage is not maximized by underdrains or by surfacing with sand. Sludge is added continuously or intermittently until the lagoon is filled, whereupon the lagoon is abandoned or cleaned. Sand beds are described in Section VII.

Lagoons may be equipped with flashboards or the like to enable the operator to decant. This is particularly desirable if filter washwater is also sent to the lagoon. As previously mentioned in Section IV, this procedure is not desirable.

Overall, lagooning must be considered a very inefficient process; nonetheless, where land is cheap it is difficult to justify any other disposal method. Where land is more expensive and sites for new lagoons cannot be found, the old lagoons can, of course, be cleaned or the dikes raised.

It is technically incorrect to state that sites for new lagoons cannot be found. What is meant is that sites cannot be found in the immediate area or that the sites are too costly. More distant sites could be found, and they would probably be cheaper. The problem is to transport the sludge to the more distant site, usually achieved by pumping. Lansing, Michigan, formerly pumped its lime sludge 7,000 feet to a lagoon until a recalcination plant was built.

Some specifics might be mentioned about the character and disposal of lagooned sludges. Alum sludge will gradually consolidate sufficiently to provide a 10 or 15% solids content. Water removal is by decantation or by evaporation, with some drainage. Evaporation may provide a hard crust, but the remaining depth is thixotropic, capable of turning into a viscous liquid upon agitation with near zero shear resistance under static load. Removal can be accomplished by dragline or clamshell, dumping the sludge on the banks to air dry previous to later removal. Willingboro, New Jersey, removes shallow layers of lagooned and thickened sludge by front-end loader to a specially prepared drying lagoon, where drying will yield a crumbly cake. This lagoon has a sanded surface to aid in draining rainwater.

New Britain, Connecticut, contracts out to have the thickened alum sludge removed and spread on the roadsides. On the other hand Somerville, New Jersey, lagoons at very shallow depths, allowing the sludge to air dry sufficiently to allow walking.

Mention might also be made of the effect of freezing and thawing by weather. Although such cases have not been seen by the authors, it is known, for example, that thin layers of sludge when frozen in winter and later thawed will dramatically increase in drainage and settling rates, producing fine granules of material.

Sludges from water softening plants (lime sludge) are more easily dewatered in lagoons. The higher specific gravity of the particles aids consolidation, and solids contents of 50% can be attained. Where lime sludges are dumped in flooded quarries or in excavations with water, perhaps only 25% solids can be expected. The latter case occurs at Miami (Hialeah) requiring sludge removal by scraper and tugger hoist. Another Miami plant (Orr) utilizes a lagoon excavated out of limestone for which the contractor paid 4¢/cu.yd. Generally, lime sludges are considered poor fill, and final disposal after lagooning is a problem.

Sludges from an iron removal treatment plant in Amesbury, Massachusetts, suggested that this type of sludge in lagoons dewaters somewhat better than an alum sludge, but not as well as a lime sludge.

Costs for lagooning will thus be highest for alum sludges. This report deduces that costs are highly variable, ranging up to $40/ton of solids. Land costs do not appear to be as important a factor on the total overall costs as may be initially expected. This is because the initial capital outlay for the land can be recovered at 100% salvage value if the lagoon is cleaned.

VII. SAND BED DRYING

Sand beds for drying water treatment sludges are basically identical to those employed in sewage treatment: a prepared underdrained sand surface. Operation may include decantaion, but basically water is removed by drainage and air drying, preferably with sufficiently shallow sludge depths to allow cracking of the sludge down to the sand-sludge interface, thus accelerating drying and yielding solid cakes.

The practice of decantation allowed Lompoc, California, to add backwash water to the lime sludge on the drying beds. Here, however, deep cracking of sludge cake to the sand-sludge interface was probably not attained, because the beds were filled to a depth of 5 feet. After four months the sludge was sufficiently dewatered (about 50% solids) to be removed by front end loader.

The Los Gatos, California, Rinconada plant charged drying beds with alum sludge. Decantation was provided for, but operating procedures have not yet been standardized. Sunol, California, also dries alum sludge on sand beds along with sludge from the washwater recovery basins. Filling depths are limited to two feet to allow cracking down to the bottom. The solids content of the dried sludge was a least 25%, and sludge removal could be done by front end loader.

The cases cited are obviously located in dry climates, and the costs (Lompoc - \$5.05/ton; Sunol - \$58.50/ton) reveal little. Part of the difference in the costs is due to the greater tonnage of lime sludge produced by softening; also, it is easier to dewater. Whether or not drying beds are superior from an economic viewpoint to lagoons is not clear. However, it appears logical that drying beds could be superior where land costs are high. The addition of underdrains and a sand surface will not greatly add to the overall costs, and drainage should be accelerated.

VIII. VACUUM FILTRATION

Vacuum filtration of lime sludges has been practiced at various plants over the last few years. Some successes and some failures have been noted. Explanations for this need extend no further than to note that belt filters have worked successfully, but coil filters have been plagued with incrustation of the coils. The two successful installations visited, Boca Raton, Florida, and Minot, North Dakota, were both of Eimco manufacture. Both received thickened lime sludge at about 30% solids, and yielded a crumbly cake at approximately 65% solids, sufficiently dry to be used as landfill. Operating problems were reported minimal, and Boca Raton found a cloth belt lasted 6 - 9 months.

Total cost for sludge disposal at Minot calculated to be \$7.29/ton of dry solids; Boca Raton, \$16.00. The difference in costs can be attributed to the quantities of sludge produced: Minot filters approximately twice as much dry cake solids.

Vacuum filtration of alum sludge has been attempted in the United States by Johns-Manville. Since the dilute sludge (here 1.25% solids) readily penetrated the filter media, a pre-coat vacuum filter using diatomaceous earth (Celite, etc.) was needed. Costs for vacuum filtration by this method were projected by Johns-Manville to be $3.96/1,000 gals, ($76.00/ton of dry solids).

In order that cost estimates for vacuum filtration of both lime and alum sludges could be compared between themselves and with other processes, model studies were initiated (see appendix). For lime softening sludge, a figure of $12.35/ton was determined, including disposal charges of $6.15/ton. Vacuum filtration of alum sludge using a precoat was found to cost $177.00/ton and upward, of which $20/ton was for trucking and disposal charges.

The great differences in costs for vacuum filtration of lime and alum sludges must be borne in mind when vacuum filtration is contemplated for other sludges of intermediate character, such as iron removal sludge. One factor cannot be sufficiently stressed: lime sludges at Boca Raton and at Minot were low in magnesium hydroxide which adversely affects the settleability, compactability, and filterability of a sludge. Thus in the cases studied good results were obtained, but lime sludges with greater concentrations of magnesium could behave more closely to alum sludges, with attendant higher dewatering costs.

In sum, vacuum filtration of alum sludge appears economically questionable, and possibly technologically unfeasible. Some thickened lime sludges, low in magnesium, can be vacuum filtered without problems. But correspondingly, when low in magnesium, the sludge is amenable to lagooning, centrifugation, and possibly recalcination.

IX. CENTRIFUGATION

Only lime softening sludges were found to be centrifuged, at treatment plants in Miami, Florida (Hialeah); Dayton, Ohio; Lansing, Michigan; and Austin, Texas. The first three plants are recalcination plants. All four used the 40" x 60" Bird continuous feed, helical conveyor centrifuge. The first installed was at Miami in 1948, and apparently because of its successful operation, the others followed suit. The choice of centrifuges for the recalcination plants is based on the ability of the centrifuge to selectively throw magnesium hydroxide out into the centrate, providing a purer sludge cake for recalcining.

A summary of these installations regarding pertinent data follows:

	Ave. flow (mgd)	Number of Centrifuges	Feed % Solids	Centrate % Solids
Austin, Texas	30	1	1.	0.5
Dayton, Ohio	61.2	3	15-25	5.5
Lansing, Michigan	23	1	20	3
Miami, Florida	81	2	40	5-10

The cakes in each case were of toothpaste consistency (60-70% solids). Moyno pumps readily handle this consistency.

Costs for dewatering be centrifugation are available only for Austin (about $25.00/ton, including $8.70/ton for transport and disposal). Thickening was not done. A model study (see appendix) utilizing thickening prior to centrifugation revealed a total cost of $11.40/ton, which includes $6.15/ton for trucking and disposal charges. This cost compares favorably to that predicted by a model study for vacuum filtration of a lime sludge.

Operating problems for the centrifuges are certainly minimal. There are some vibration problems, and in Dayton there is some heavy wear on the helix. However, all cases visited had sludges with low magnesium contents. More impure sludges could be difficult to centrifuge.

X. RECOVERY AND REUSE OF LIME

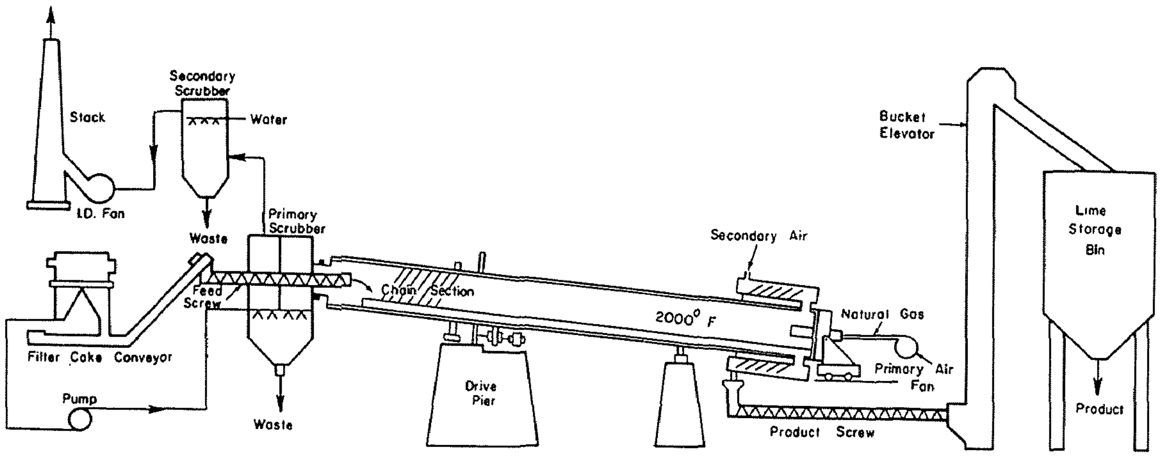
Two different processes are being used to recalcinate lime softening sludges today:

The rotary kiln illustrated is used at Miami, Florida, and at Dayton, Ohio. Both installations were designed by Black, Crow and Eidsness. This firm also designed a rotary kiln for San Diego, which operated successfully until San Diego ceased softening water.

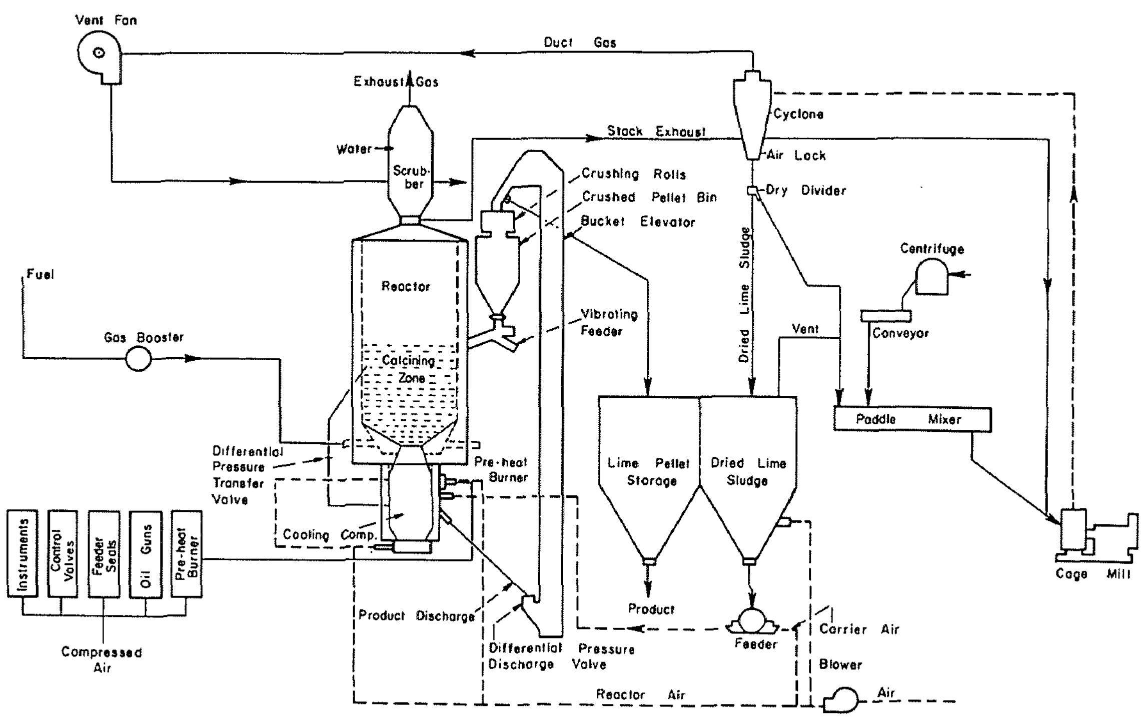
The "Fluo-solids' reactor is a vertical kiln illustrated manufactured by Dorr-Oliver, and operating at Lansing, Michigan. It is claimed that this installation is better adapted to smaller plants than is the rotary kiln. Certainly the latter requires a larger land area, and being less compact, dissipates more heat.

RECOVERY OF LIME FOR REUSE

Rotary Kiln and Vertical Kiln Processes



Lime Sludge Calcining
Rotary Kiln Flow Sheet



Lime Sludge Calcining
Fluosolids Flow Sheet

Proper recalcination places a premium on the purity of lime sludge produced. Split treatment is required to minimize magnesium impurities to less than 10%, and successive sludge thickening de-watering operations must emphasize reduction to a minimum of the magnesium. It would appear, however, that only certain ground waters are suitable for producing a sludge by excess lime treatment with minimal impurities. Hence recalcination is limited by existing technology to a few instances.

Miami and Dayton plants show profits from their recalcination. In both instances they produce more lime than needed in treatment. The profitability of their operations is sharply dependent on the value placed on these excess quantities. Lansing did not show a profit, but it is a smaller plant, and cannot produce sufficient lime for its own purposes, let alone for sales. This is not a fault of the vertical kiln, but rather a result of the design of the third stage sedimentation basins. Removal of sludge is intermittent, and the sludge cannot be stored; hence it is discharged to a distant lagoon.

Considering the cost of lime sludge disposal, all recalcination plants visiting would show a large profit. With this in mind, perhaps greater attempts at recalcination are needed, even at smaller plants. The question of raw water quality remains, and is certainly a key factor in deciding the efficacy of recalcination.

XI. FREEZING AND MISCELLANEOUS PROCESSES

Freezing: The freezing and thawing of alum sludge has been proven to significantly increase rates of settling and filtration by conversion of a hydrogel into a suspension of granular solids. A batch process has been developed in England and Japan, but, according to the latest information, power costs and maintenance costs on the freezing tanks are prohibitive.

Pressure Filtration: The trend in England is to this process. Both the Atlanta, Georgia, and Passaic Valley, New Jersey, water utilities are considering this method. A large body feed (usually of lime) is required for the pressure filtration of alum sludge. This is batch process, but operating costs are said to be lower than previously assumed because of new developments with rubber gaskets and filter cloths. The waterworks mentioned above have had their sludges tested by Beloit-Passavant. The sludge cakes were dense (65% solids) and suitable for landfill.

Thickening: Thickening of lime sludge was employed at Minot, North Dakota; Dayton, Ohio; Lansing, Michigan; Boca Raton, Florida; and Miami, Florida. Solids contents of up to 35% were produced. No clearcut design bases were noted. Miami used their thickeners primarily for equilization of the sludge flows. Both Minot and Boca Raton operated their thickeners intermittently, which then allowed solely day-time operation of the vacuum filters. Lansing had a steel 4-tray thickener, whereas the others were all of the circular, concrete, sloping floor design. Boca Raton had an interesting torque control on their scraper mechanism.

Thickening of alum sludge is being considered at Atlanta, Georgia. Possibly a 5% solids content can be obtained with the aid of chemical conditioning.

Alum Recovery: The recovery and reuse of alum by treatment of alum sludge with sulfuric acid is being tested by Minneapolis. St. Petersburg, Florida, has pilot-plant tested this method several years ago. Apparently costs were excessive. Alum recovery is still in the experimental stage.

XII. CONCLUSIONS

1. Filter washwater is increasingly considered a pollutant, and action is being taken by state regulatory agencies to require its treatment prior to discharge to surface waters. Washwater recovery can be accomplished by direct recycle to the flocculation basins, or to the reservoir. There is some concern over algae buildup, however, and thus recycling may be best suited for softening of ground waters. Water-scarce areas find washwater reclamation practical if the washwater is first clarified by sedimentation.

2. Disposal of alum sludges to the sewer appears to be a practicable solution, recognizing that the capacity of the sewage treatment plant must be adequate and acknowledging that the sewage treatment plant inherits the problem of ultimate disposal. No deleterious effects of the alum sludge on the sewage treatment processes are known. Lime sludges are not recommended for inclusion in the sewage due to problems of deposition in the sewers and in the digesters.

3. Lagooning is presently the most widespread process for

dewatering and disposing of sludges. Washwater should be separately handled. At present there are few alternatives to lagooning, and efforts to improve this process, such as by underdraining and by operation as sand drying beds, should be more widely attempted. Natural freezing and thawing may improve performance greatly, and this encourages the filling of lagoons to very shallow depths.

4. Vacuum filtration or centrifugation of lime softening sludges is entirely feasible for sludges with low magnesium content. The two methods are comparable in cost, but the centrifuge is capable of passing non-calcium impurities out with the centrate, desired for recalcination.

5. Recalcination is presently limited to softening plants treating ground water low in magnesium. Either of the two processes, the vertical kiln or the rotary kiln, is sound, but only applicable to large treatment plants. Profits from recalcination are marginal from a business standpoint, but considering the reduction or elimination of the sludge problem, it is clear that recalcination is saving the taxpayer a great deal of money.

6. Both vacuum and pressure filtration of alum sludge have been attempted on a pilot scale. While both processes may be technically feasible, cost data are lacking, and definite conclusions as to the economic feasibility cannot be made at this time.

7. Thickening of lime softening sludges is entirely practical, although perhaps unnecessary where centrifugation follows. Thickened lime sludges readily clog piping. The thickening of alum sludge is of great potential benefit.

8. Freezing and thawing of alum sludge by mechanical means has been practiced in England and Japan. Although dewatering and settling characteristics are greatly enhanced, questions about the economic feasibility of this method remain. Recovery and reuse of alum has not evolved beyond the experimental stage.

9. Disposal of diatomaceous earth washwater can be accomplished by discharge to the sewer, or by direct vacuum filtration, as practiced at Goleta, California.

10. Brine disposal to the sewer is satisfactory, provided sufficient dilution occurs at the treatment plant.

11. Costs for disposal of water treatment sludges were found to be as shown in the following Table.

TABLE

Costs for Disposal of Water Treatment Sludges

Location	Sludge Type	Processes	Total Disposal Cost		
			$/mg	$/ton dry solids	$/ton lime
Austin, Texas	Lime	C	25.10	25.10	--
Boca Raton, Florida	Lime	T&VF	16.00	16.00	--
Dayton, Ohio	Lime	TC&R	2.20*	1.50*	0.79*
Goleta, California	D. Earth	VF	14.10	126.60	--
Lansing, Michigan	Lime	TC&R	2.00	6.15	2.60
Lompoc, California	Lime & D.E.	S	24.20	4.89	--
Miami, Florida	Lime	TC&R	6.95*	10.55*	5.08*
Minot, North Dakota	Lime	T&VF	21.80	7.29	--
New Britain, Conn.	Alum	L	3.30	39.00	--
Somerville, N.J.	Alum	L	0.09	2.00	--
Sunol, California	Alum	S	1.18	56.60	--
Willingboro, N.J.	Alum	L	4.90	33.50	--
Model Studies	Alum	T&VF	36.90	177.00	--
	Lime	T&VF	12.35	12.35	--
	Lime	T&C	11.40	11.40	--

Process Symbol: C= Centrifuge/ L= Lagooning/ R= Recalcination/ S= Sand Beds/ T= Thickening/ VF= Vacuum Filtration.
*Profit from recalcined lime.

12. Sludge disposal will generally add about 5% to the total cost of treating water; however, all conclusions as to costs are subject to many conditions and limitations. It is felt that each sludge disposal problem is unique.

13. As new installations to dispose of sludge are built, efforts to ascertain their construction and operating costs should be made. Particular emphasis is needed to determine the solids quantities through rigorous measurement procedures.

APPENDIX

Cost Analyses

The cost analyses provided in the appendix follow standard engineering-economic evaluation procedures. However, some clarification of the procedures used may be helpful.

Of primary interest to waterworks engineers is the cost for sludge disposal per unit volume of water treated. This was done here, and expressed in units of dollars per million gallons of water treated. This presupposes a cost calculated on the basis of actual operating expenses and capital recovery, summed together.

Also of special interest to those specializing in ultimate disposal is the sludge disposal cost per ton of dry solids. This, too, was done here, again including both actual operating expenses and capital recovery. In the few instances where recalcination was practiced, costs (or profit) were also calculated on the basis of dollars per ton of lime produced (90% pure CaO).

The form of ownership of the water utility creates some difficulty in the analyses, for public ownership can have available free land, lower interest rates, and freedom from taxation. The basic calculations used in this report include the cost of land, interest at 6%, with no taxes; which is to represent conditions for public operation.

Calculations for taxes and insurance, and interest on land costs are included in parentheses, and represent a private operation. Higher interest rates could have been allowed for here. One notes numbers in parentheses under "Disposal Costs/Unit" for each plant. These numbers include the costs for private operation mentioned above.

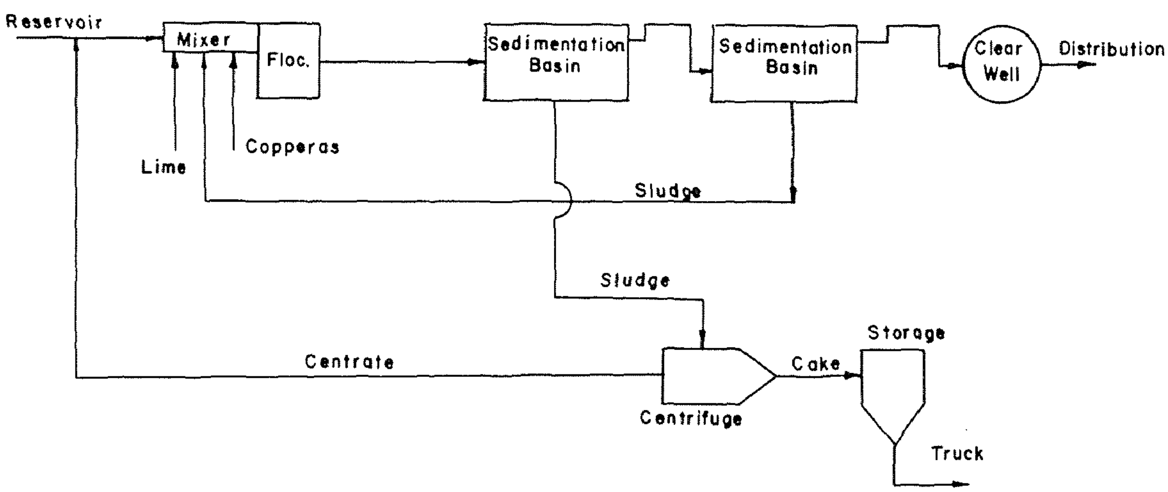
Emphasis must be placed on the method for land cost calculations. The purchase price for land need not be recovered, since land is considered a fixed asset (non-depreciable). Therefore only the interest on the purchase price is involved. Any cost for returning the land to the original purchase condition was deducted from salvage value of equipment and buildings.

Capital recovery of equipment and buildings followed a 6% interest rate, generally over a 25-year period, with 25% salvage value at the end of the 25 years. Taxes and insurance were assumed to amount annually to 2% of the capital cost (including the cost of land).

The accuracy of certain figures in this report will undoubtedly be questioned by some. The authors have used actual data supplied by plant superintendants and operators, when such data was considered by the authors to be accurate and representative of average operating conditions. Much data was unfortunately not available, and had to be estimated by the authors. It is felt that uncertainties in the estimates tended to balance out. Noticeable exceptions occur in the calculations for costs/ton of dry solids. Most treatment plants had no information on the quantities of solids produced, and thus costs/ton cannot be completely reliable.

AUSTIN, TEXAS

Northwest Plant - Flow Diagram



AUSTIN, TEXAS
Northwest Plant

PLANT VISITATIONS

AUSTIN, TEXAS

Treatment by Centrifugation

Population: 186,545 (1960)

Ownership: Municipal

Superintendent: Curtis E. Johnson

Water Source: Reservoir

Flow: ave. 30 mgd
peak 80 mgd
cap. 120 mgd

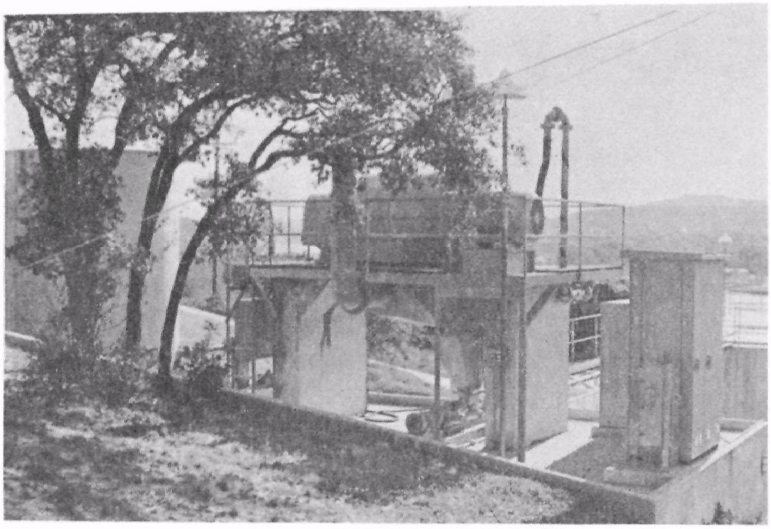
Influent Quality:	Total hardness	165 mg/l as $CaCO_3$
	Carbonate hardness	133 mg/l as $CaCO_3$
	Magnesium	14 mg/l
	Turbidity	10 - 60
	pH	8

Method of Treatment: Flocculation and sedimentation.

Chemicals Added:	Lime	90 mg/l
	Copperas	5 mg/l

Description of Disposal Process

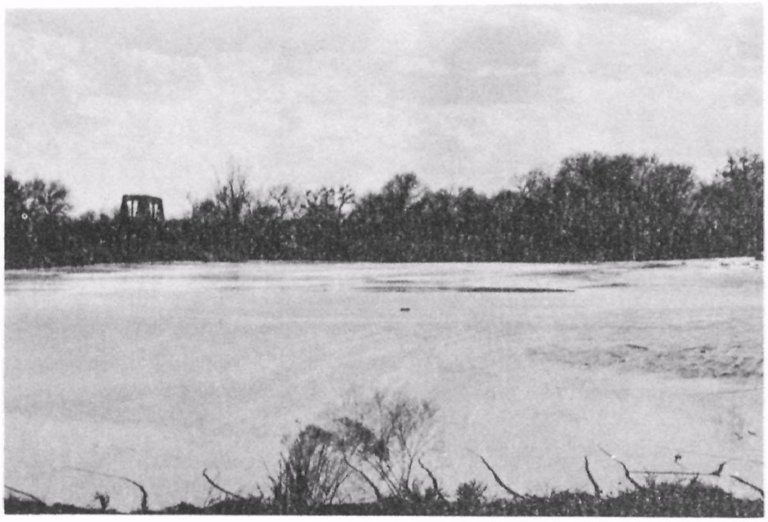
Sludge is removed at 5-10% solids from the primary settling tanks equipped with scrapers. The sludge from the secondary units, representing 30-35% of all sludge produced, is recycled. The primary sludge is sent to a 40" x 60" centrifuge, leaving at 55-60% solids. Centrate contains less than 0.5% solids, and is returned to the lake. Cake (paste) is pumped by Moyno pump to a



Center: Centrifuge for Dewatering Lime Sludge

Left: Hopper for Cake Storage

Truck for Hauling Centrifuged Sludge Cake



Final Sludge Disposal Area

storage hopper (14' x 35' x 15' deep) equipped with 4 draw-off points. 24 hours storage at capacity operation is provided.

Sludge is hauled by trailer truck about 12 miles to a 200' x 200' disposal area near a creek bottom.

COST OF SLUDGE DISPOSAL

Construction

The following items were installed in 1963:

Centrifuge	$30,000
Motor and switchgear	4,000
Pump	600
	34,600
Installation	5,000
	$39,600

The hopper was fabricated locally of steel. An estimated cost would be $20,000. A total replacement value of $80,000 would be expected today. (Note that the centrifuge is located outdoors). Set a salvage value of 25% after 25 years.

Land

Land required at the plant is about 5,000 ft^2. A value of $20,000/acre may be set, or $2,500. The disposal site has a few years of life expectancy at best. Over a 25-period, with a 10 ft. final depth, about 20 acres will be required. This could cost $40,000.

Operation

Labor and supervision costs are considered negligible; however, a probable figure of $2,000/year could be assumed. Maintenance, power and supply costs were $7,360 in the last year (August 1, 1966 - July 31, 1967). This appears to be far too low.

Maintenance alone will run about $5,000/year. A figure of $10,000 is used here.

Trucking

Records state trucking costs are $9,600/year.

Annual Costs

Capital recovery ($60,000 @ 6% for 25 years)	$ 4,700
Operation	12,000
Trucking	9,600
(Interest on salvage)($20,000 @ 6%)	1,200
(Interest on land)($42,500 @ 6%)	(2,550)
(Taxes and Insurance) ($122,500 @ 2%)	(2,430)
Total	$ 27,600/yr.($31,580)

Cost / Unit

Cost/mg

$27,600/1,100 mg = $25.10/mg ($28.70)

Cost/ton of sludge solids

It is said that one ton of dry solids originates from one mg of water treated, or

$25.10/ton ($28.70)

Discussion of Cost

Approximately one third of the costs is for trucking, and about the same can be said for operating expenses. The remainder of the costs are items for which Austin does not pay, as financing was out of current revenues.

BOCA RATON, FLORIDA

Thickening and Vacuum Filtration

Population: 30,000 permanent, 10,000 temporary, plus 5000 students

Superintendent: Augustave P. Hager

Ownership: Municipal

Water Source: Wells

Flows: Ave. (1968) 7.61 mgd
Cap. 23 mgd

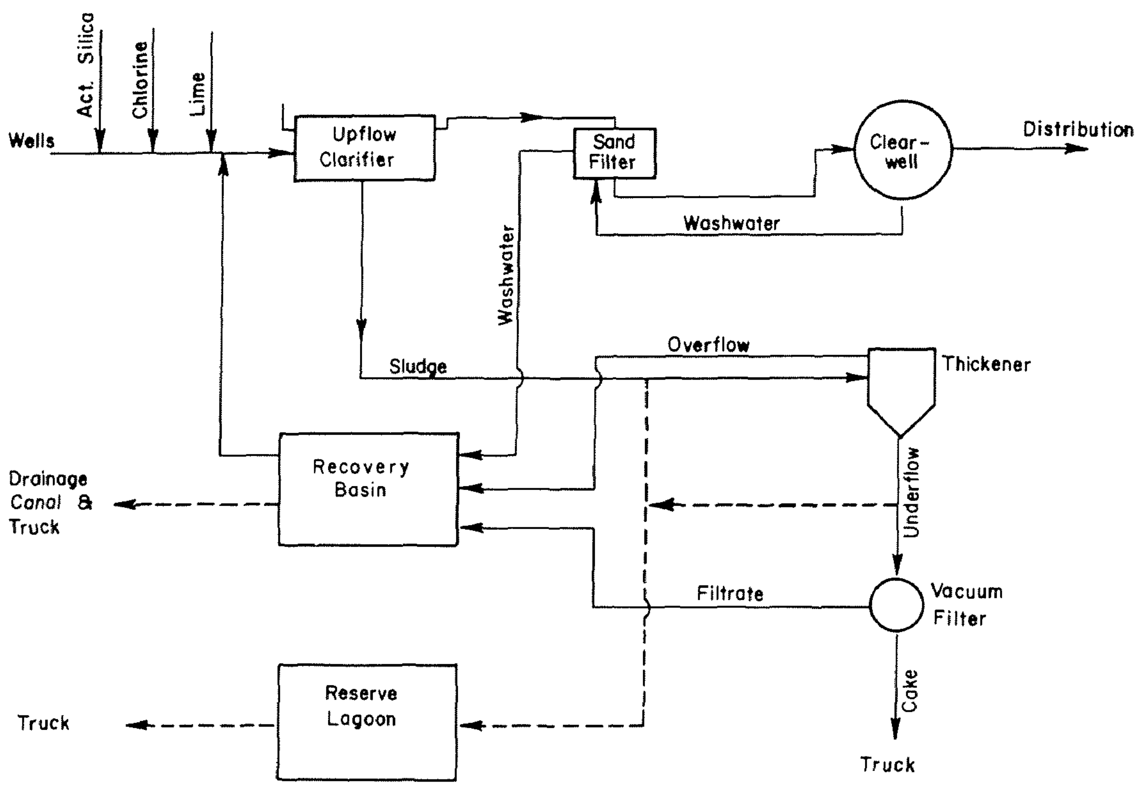
Influent Quality:	Total solids	312 mg/l
	Iron	0.5-1.5 mg/l
	Total hardness	210-250 mg/l as $CaCO_3$
	Temporary hardness	192 mg/l as $CaCO_3$
	Magnesium	6 mg/l
	Alkalinity	190 mg/l as $CaCO_3$
	pH	7.3
Effluent Quality:	Total hardness	68 mg/l as $CaCO_3$
	Temporary hardness	26-28 mg/l as $CaCO_3$
	Alkalinity	26 mg/l as $CaCO_3$
	pH	9.5

Method of Treatment: Coagulation, clarification, and rapid sand filtration; with pre-chlorination.

Chemicals Added:	Lime	120-130 mg/l
	Chlorine	6.5 mg/l
	Sodium silicate	5.7 mg/l

BOCA RATON, FLORIDA

Flow Diagram



BOCA RATON, FLORIDA

Description of Sludge Disposal Process

Sludge is removed continuously from the upflow clarifiers at a 1-4% solids content and sent to a 25' thickener. The sludge is taken during the day and thus several feet of dense sludge accumulate. To prevent damage to the scraper blades, provision was made to raise and lower them. If the operator sets the blades too deep into the sludge, a torque control will stop the drive unit.

Thickened sludge (28-32% solids) is pumped up to the vacuum filter building. Rotary pumps are used for this purpose. The sludge is then filtered on a 6' diameter rotary belt cloth filter. Cake is discharged to a waiting 2½ ton dump truck below. With a 65-70% solids content, the cake if friable and ready for direct use for highway construction as a road stabilizer. No revenue is derived. The 6-mile round trip is driven by the plant personnel.

The backwash recovery basin receives thickener overflow, and vacuum filtrate in addition to backwash waste. It is a gunnited approximately 65' x 115' x 12' deep basin equipped with pumps to recirculate the entire flow. Past operation has been to recirculate only the clearer water, flushing and pumping the deposited solids into a nearby drainage canal. A reserve unlined lagoon measuring approximately 30' x 30' x 12' deep serves to store sludge during holiday weekends and repairs to the thickener or vacuum filter. It is cleaned by dragline 1 - 2/ year, and the sludge is trucked away and dumped.

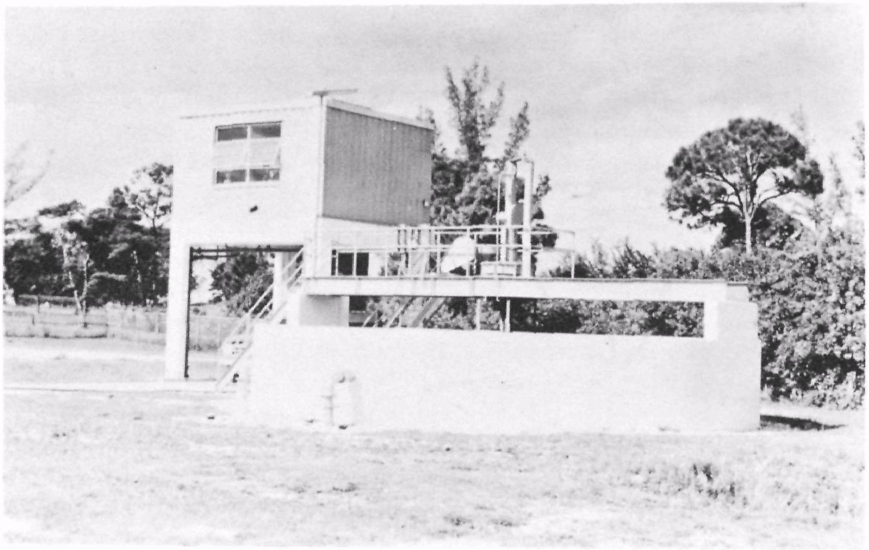
COST OF SLUDGE DISPOSAL

Construction

The disposal facilities were built in 1964-1965. An approximate breakdown of costs is as follows:

Thickener	$10,000
Vacuum filter	35,000
Building and miscellaneous	35,000
Total	$80,000

BOCA RATON, FLORIDA



Lime Sludge Thickener and Vacuum Filter Building

Recovery Basin for

Thickener Overflow, Vacuum Filtrate, and Filter Washwater

The reserve lagoon does not have a direct cost attached, as it was part of a larger abandoned lagoon on which the present facilities are located. Salvage is figured at 25%.

Land

About ¼ acre of land is used, with a true value (1968) of about $9,000. The land is municipally owned.

Labor and Supervision

Vacuum filter operation of 4 hours per day costs about $18,000/year. Another 2 hours is spent on maintenance of the system ($9,000/year). Supervision is estimated at $4,000.

Power

Only a crude estimate may be made. Rated horsepower of the motors driving the vacuum pump, rotary pumps, etc. totaled some 50 hp. Operation of these 4 hours/day at 1.5¢/KWH would cost approximately $1,400. There is no heating needed.

Maintenance

Two filter belts a year @ $80 apiece are needed. Practically all repairs are charged under labor. A total figure for maintenance is listed here as possibly $2,500.

Trucking

The truck was bought for about $4,500 in 1965. It is maintained by the Public Works Department and is used for purposes other than sludge disposal. Probably the best estimate is 20¢/mile, 3 loads/day, 12 miles/load - or $2,600/year.

Cleaning of Lagoon

It takes 6-8 hours to clean. The dragline costs \$20/hour. Probable cost: \$500/cleaning or \$1,000/year.

Total Disposal Costs

Capital recovery (\$80,000-20,000 @ 6% for 25 years)	\$ 4,690
Annual costs	38,500
(Interest on land) (\$9,000 @ 6%)	(540)
(Taxes and Insurance) (2% of \$89,000)	(1,780)
Interest on Salvage (\$20,000 @ 6%)	1,200
Total	\$ 44,390/year (\$46,710)

Disposal Cost / Unit

Cost / mg of water treated:

\$44,390/7.61·365 = \$16.00/mg (\$16.80)

Cost / ton of dry solids:

The amount of sludge produced was said to be 1 ton of solids per mg. This checks out, yielding a cost of \$ 16.00/ton. (\$16.80)

Discussion of Cost

The costs are about 70% due to labor and supervision. Since the construction costs are recent, little change would result in updating prices. Land costs, taxes and insurance in the case of a private utility would add about 6% to the costs. Note that the sludge is low in magnesium hydroxide, and thus easy to filter.

Washwater Recovery

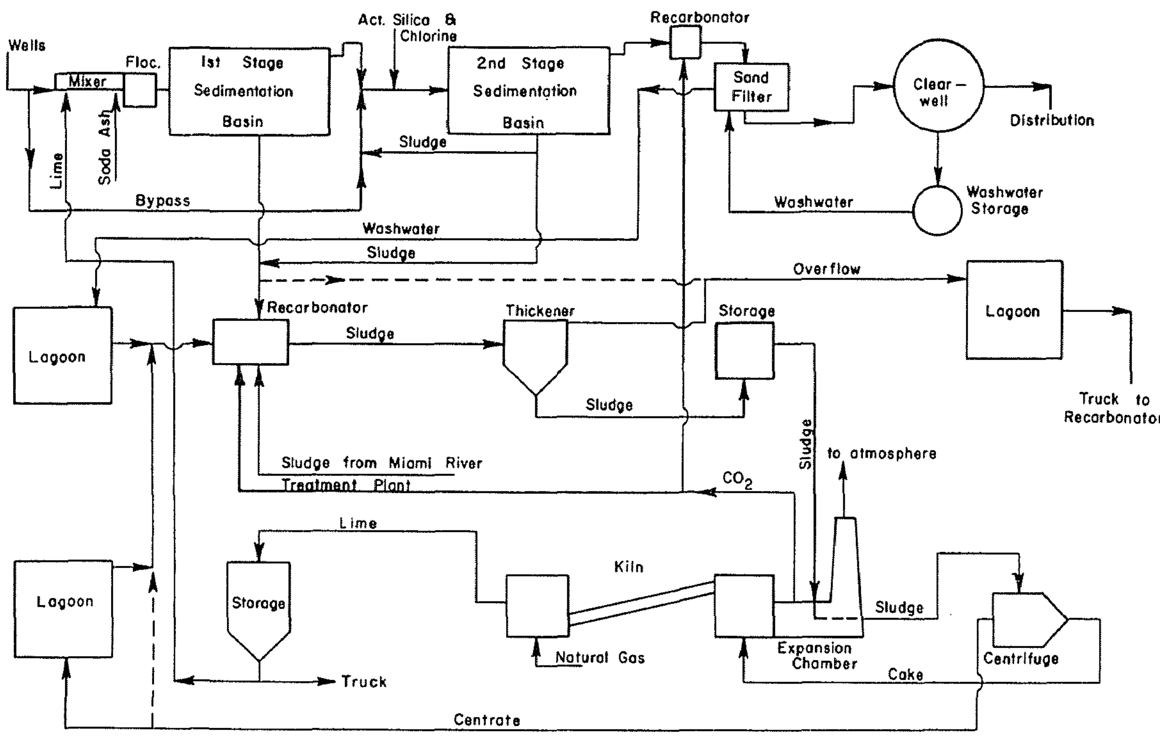
The washwater recovery basin was constructed at a cost of $20,000 in 1964-65. Operating costs etc. are probably less than $1,000/year. The total backwash flow is 30 mg/year. Salvage value of the basin is assumed zero.

Capital recovery ($20,000 @ 6% for 25 years)	$1,560
Annual costs	1,000
(Interest on land) ($9,000 @ 6%)	(540)
(Taxes and Insurance) (2% of $29,000)	(580)
	$2,560/yr.($3,680)

This is calculated to be $2,560/30 mg = $85.00/mg ($120). Boca Raton produces water at $200/mg, and thus a savings through recycle is likely because a significant percentage of water supply costs is due to the chemicals added and to well development and operation.

DAYTON, OHIO

Ottawa Street Plant - Flow Diagram



DAYTON, OHIO
Ottawa St. Plant

DAYTON, OHIO

Recalcination

Population: 262,332 (1960)

Superintendent: Robert Stout

Ownership: Municipal

Water Source: Wells

Flows:	Miami Plant	ave. (1967) 7.6 mgd cap. 24 mgd
	Ottawa Plant	ave. (1967) 53.6 mgd cap. 96 mgd

Influent Quality:	Total hardness	365	mg/l as $CaCO_3$
	Carbonate hardness	263	mg/l as $CaCO_3$
	Magnesium	34	mg/l
	Iron	0.15	mg/l
	Total solids	463	mg/l
	pH	7.6	
Effluent Quality:	Total hardness	108	mg/l as $CaCO_3$
	Carbonate hardness	34	mg/l as $CaCO_3$
	Magnesium	10	mg/l
	Iron	0	
	Total solids	242	mg/l
	pH	9.0	

Method of Treatment: Split treatment (water softening), including coagulation, sedimentation, and rapid sand filtration; with pre-chlorination.

Chemicals Added:	Lime	227 mg/l
	Soda ash	23.9 mg/l
	Sodium silicate	0.36 mg/l
	Chlorine	0.87 mg/l

Method of Sludge Disposal:

The sludge from the primary basins at both plants is brought to a carbonation basin at the Ottawa plant. The solids content is from 2 - 4%. It is then thickened to between 15 and 25% solids, and stored in a holding tank equipped with an agitator to keep the sludge in suspension. Flue gas from the kiln is used for carbonation, the purpose of which is to reduce the magnesium content of the sludge solids from 7% to 4% (as MgO), the difference resulting from the conversion of magnesium hydroxide to a dissolved magnesium carbonate which passes out in the overflow from the thickener to a lagoon.

Sludge from the storage tank is sprayed into the expansion chamber of the kiln exhaust system, in part to scrub and cool the gases, and in part to heat the sludge (up to 50°C) and create better liquid-solids separation in the centrifuges which follow. The solids content increases by centrifugation to about 60% solids, and the magnesium content decreases to 2%. Centrate is passed to a lagoon, or at times back to the sludge carbonation basin.

The cake, of toothpaste consistency, is pumped by a Moyno pump into the rotary kiln, and leaves the kiln as better than 90% pure CaO. A screw conveyor and bucket elevator transport the lime to two storage bins. Lime is trucked to the Miami plant, or is sold.

Each water treatment plant has a washwater recovery lagoon. In addition, the recalcination plant has a nearby lagoon for the centrate. Further away (800 yards) lies a ten-acre lagoon which receives the thickener overflow. Until 1957, when the recalcination plant was built, this lagoon was used for the disposal of all Ottawa plant sludge. The accumulated sludge from this lagoon later supplemented the sludge production of the Ottawa plant, for there is a significant reserve in recalcination capacity. Present average production of lime is about 100 tons/day; the capacity is 150 tons/day. The accumulated sludge was exhausted in 1962. A dredge is available to remove further accumulations due to the thickener overflow and emergency bypassing.

A more complete description of the recalcination plant is available in the literature. For the purposes here intended, the following data is important:

Thickener: 130 feet in diameter, with continuous removal. Depth of 8 to 15 feet. Volume - 1 mg.

Centrifuges: Three. 40" diameter, 60" long. Two in continuous operation suffice for present production.

Kiln: 265 feet long, 9½ feet in diameter.

A very approximate solids and total flow balance may be made:

Solids Balance (ave. daily)

		Flow Rate	Solids Content (%)	Solids Rate (tons)
Thickener	Influent	1,000,000 gals (+ 130,000)	4.0 (4.1)	167 (+27)
	Overflow	920,000 gals	0.1	5
	Underflow	210,000 gals	21.6	189
Centrifuge	Feed	"	"	"
	Centrate	145,000 gals	5.0	30
	Cake	65,000 gals (271 tons)	59.	159
Kiln	Input	271 tons	"	"
	Output	89 tons	$CaO(=\frac{56}{100}CaCO_3)$	89

The actual average total of lime produced is 88 tons/day. Note that about 90% of the centrate is returned to the carbonation basin and thence to the thickener. A sludge density of 62.4 lbs/ft^3 was used in the calculations, which creates a slight error in the flow rate.

COST OF SLUDGE DISPOSAL

Construction

The initial cost for the recalcination plant was $1,500,000 (1956-57). An additional lime storage tank costing $85,000 has since been added. A 1968 total replacement cost would be about \$2,500,000. There should be a salvage value of perhaps 25% at the end of 25 years.

Land

About 3 acres of land are used for the lime recovery operation, plus an additional 10 acres for lagoons. At \$6,000/acre, this yields a purchase price of \$78,000.

Operation

The best information here is from the 1967 records.

Operation (14 men)	\$130,533
Supervision	19,155
Fuel and power	184,440
(gas is \$0.52/1,000 cu.ft.)	
Materials and supplies	\$ 25,469
(and Maintenance)	

However, it must be noted that these costs are based on less than capacity operation. If operation were to take place at capacity (150 tons/day) for 90% of the year, the year's production would be 49,400 tons, and not 32,604 tons as in 1967. Since fuel and power costs are approximately directly proportional to the quantity of lime produced, a figure of \$279,000/year should be used. The total gross operating cost would then be \$454,000. From this should be subtracted the value of the CO_2 delivered to the water treatment plant. Dayton assumes a value of \$24,000 for the CO_2.

Value of Lime

Prior to the building of the lime recovery plant (1957), Dayton paid \$18.60/ton delivered. The plant has depressed prices in the area, as Dayton sells about 20% of its production to nearby treatment plants. Commercial prices are at present \$16.00/ton, and it is felt that if Dayton were to buy its lime supply, a price of at least \$20.00/ton would be charged. Dayton sells lime to itself for \$12.00/ton, and to communities for \$10.50/ton plus freight. This low price is provided because of the uncertainty of supply quantity. Higher prices could be set, but Dayton believes a price of \$12.00 is necessary to maintain a strong competitive position. A compromise between \$16.00 and \$12.00 is used here.

Annual Costs

Capital recovery (\$1,750,000 @ 6% for 25 yrs.)	\$137,000	
Interest on salvage (\$750,000 @ 6%)	45,000	
(Interest on land) (\$78,000 @ 6%)	(4,700)	
Operation, etc.	454,000	
(Taxes and Insurance) (2% of \$2,578,000)	(51,600)	
Sub-Total	\$636,000	(692,300)
Less value of lime (49,000 tons @ \$14.00)	686,000	
Less value of CO_2	24,000	
Gross Profit	\$ 74,000/yr.	(17,700)

Profit / Unit

Profit/mg of water treated:

$$\$74,000 \;/\; \frac{61.2 \cdot 49,400 \cdot 365}{32,600} = \$2.20/\text{mg} \quad (\$0.52)$$

Profit/ton of lime produced:

$$\$74,000/49,400 = \$1.50/\text{ton} \quad (\$0.36)$$

Profit/ton of sludge solids:

$$\$1.50/\; \frac{167}{88} = \$0.79/\text{ton} \quad (\$0.19)$$

Discussion of Profit

The profit from lime recovery as a per cent of investment is

3%, and about ½% if allowance is made for property taxes and insurance. This is low. If the operation were entirely private, a loss would occur because of higher interest rates. Thus it appears that lime recalcination of water softening sludge, as an independent and private operation, is questionable.

Yet it should be noted that a profit is shown, as opposed to a deficit for all other disposal methods. This should be taken into account. Also, one must note the possibility of wide ranges in market price of lime and its effect on net profitability. A sale price of $15.50/ton would double the profit attained from sales of $14.00/ton.

Dayton figures their costs at $12.46/ton (before sales of lime), but this is from an originally much lower capital cost, with no taxes or land costs included in the annual expenses. On the other hand, their present operation is only running at 2/3 capacity. Bonding was at 3¼%.

GOLETA, CALIFORNIA

Vacuum Filtration

Superintendent: Temple A. Tucker

Ownership: Goleta County Water District

Water Source: *Lake Cachuma*

Flow: ave. (1967) 2.6 mgd
cap. 6.7 mgd

Influent Quality: (Lake Cachuma 1966)

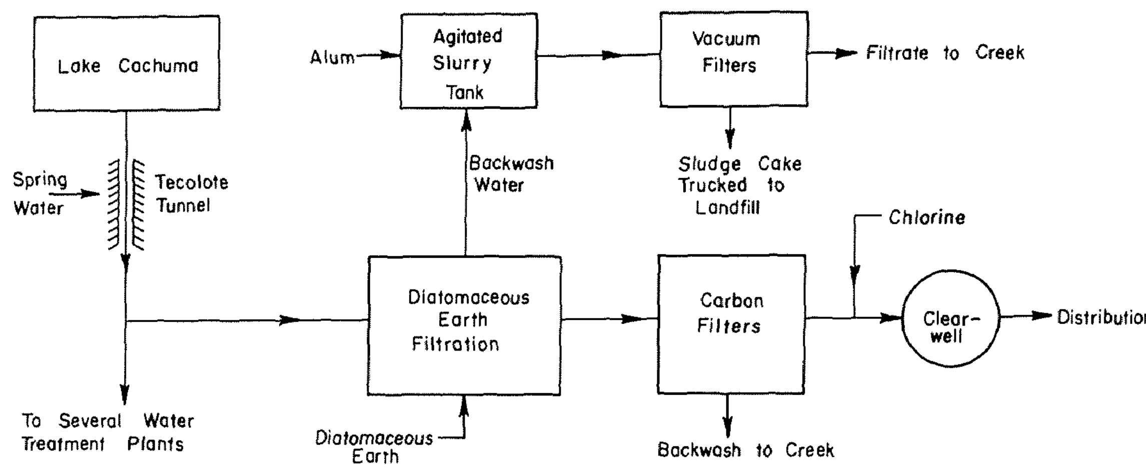
Calcium	74	mg/l
Magnesium	31	mg/l
Sodium and Potassium	56	mg/l
Bicarbonate	196	mg/l
Sulphate	225	mg/l
Chloride	27	mg/l
Iron	0.72	mg/l
Nitrate	0.20	mg/l
Hardness	312	mg/l as $CaCO_3$
Turbidity	4.0	mg/l

Method of Treatment: Diatomaceous earth filtration of the raw water without pretreatment; activated carbon filtration followed by chlorination.

Chemicals Added: Chlorination prior to Tecolote Tunnel
Sodium bisulfite at the plant
Post chlorination

GOLETA COUNTY WATER DISTRICT, CALIFORNIA

La Vista Plant - Flow Diagram



GOLETA COUNTY WATER DISTRICT
CALIFORNIA
La Vista Plant

Description of Sludge Disposal Process

Having no clarification process, all of the solids to be disposed of come from backwashing the diatomaceous earth filters or the activated carbon beds. The activated carbon beds are backwashed at 6-week intervals to remove a small carry-over of diatomaceous earth with the backwash discharged to a creek. The diatomaceous earth filters are backwashed every 48 hours. Each backwash contains about 850 lb of precoat and body feed, in addition to about 70 lb of the removed suspended solids. Annual sludge production would be 85 tons. Part of the suspended solids consists of colloidal sulphur particles which are removed by filtration. The backwash is passed to an agitated slurry tank, then it is vacuum filtered.

Two Komline-Sanderson drum vacuum filters are used. Each has a 36-inch drum diameter and a length of 36 inches. The vacuum fluctuates between 7-10 inches Hg during operation. There is no provision for chemical conditioning of the sludge prior to vacuum filtration, although about 6 lb of alum is added by hand to the agitated slurry tank. The filter cake is discharged to a bin which can be wheeled to a truck for hauling to the landfill disposal site about 1.5 miles away. Filtrate is discharged directly to a nearby creek.

COST OF SLUDGE DISPOSAL

The cost of vacuum filtering was reported to be \$2.00 per million gallons of water treated (1967). Included in the cost was power, washwater, alum conditioner, labor and replacement costs. With an average flowrate of 2.5 mgd, the above cost would be \$1,825 per annum.

Construction Costs

No cost figures were available, but assuming 2,000 ft^2 was allocated to sludge handling and a unit cost of \$15 per ft^2, the capital cost would be \$30,000. Annual cost at 6% for 25 years assuming 25% salvage value would be \$2,210.

Truck

Assuming an initial value of $6,000, an economic life of 6 years and a salvage value of $1,500, the annual cost would be $1,005. However, the truck has other uses at the plant, so half may be charged to other purposes, leaving an annual cost of $502. Maintenance, operation, insurance, licensing are calculated at $.20 per mile. One trip per week yields an annual charge of $31. Total annual trucking cost would be $533.

Land

The land requirements were small, consisting of the land area covered by the building and driveway. Assuming a land cost of $15,000 per acre and 0.10 acre for the sludge handling facilities, 100% salvage value results in an annual charge of $1,500 x 6% = $90.

Vacuum Filters

The cost of each 3-ft. x 3-ft. vacuum filter is estimated as $12,800 + 37,200 (sq.ft./100), or $23,360 for an ENR index of 812. Using an ENR index of 1,200 yields a cost of $34,500. The total annual cost at 6% assuming a 20 year life and no salvage value would be 2 x 34,500 x 0.08718 = 6,200.

Total Disposal Costs

(Interest on Land) (6% of 1,500)	$ (90)	
Power, wash water, alum, labor and maintenance	1,825	
Building	2,210	
Truck	533	
(Taxes and Insurance)(2% of $99,000)	(1,980)	
Vacuum Filters	6,200	
Total	$ 10,768	($12,838)

Disposal Cost / Unit

Cost per mg of water treated:

$10,768/365·2.5 = $11.80/mg ($14.10)

Cost per ton of dry solids:

$10,/768/85/ton = $126.60/ton ($151.10)

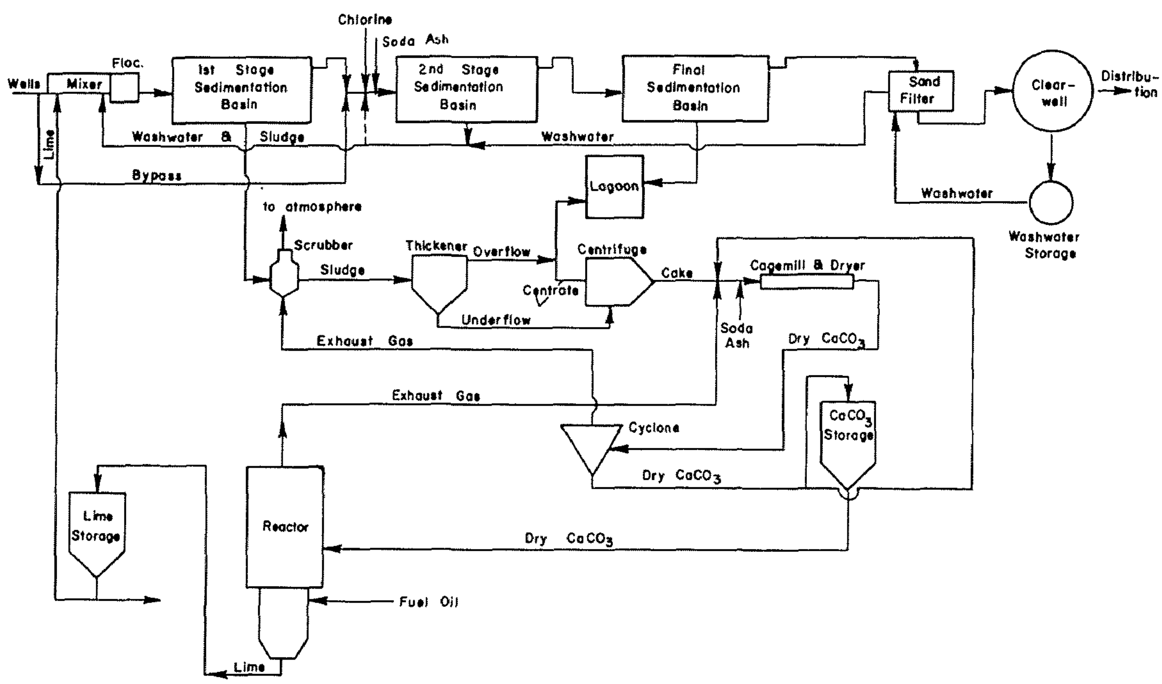
Discussion of Cost

The cost of supervision may have been omitted from the above costs. Naturally, if it was not included in the plant's cost allocation to sludge handling, the above figures would be proportionately low.

The high proportion of diatomaceous earth in the slurry fed to the vacuum filters accounted for most of the weight of the solids. Filtrate recovery has not practiced due to the absence of chemical coagulation. It would have had a minor influence on the costs. A private system would have been about 20% more expensive.

LANSING, MICHIGAN

Flow Diagram



LANSING, MICHIGAN

LANSING, MICHIGAN

Recalcination

Population: 107,807 (1960)

Operator: Fred Krause

Ownership: Municipal (Board of Water and Light)

Water Source: Wells

Flows: ave. (1968) 23 mgd
cap. 40 mgd

Influent Quality:	Total hardness	390 mg/l as $CaCO_3$
	Carbonate hardness	310 mg/l as $CaCO_3$
	Magnesium hardness	140 mg/l as $CaCO_3$
	Total solids	550-600 mg/l
	pH	7.1

Effluent Quality:	Total hardness	85 mg/l as $CaCO_3$
	Carbonate hardness	35 mg/l as $CaCO_3$
	Magnesium hardness	40 mg/l as $CaCO_3$
	Total solids	210 mg/l
	pH	10.3

Method of Treatment: Split treatment (water softening), including coagulation, sedimentation, and rapid sand filtration; with second-stage chlorination. Three stage settling is used.

Chemicals Added:	Lime	250 mg/l
	Soda ash	22.8 mg/l
	Chlorine	
	Glassy polyphosphate	0.06 mg/l

Method of Sludge Disposal

Sludge to be recalcined is removed from the 1st stage sedimentation basin. This represents about 85% of all sludge produced. The 2nd stage basin sludge is recycled, whereas the sludge from the final basin is sent annually to a lagoon.

The sludge in the 1st stage basin is removed continuously by scrapers. It contains 86-88% calcium carbonate at a solids content of 12-18%, and is sent to the gas scrubber of the recalcination plant. Here the exhaust gases are cleaned, the sludge pH dropped (setting magnesium into solution), and the sludge temperature raised to 130°F (to increase efficiency of thickening and centrifugation).

A 4-tray 30-ft. diameter thickener is used to concentrate the sludge to 20% solids. Then follows centrifugation (40" x 60"). The cake is sticky (60% solids), and requires the addition of dried sludge to create a sufficiently lumpy material which can be sent to the waste gas stream and dried. This dried sludge is removed in a cyclone and part is sent to a storage hopper and part back to be mixed with the centrifuge cake. The majority is blown into the reactor.

Recalcination is accomplished by driving off CO_2 from the $CaCO_3$, which is done here with heat from the burning of fuel oil. The vertical reactor is fired near the bottom. Dry sludge enters near the bottom and rises with the gas stream. As agglomeration develops, the pellets formed drop. The lime is removed at the bottom and sent by bucket elevator to the lime storage bin. Some dusty lime is recirculated, and soda ash (0 - ½%) is added to aid agglomeration. One lagoon of 16.5 acres serves to receive sludge from the final sedimentation basin, the thickener over-flow, and the centrate. It is located along the river, 7,000 feet away. The pipeline and pumps were installed at the time of original construction of the water treatment plant (1939).

The system described is the "Fluo-Solids Calciner" built by the Dorr-Oliver Company. Advantages of low fuel requirements are claimed. The reactor, centrifuge, etc. (except the thickener) are located in one compact building (see photo).

A very approximate average flow and solids balance follows:

Solids Balance (ave.daily)

		Flow Rate	Solids Content (%)	Solids Rate (tons)
Thickener	Influent	100,000 gals	12.	50
	Overflow	30,600 gals	0.9	1
	Underflow	59,400 gals	20	49
Centrifuge	Feed	"	"	"
	Centrate	43,400 gals	3.	5
	Cake	16,000 gals (68 tons)	65.	44
Reactor	Input	44 tons	$\sim$ 100.	44
	Output	25 tons	$CaO = \frac{56}{100} CaCO_3$	25

A sludge density of 62.4 lbs/ft^3 was used in the calculations. This leads to a slight error in the balance. More correctly, for instance, a figure of 68 lbs/ft^3 should be used at a 15% solids content.

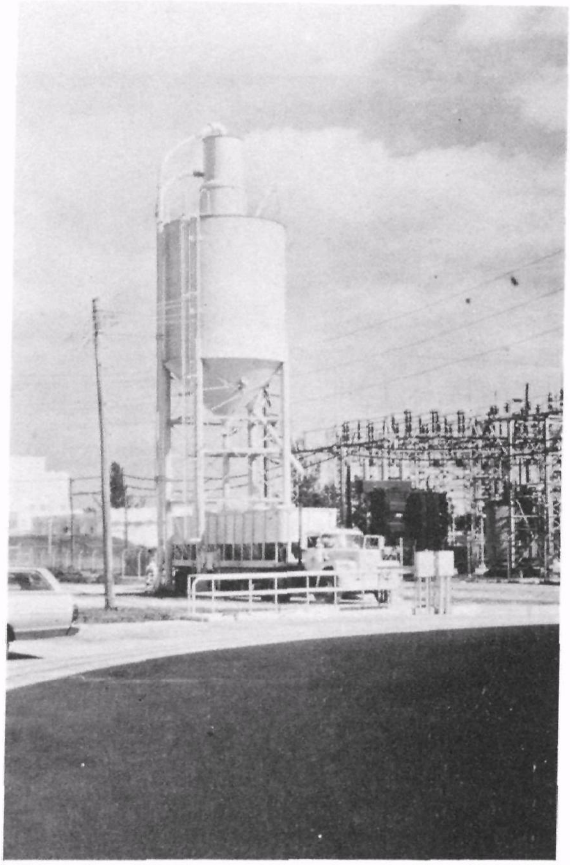
COST OF RECALCINATION

Capital Costs

The existing plant was built in 1954 at a cost of $420,000, financed from revenues. It is claimed that $80,000 of equipment was unnecessary. However, the lagoon was built in 1939, along with the pipeline and pumps. Hence a figure of $1,000,000 as 1968 replacement value could be used. Salvage value after 25 years is figured at 25%.

Land Costs

The recalcination plant and thickener use little land ($<$ 1 acre). Assume $40,000, which will also allow for the lagoon.



MIAMI, FLORIDA

Hialeah Plant

Lime Storage Silo

LANSING, MICHIGAN

Recalcination Building

Sludge Thickener in

Left Background

Operation

The plant is running at 2/3 capacity; that is, 1967 production was 7,500 tons of lime, or 20.5 tons/day. Plant capacity is 31.5 tons/day and shutdowns are infrequent. Were sufficient sludge available, a 90% utilization should be obtainable (10,400 tons/year). As of now this figure is reached only occasionally over a one or two month period.

It takes 60-65 gallons of modified #6 oil per ton of lime. This oil sells at 8.3¢/gal, with a resulting annual fuel cost of $57,300.

Only one man is required per shift, necessitating a staff of five. Their wages could be $10,000/year/man, or $50,000/year. An additional 10% should be charged for supervision.

Maintenance would be about $15,000/year; power at $37,000/year. (These figures are based on 1960-1962 data for 5,000 tons/year production). Similarly, supplies would cost perhaps $8,000 per annum.

Value of Lime

Only 85% of the lime needs of the water treatment plant are met by the lime production from the recalcination plant. The remainder is purchased at $17.50/ton.

Total Costs

Capital recovery ($1,000,000-$250,000 @ 6% for 25 yrs.)	$58,600
Interest ($250,000 @ 6%)	15,000
Operation	172,300
(Taxes and Insurance) ($1,040,000 @ 2%)	(20,080)
(Interest on Land) ($40,000 @ 6%)	(2,400)
Sub-Total	$245,900/year
Less sale of lime (10,400 tons @ $17.50/ton)	182,000
Gross loss	$ 63,900/year ($86,400)

Cost / Unit

Cost / mg of water treated:

Sufficient sludge is not produced to allow for a 90% utilization of calcination capacity. A raw influent flow of $\frac{10,400}{7,500}$. 23 = 32 mg would be required.

$ 63,900/32 = $2.00/mg ($2.70)

Cost / ton of lime produced:

$ 63,900/10,400 = $6.15/ton ($8.30)

Cost / ton of sludge solids:

Two tons of solids yield approximately one ton of lime. Approximately 85% of the sludge is used for recalcination.

$ 63,900/20,800/0.85 = $2.60/ton ($3.50)

Discussion of Cost

According to the assumptions used, the value of the lime produced is approximately equal to the cost of recalcination. However, this does not take into account the fact that the sludge disposal problem is eliminated, a large saving in itself. It should also be noted that a slight change in the estimated costs can sharply increase or decrease the cost for recalcination per unit.

Figures supplied by Lansing are as follows:

	1960-61	61-62	62-63	63-64	64-65	65-66
Production cost	$ 17.72/ton	17.52	---	16.69	16.76	16.73

A slight profit is seen here, but again the savings from eliminating the sludge disposal problem are not included. The original construction had the benefit of no financing or land charges.

LOMPOC, CALIFORNIA

Lime-Soda Softening and Diatomaceous Earth Filtration

Superintendent: Dale E. Batchelor

Ownership: Municipal

Water Source: Wells

Flows: ave. 4.1 mgd
cap. 7.0 mgd

Influent Quality:

Ca	Mg	Fe	Mn	Cl	SO_4	TDS	Turb.	T Hardness ($CaCO_3$)
159	69	1.83	0.57	99	400	1,158	0.65	684

Effluent Quality:

Ca	MG	Fe	Mn	Cl	SO_4	Cl_2	TDS	Turb.	T Hard. ($CaCO_3$)
29	18	0	0	100	390	0.39	835	0.21	147

Method of Treatment: Pre-chlorination, coagulation, sedimentation, recarbonation, diatomaceous earth filtration; post chlorination.

Chemicals Added: (July 1968)

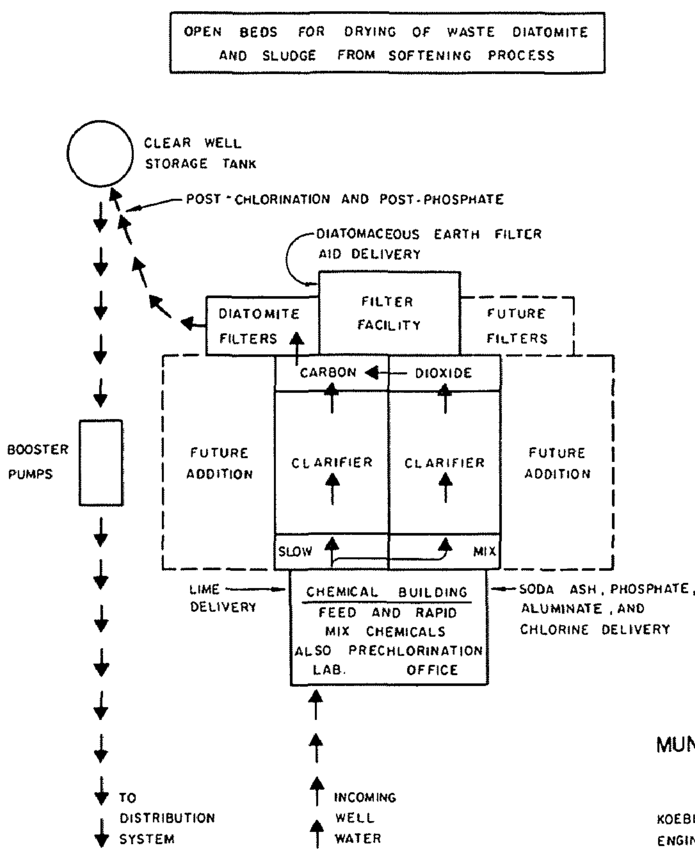
Lime	376 mg/l
Soda Ash	295 mg/l
Nalco 671	0.251 mg/l
Chlorine	2.3 mg/l
Diatomaceous Earth	10.31 mg/l

Sludge Production:

Softening sludge	120,000 gals/day @ 4% solids
Diatomaceous earth backwash	2,600 gals/day

LOMPOC, CALIFORNIA

Flow Diagram



PLANT CAPACITY	
INITIAL	7,000,000 GALLONS PER DAY
EVENTUAL	14,000,000 GALLONS PER DAY

PLANT CAPABILITY		
TYPE OF WATER	TOTAL HARDNESS, $CaCO_3$	
	PARTS PER MILLION	GRAINS PER GALLON
RAW	750	44
TREATED (AVERAGE)	150	8.8

NOTE: DELIVERED WATER HARDNESS IS ADJUSTABLE.

CITY OF LOMPOC, CALIFORNIA
MUNICIPAL WATER TREATMENT PLANT
DECEMBER 19, 1963

KOEBIG & KOEBIG, INC
ENGINEERING - ARCHITECTURE

FRED J EARLY CO, INC
GENERAL CONTRACTOR

Description of Sludge Disposal Process

The sludge from the softening units is pumped to the dewatering and drying beds. However, about 20% of the sludge from the bottom of the clarifier is pumped back to the flash mixer. The recirculated sludge stabilizes the softening process and saves some chemical costs. Also, the wash water is pumped directly to the beds.

The dewatering and drying beds are filled with sludge, then they are decanted with the decant returned to the plant influent. Each of the 8 beds measures 140 ft. x 140 ft. on the bottom, and 160 ft. x 160 ft. at the top. The berm separating the beds is about 10 ft. wide. A total of 6 acres is now devoted to the sludge dewatering and drying beds. When the bed is filled with 4 to 5 ft. of sludge, it is left to drain and dry. In about 4 months the sludge has dried to a 50% solids content. It is then removed with front end loaders and placed in trucks for transport to a landfill disposal site about 2 miles away.

The beds were constructed with sand bottoms and a special 15 ft. diameter core in the center of the bed was dug about 15 ft. deep, then refilled with sand. Its purpose was to aid dewatering by intersecting a permeable natural sand layer at the 15 ft depth.

Softening sludge production is 365 x 120,000 gals/day x 0.04 lb/sludge x 8.34 = 14,600,000 lb/yr. = 7,300 tons/yr. In addition, perhaps 100 tons/yr. of backwash solids are added to the beds.

COST OF SLUDGE DISPOSAL

Land

Land costs are estimated at $10,000 per acre near the plant, yielding a land value of $60,000. Preparation of the dewatering and drying beds was assumed to cost $5,000 per acre, or a total of $30,000.

Sludge Removal

Sludge removal and transport to the fill site is estimated to cost $20,650.

Labor and Supervision

Perhaps 10% of the plant's labor and supervision time is devoted to the dewatering and drying beds, yielding a cost of $7,725.

Maintenance and Operation

Power for sludge pumping is estimated at $1,000 per annum. Maintenance is estimated to cost $1,000 per year.

Total Disposal Costs

(Taxes)(2% of $60,000)	$ (1,200)	
(Interest on Land)(6% of $60,000)	(3,600)	
Land Preparation ($30,000 @ 6%, 30 years)	2,180	
Sludge Removal	20,650	
Labor and Supervision	7,725	
Maintenance and Operation	2,000	
Total	$ 36,155	($37,355)

Disposal Cost / Unit

Cost per mg of water treated:

$36,155/365·4.1 = $24.20/mg ($25.00/mg)

Cost per ton of solids:

$36,155/7,400/ton = $4.89/ton ($5.05/ton)

Discussion of Costs

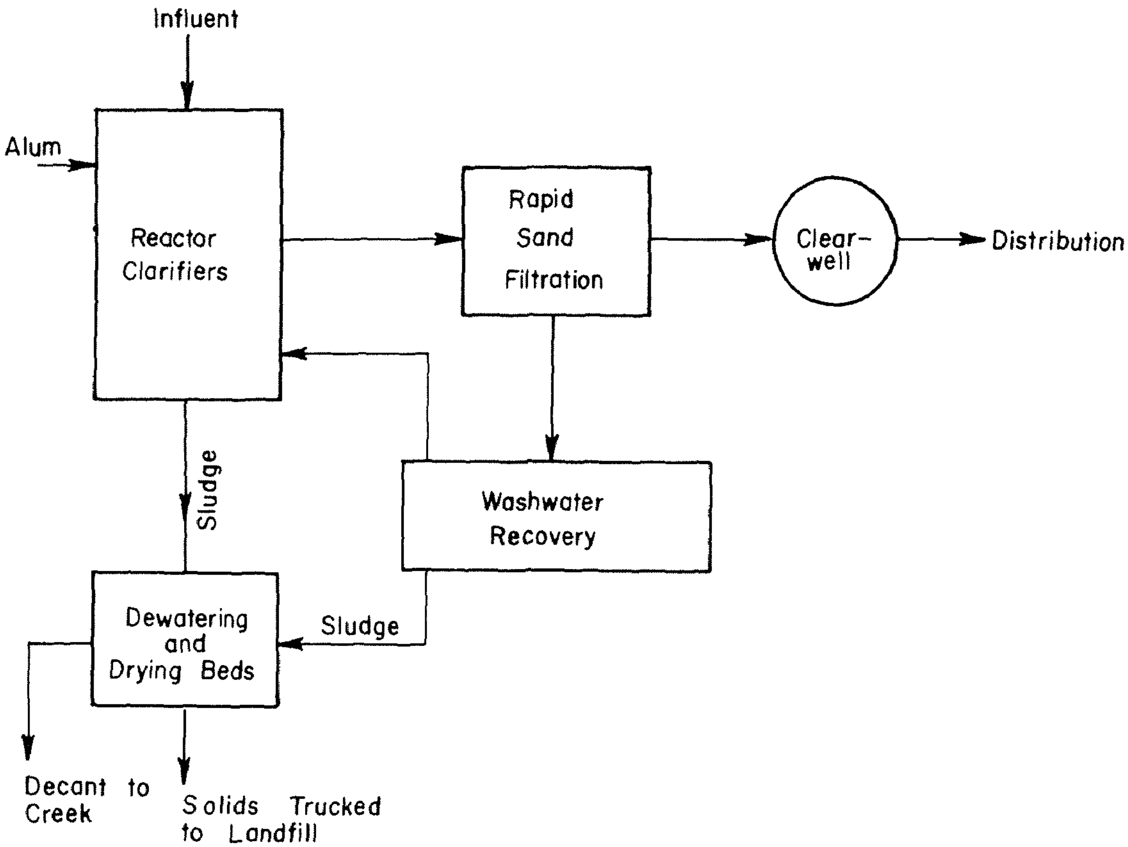
The sludge removal and disposal cost of $20,650 appears to be a reasonable estimate based upon extensive documentation from prior years' costs.

No allowance was made for the value of the decant which was reclaimed. However, based on the cost of pumping an equivalent volume of water from the well field, the decant had a value of about $5,000 per year.

The land cost was taken as a high value of $10,000 per acre. However, each $1,000 per acre increase in land costs would only increase the sludge handling cost by 1.5%.

LOS GATOS, CALIFORNIA

Rinconada Treatment Plant - Flow Diagram



SANTA CLARA COUNTY
CALIFORNIA
Rinconada Water Treatment Plant

LOS GATOS, CALIFORNIA
RINCONADA WATER TREATMENT PLANT

Alum Sludge to Drying Beds

Ownership: Santa Clara County Flood Control and Water Conservation District

Flows: ave. 10 mgd
cap. 40 mgd

Influent Quality: (Composite October 1968)

Ca	Mg	Na	K	Fe	HCO_3	Cl	SO_4	F	B	TDS	
18.8	10.4	32	2.9	1.05	66	56	35	0.2	0.26	268	mg/1

Turbidity 52
Total Hardness ($CaCO_3$) 88

Method of Treatment: Flash mixing, flocculation, sedimentation, rapid sand filtration, chlorination.

Chemicals Added: Alum 16-20 mg/1
Chlorine

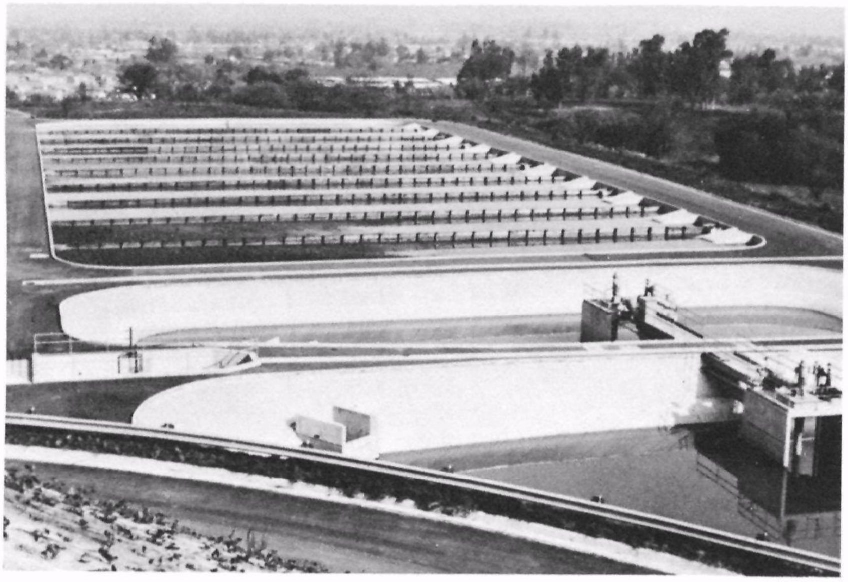
Description of Sludge Disposal Process

Wash water recovery is practiced by discharging the wash water to two 700,000 gallon capacity recovery basins. The sludge may be flushed to the drying beds. It is estimated that the wash water recovery basin will be cleaned once every six months. As the plant is new, it has been cleaned only once.

The sludge from the sedimentation basins may be discharged to any of a set of 10 drying cells measuring 21 ft. x 100 ft. x 3½ ft.

LOS GATOS, CALIFORNIA

Drying Alum Sludge



Alum Sludge Dewatering and Drying Beds

Crack Development in Drying Alum Sludge

deep, or to either of two other drying beds measuring approximately 80 ft. x 600 ft. All the drying beds are underdrained.

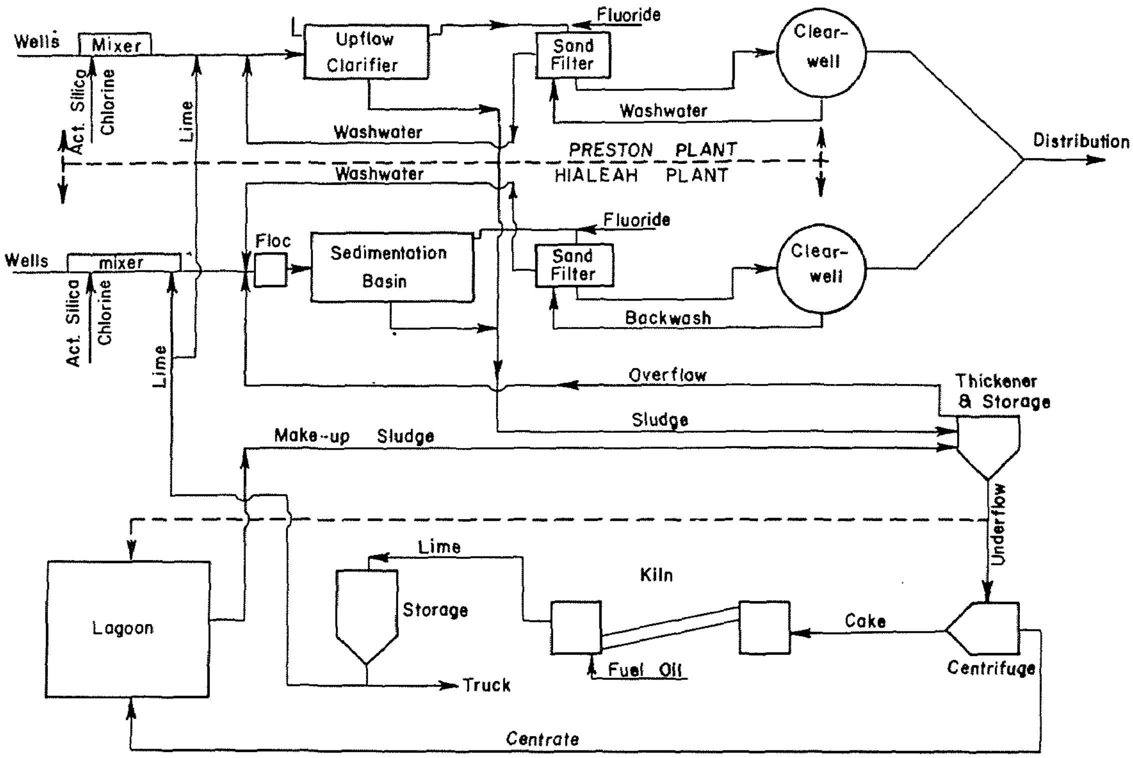
The drying beds may be decanted with the decant discharged to a creek.

Cost of Sludge Disposal

The plant is new, and sludge disposal costs are not yet available.

MIAMI, FLORIDA

Hialeah Plant - Flow Diagram



MIAMI, FLORIDA

MIAMI, FLORIDA

Recalcination

Population: Three treatment plants serve 730,000 (1965)

Superintendent of Lime Recovery: Guy C. Collins

Ownership: Municipal

Sources: Wells

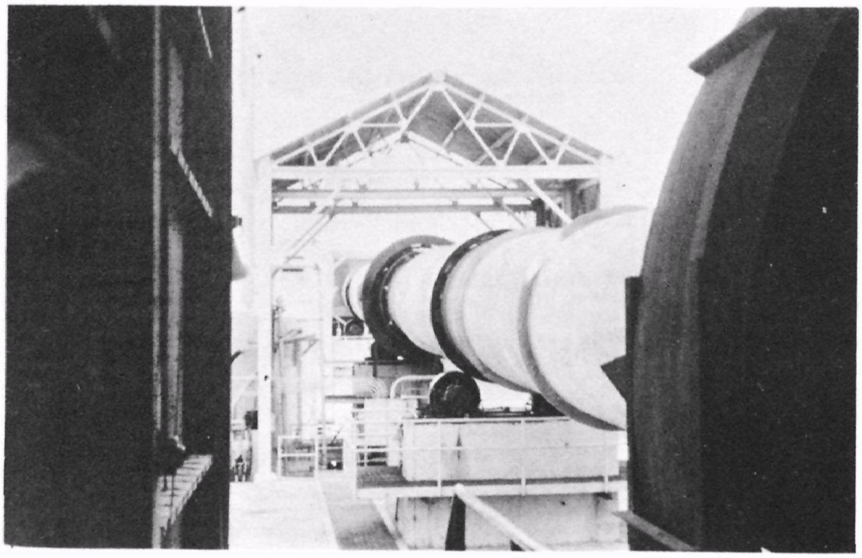
Flows:	Hialeah Plant	ave. (1958)	36 mgd
		cap.	60 mgd
	Preston Plant	ave. (1968)	45 mgd
		cap.	60 mgd

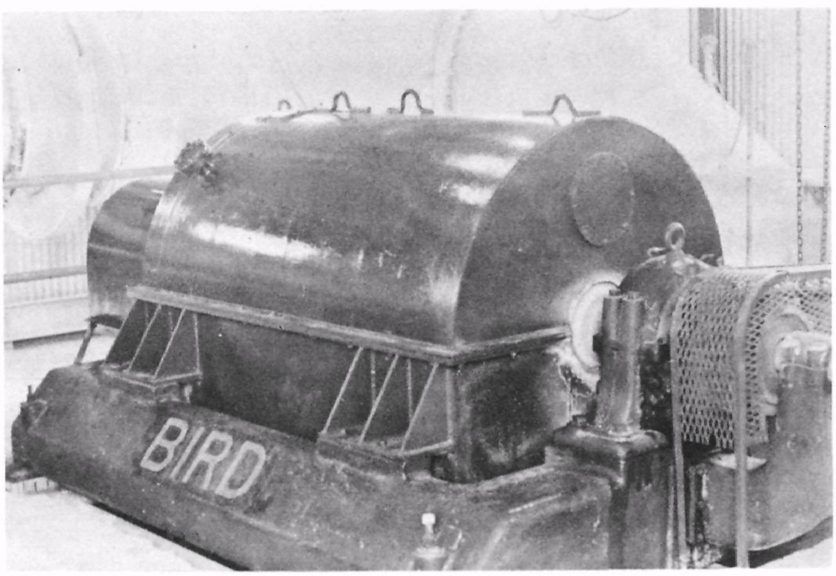
Influent Quality:	Total hardness	236	mg/l as $CaCO_3$
	Carbonate hardness	224	mg/l as $CaCO_3$
	Magnesium	6.4	mg/l
	Total solids	330	mg/l
	Iron	1.1	mg/l
	pH	7.3	
Effluent Quality:	Total hardness	75	mg/l as $CaCO_3$
	Carbonate hardness	40	mg/l as $CaCO_3$
	Magnesium	5.5	mg/l
	Total solids	185	mg/l
	Iron	0	
	pH	9.0	

Method of Treatment: Coagulation, sedimentation (Hialeah), or upflow clarification (Preston), and rapid sand filtration; with pre-chlorination and fluoridation.

MIAMI, FLORIDA

Hialeah Plant





Centrifuge for Dewatering Lime Sludge

Chemicals Added:	Lime	150-160 mg/l
	Sodium silicate	2 mg/l
	Chlorine	
	Fluoride	1 mg/l

Method of Sludge Disposal

The Hialeah and Preston plants are adjacent to one another. Recalcination is done at the Hialeah plant and receives sludge from both. Sludge from Preston is removed continuously over to one of three thickeners at Hialeah, where it joins the intermittent (5 min. on, 5 min. off) flow of sludge from the Hialeah sedimentation basins.

The large thickener (90 ft. diameter) serves partially as a storage unit, whereas the other two, each 32 ft. in diameter, are operated continuously. The sludge enters at a high solids content (up to 30%) and leaves at about 40%. Overflow is returned to the head of the plant.

The sludge is then sent to two centrifuges (40" x 60") and brought to a toothpaste consistency of 65% solids. The centrate, containing about 5% solids, is sent to a lagoon, where by-pass and excess sludge is also sent.

A screw conveyor carries the sludge cake into the 7.5 ft. diameter, 230 ft. long rotary kiln. There are three lime storage silos from which lime is drawn to supply both treatment plants (Hialeah and Preston) plus a portion of a third plant. Each pound of lime added in treatment yields 1.35 pounds of lime by recalcination.

The lagoon previously described covers 20 acres. Sludge is withdrawn from here at times by a scraper and tugger hoist and trucked to the plant to provide make-up material for the recalcination plant. This lagoon has accumulations from times previous to the construction of the plant (1936-1949).

The recalcination plant is shut down about 20 days each year, or about 5% of the time. Capacity of the plant is 97 tons/day, although the initial rating was 80 tons/day. A flow and solids balance sheet might look like this:

Flow and Solids Balance (ave. daily)

		Flow Rate	Solids Content (%)	Solids Rate (tons)
Thickener	Influent*	320,000 gals	12.	160
	Overflow	230,000 gals	1.	10
	Underflow	90,000 gals	40.	150
Centrifuge	Feed	"	"	"
	Centrate	39,000 gals	7.5	12
	Cake	51,000 gals (213 tons)	65	138
Kiln	Input	213 tons	"	"
	Output	77 tons	$CaO\left(= \frac{56}{100} CaCO_3\right)$	77

*includes an average of 11-12% make-up sludge. Note also that a sludge density of 62.4 lbs/ft^3 was used throughout the table.

COST OF SLUDGE DISPOSAL

Construction Costs

The original construction cost for the plant was $792,000 in 1948. Since then additions have brought this figure to approximately $1,200,000. A silo was added in 1964 at a cost of $100,000, and the large thickener at a cost of about $150,000 in 1965. The Handy-Whitman Water Works Cost Index suggests a present day replacement value of $2,200,000. Miami depreciates at 1½%/year (straight-line). This is unrealistic, and a more likely salvage value at the end of 25 years is $550,000 (25%). This should include sufficient allowance for lagoon construction costs (originally a pond).

Land Costs

The plant uses about 3 acres, valued at $15,000/acre. The lagoon covers 20 acres, but could be smaller for a new design. Its value may be set at $100,000.

Operating Costs

Projections based on past years indicate \$250,000/year for a production of 32,000 tons/year, representing 90% of capacity production.

Value of Lime

Additional lime needed for the third treatment plant costs \$21.13/ton delivered.

Annual Costs

Capital recovery (\$1,650,000 @ 6% for 25 years)	\$129,000	
Operation	250,000	
Interest on salvage (\$550,000 @ 6%)	33,000	
(Interest on land) (\$145,000 @ 6%)	(8,700)	
(Taxes and Insurance) (2% of \$2,345,000)	(46,900)	
Sub-Total	412,000/yr.	(\$467,600)
Less value of lime (32,000 tons @ \$21.13/ton)	676,000	
Gross Profit	\$264,000/yr.	(\$208,400)

Profit / Unit

Profit/mg of water treated:

Sludge is in fact "mined" from the lagoon, and as a result the lime produced beyond 25,000 tons/year comes from past accumulations and flows. A production of 32,000 tons/year represents a flow of 38,000 mg.

\$264,000/38,000 = \$6.95/mg (\$5.50)

Profit/ton of lime produced:

\$264,000/25,000 = \$10.55/ton (\$8.35)

Profit/ton of sludge solids

$$\$10.55/\frac{160}{77} = \$5.08/\text{ton} \ (\$4.00)$$

Discussion of Profit

The profits indicated are about 11.2% (8.9%) of the total investment, which is attractive. Lime prices in the region appear stable, and it seems that lime recovery in this instance is to be recommended. Miami has calculated their profits to be running at $300,000/year. The calculations here show lower profits, chiefly due to the differences in interest rates (6% vs. 2.8%) and, of course, capital costs.

MINOT, NORTH DAKOTA

Vacuum Filtration of Lime Softening Sludge

Population: Minot 35,000: Air Force Base 15,000

Superintendent: Glenn Berg

Ownership: Municipal

Water Source: Mouse River and 13 wells. The river supplies about half the water and the wells the other half.

Flow: Plant capacity 18. mgd
Summertime water availability limits the production to 10 mgd, winter production is 3.5 mgd

Influent Quality:

Total hardness for combined flow from wells varies from 250-450 mg/l as $CaCO_3$.
Total hardness for the river is low during spring runoff and reaches 480 mg/l as $CaCO_3$ during low flows.
Typical Analyses of wells (as $CaCO_3$):

	Hardness	Ca	Mg	Na+K	HCO_3	Cl	SO_4	Fe as Fe
Well No.1	166	93	73	395	440	108	17	1.0
Well No.2	315	188	127	539	577	175	100	2.0
Well No.3	347	233	114	1,029	806	423	149	3.0

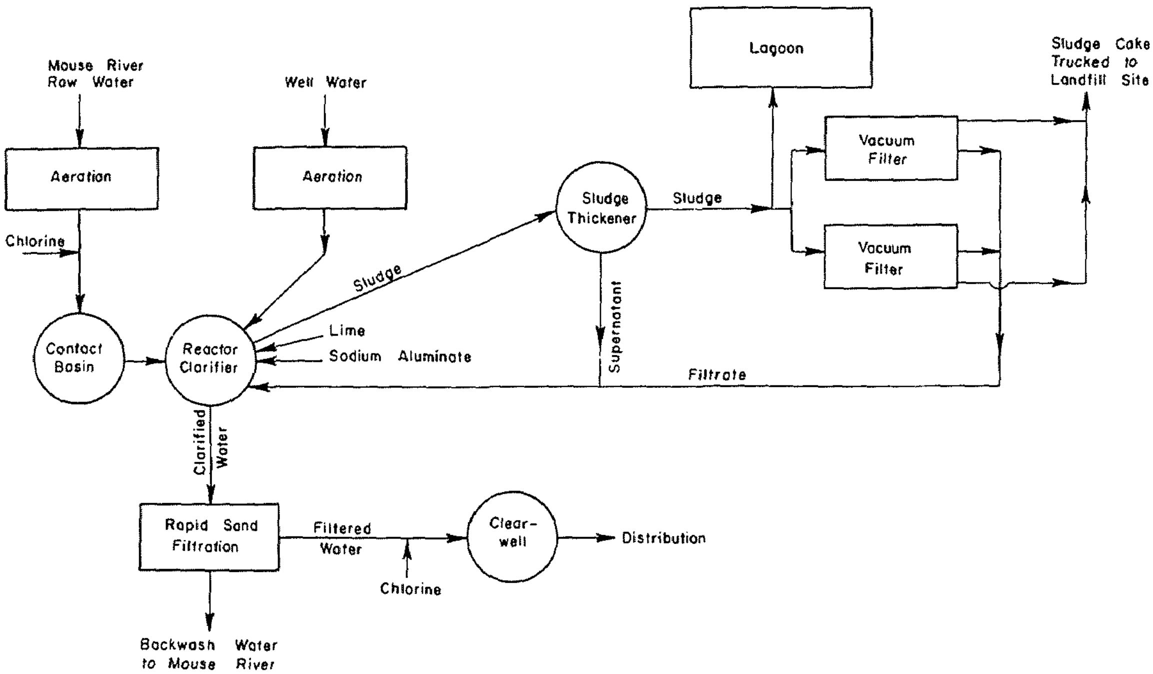
Effluent Quality:

Total hardness	84 mg/l as $CaCO_3$
Calcium hardness	39 mg/l as $CaCO_3$

Method of Treatment: Well water receives aeration, sodium aluminate addition, lime softening,

MINOT, NORTH DAKOTA

Flow Diagram



MINOT, NORTH DAKOTA
Water Treatment Plant

Method of Treatment: (continued)	clarification, recarbonation, rapid sand filtration and chlorination. River water receives aeration, pre-chlorination, sedimentation, sodium aluminate addition, lime softening, clarification, recarbonation, rapid sand filtration and chlorination. The river and well waters are mixed at the sodium aluminate addition step.

Chemicals Added:	Chlorine	
	Sodium aluminate	
	Lime	426 mg/l
	Polyphosphate	

Description of Sludge Disposal Process

Sludge from filter backwash water is discharged directly to the Mouse River. Approximately 3 tons of dry solids are produced per million gallons of water treated. The sludge from the upflow Walker Process clarification unit is discharged to a sludge thickener located in a separate building housing the vacuum filters. From the thickener the sludge goes to two EIMCO vacuum filters, one 8-ft. diameter by 10-ft. long, and the other 8-ft. diameter by 8-ft. long. The vacuum filters are equipped with Eimcobelt filter cloths.

The two filters operate three days/week in the winter, and more often in the summer. They each average 18 hours of operation for each 70 hours of plant operation. Filtrate is returned to the clarifier.

The sludge cake, having approximately 44% solids, is moved by conveyor belt from the vacuum filters to discharge to one of three hoppers. The hoppers can be emptied into a dump truck for transport to the landfill disposal site on the plant grounds. At the landfill site the sludge is dumped over the edge of an embankment of sludge cake. Spreading several inches of gravel on the surface of the fill provides sufficient traction for the truck. No problem of embankment settlement has been noted.

Special modifications consisting of the installation of rubber seals in the dump truck box were necessary to minimize sludge leakage during transport. Prior experience in hauling sludge cake to the town dump had shown vehicles could easily become stuck in any sludge spilled on the ground.

Total sludge production was estimated to be three tons of dry solids per million gallons. Annual production based on an average flow of 5 mgd would be $5 \text{ mgd} \cdot 3 \frac{T}{mg} \cdot 365 \frac{day}{yr} = 5{,}470$ tons/yr.

COST OF SLUDGE DISPOSAL

Land

It is estimated that 5 acres of the land is devoted to sludge handling purposes, including the disposal site. The unit cost is estimated as $1,000 per acre, resulting in a land value of $5,000. Full salvage is assumed.

Building

A 70-ft. by 40-ft. two-story building which houses the thickener and vacuum filters cost $184,700 in 1962. However, this figure included the sludge thickener and the 10-ft. by 10-ft. vacuum filter. Deducting $37,000, the estimated 1962 cost of the vacuum filter leaves a building and thickener cost of $147,700. An economic life of 30 years with a 25% salvage value is assumed.

Vacuum Filters

The 8-ft. by 10-ft. vacuum filter was salvaged from the sewage treatment plant and converted for use at the water treatment plant at a cost of $7,200. For purposes of calculating sludge disposal costs it is preferred to calculate the vacuum filter's 1962 replacement value as $33,000. The 1968 cost of the two vaccum filters would be $70,000 x 1,200/850 = $99,000.

Operation and maintenance is estimated to be $19,250 per year based on the report WP-20-9 and an average flow of 5 mgd.

Truck

The estimated cost of the truck is $7,500. Due to the modified box for sludge hauling, it has few other uses. Operation and maintenance is estimated as $500 per annum. 25% salvage after six years is assumed.

Labor

Included in operation and maintenance of the vacuum filter.

Annual Costs

Vacuum Filters ($99,000 @ 6% for 20 years)	$ 8,630	
(Interest on land) ($5,000 x 6%)	(300)	
Building (75% of $147,700 @ 6% for 30 years)	8,040	
Interest on building salvage (25% of $147,700 @ 6%) .	2,210	
Truck (75% of $7,500 @ 6% for 6 years)	1,141	
Interest on truck salvage (25% of $7,500 @ 6%)	112	
Operation and maintenance of truck	500	
Operation and maintenance of vacuum filters	19,250	
(Taxes and insurance) (2% of $251,700)	(5,034)	
Total	$ 39,883	($45,217)

Cost / Unit

Cost per million gallons:

$39,883/5·365 = $21.80/mg
$45,217/5·365 = ($24.80/mg)

Cost per ton of dry solids:

$39,883/5,570 ton = $7.29/ton
$45,217/5,470 ton = ($8.26/ton)

Discussion of Cost

The major cost item was the operation and maintenance of the vacuum filters. Included in the cost were the labor and supervision charges. The plant superintendent estimated two full-time equivalent men were required for the vacuum filter operation at a wage cost of $10,400 per annum. Indirect costs would increase this figure, as would cost of supervision, which may run to $2,000 per year. Power costs, repairs and special maintenance are thought to be sufficient to bring the operation and maintenance estimate to $19,250.

The large reduction in hardness with the concomitant large sludge production makes the unit cost per ton quite low. The average influent turbidity was low due to upstream reservoirs on the Mouse River and the availability of groundwater to use should the river water temporarily become turbid. The dewaterability of softening sludge is high in contrast with an alum sludge. Had the influent been more turbid, there undoubtedly would have been a significant increase in the sludge handling costs.

The cost is relatively independent of changes in land prices. Had the land price been $10,000 per acre instead of $1,000, the sludge handling costs would have increased less than 10%.

NEW BRITAIN, CONNECTICUT

Serial Lagoons

Population: 85,000

Superintendent: Fred Sarra

Ownership: Municipal

Water Source: Reservoirs

Flow: ave. (August 1967-1968) 9 mgd
cap. 20 mgd

Influent Quality:	Total hardness	17 mg/l as $CaCO_3$
	Alkalinity	15 mg/l as $CaCO_3$
	Color	12
	Turbidity	2 - 5
	pH	6.9
Effluent Quality:	Total hardness	37 - 39 mg/l as $CaCO_3$
	Alkalinity	17 mg/l as $CaCO_3$
	pH	8.7 - 8.8

Method of Treatment: Coagulation, sedimentation, and rapid sand filtration; with chlorination.

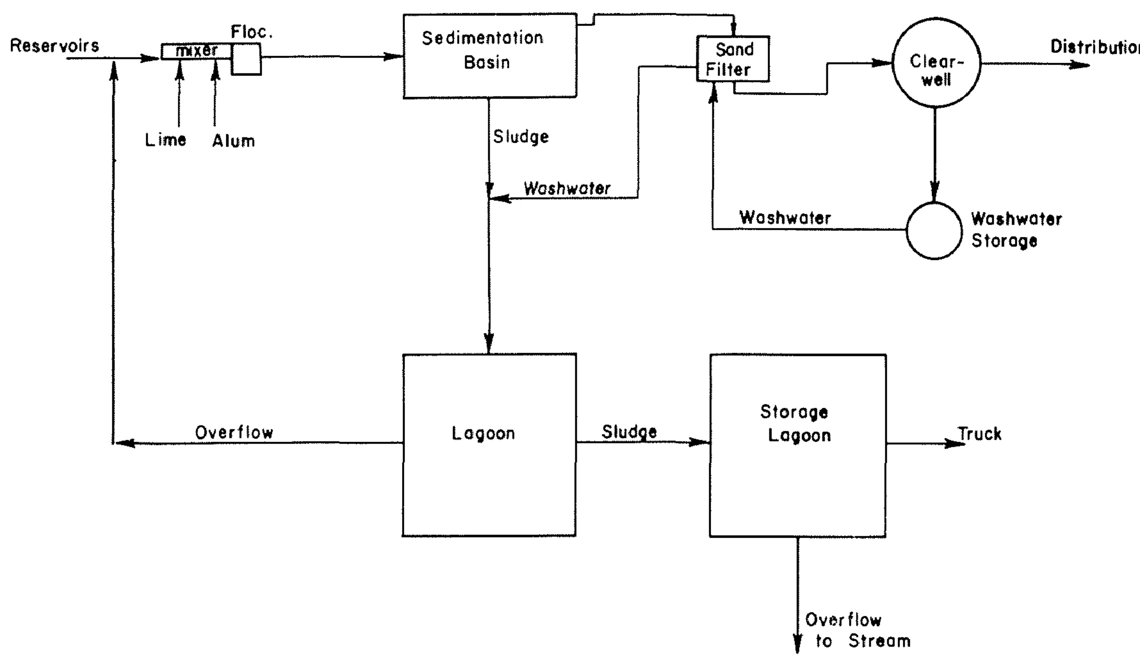
Chemicals Added:	Lime	10 mg/l
	Alum (aluminum oxide)	10 mg/l
	Chlorine	

Description of Sludge Disposal Process

Washwater is sent to a concentration lagoon, with an overflow

NEW BRITAIN, CONNECTICUT

Flow Diagram



NEW BRITAIN, CONN.

to a canal leading to one of the reservoirs. Flashboards at another point can decant to the canal, leaving sludge to be sent by gravity to a sludge storage lagoon.

Every 4 months, the 4 sedimentation basins are cleaned out by gravity flow and flushing. A cleaning period of 7-10 days is required. The sludge flows through the previously emptied washwater concentration lagoon into the storage lagoon. This storage lagoon is equipped with flashboards for decantation into a stream.

The concentration lagoon is built out of a hillside, with a 13 ft. high levee on the downslope side. This elliptical lagoon has an area of 3/4 acre, with an average depth of 6 ft. Approximately the same dimensions apply to the storage lagoon, with the exception of the depth, which is only 4.5 feet.

Cleaning of the storage lagoon by contract is about every 5 years, using a dragline. The sludge is spread on the roadsides of the large watershed belonging to the system. The lagoons are 30 years old.

COST OF SLUDGE DISPOSAL (ALL 1968 COSTS)

Construction

Figured from construction drawings

Piping	$ 19,500
Excavation	18,100
Embankments	36,200
Drainage structures and misc.	10,000
Sub-Total	83,800
+ 25%	20,950
Total	$104,750

Land

The 3 acres are worth $9,000.

Operation

Perhaps ½/hr/day should be allotted for the daily tour, in addition to 2 men required to coordinate controls during basin cleanings. Estimate $5,000 for all labor and supervision per year, plus auto costs, etc.

Disposal

A cleaning of the storage lagoon every 5 years costs $7,500, or $1,500/year.

Total Disposal Costs

Capital recovery ($105,000-25,000 @ 6% for 25 years)	$ 6,250
Annual costs	3,000
Interest on salvage ($25,000 @ 6%)	1,500
(Interest on land) ($9,000 @ 6%)	(540)
(Taxes and Insurance) (2% of $114,000)	(2,280)
Total	$10,750/year ($13,570)

The washwater recovered is negligible, as much of it infiltrates over the half-mile length of canal. There is a salvage value to the lagoons, however. This may be estimated to be $25,000.

Disposal Cost / Unit

Cost/mg of water treated:

$10,750/9·365 = $3.30/mg ($4.10)

Cost/ton of dry solids:

The basins when emptied contain 8-10 feet of sludge. The volume of sludge per year is 3·27,800·9 = 750,000 ft.^{3}, or assuming a solids content of 1.5%, the tons/year is 350. Four feet of sludge at 5% solids accumulated in 5 years calculates out as 200 tons/year.

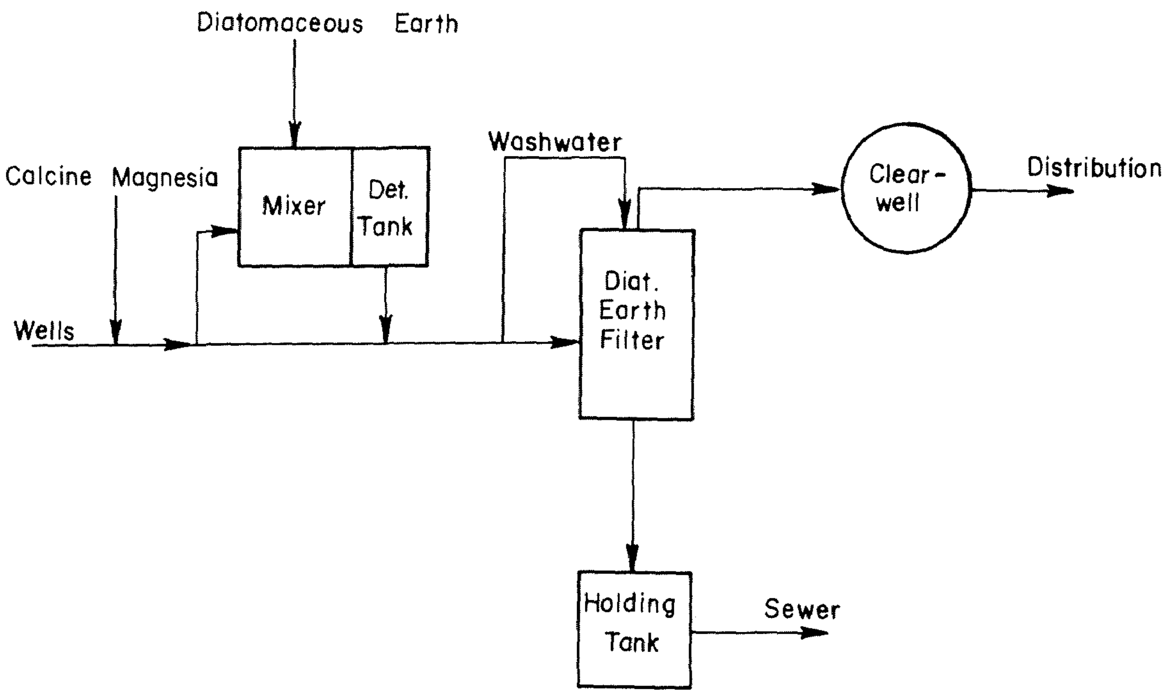
$10,750/275 = $39.00/ton ($49.30)

Discussion of Cost

The costs are highly dependent on the initial construction, and in turn the useful life of the lagoons. Costs for a private system would be about 25% greater. It should be noted that the concentration lagoon serves little purpose for sludge disposal, and its cost should be allocated to backwash disposal.

POINT PLEASANT BEACH, NEW JERSEY

Flow Diagram



POINT PLEASANT BEACH, NEW JERSEY

POINT PLEASANT BEACH, NEW JERSEY

Disposal to Sewer

Population: 4,500 permanent, 25,000 temporary

Operator: Robert K. Mickle

Ownership: Municipal

Water Source: Wells

Flows: ave. 0.75 mgd
peak 2.0 mgd

Influent Quality:			
	Total hardness	26-42	mg/l as $CaCO_3$
	Alkalinity	24-33	mg/l as $CaCO_3$
	Calcium	10-26	mg/l
	Iron	1.2-4.0	mg/l
	pH	6.48	

Method of Treatment: Flocculation, diatomaceous earth filtration, and, chlorination.

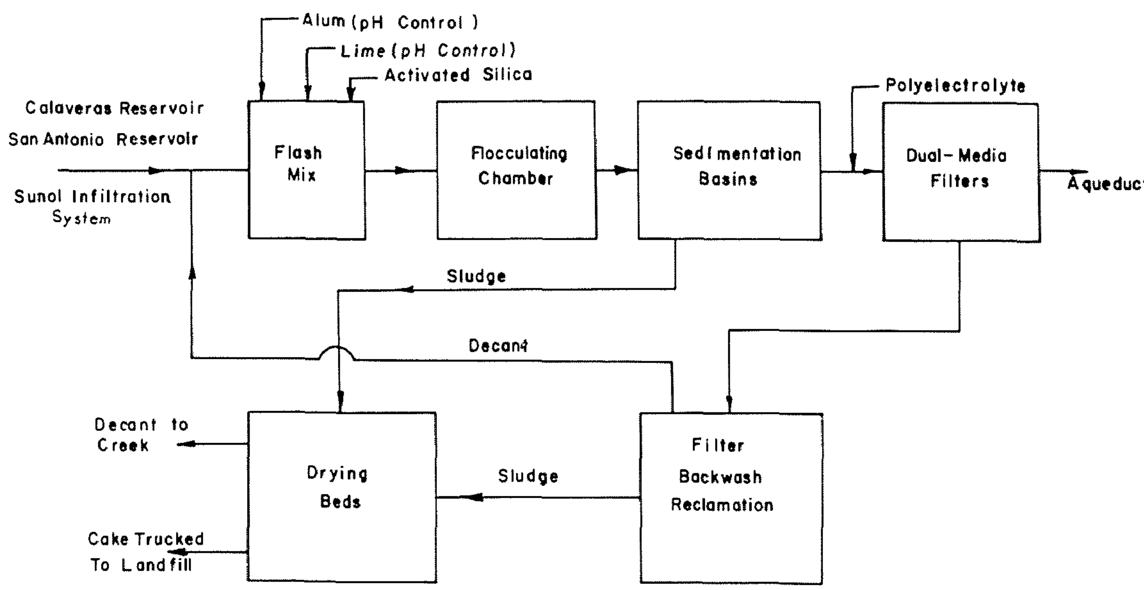
Chemicals Added: Calcine magnesia
Chlorine

Description of Disposal Process:

The washwater is collected in a 10,000 gallon holding tank, from which it is pumped into an 8" sewer. The tank was needed to distribute the flow, as the sewer has a capacity of only 230 gpm. The sewage treatment plant, municipally owned, provides only primary treatment. No problems from the washwater have been encountered, and no charges are levied.

SAN FRANCISCO, CALIFORNIA

Sunol Valley Filtration Plant - Flow Diagram



San Francisco Water Department

Sunol Valley Filtration Plant

SAN FRANCISCO, CALIFORNIA

SUNOL, VALLEY FILTRATION PLANT

Alum Sludge to Drying Beds

Superintendent: David M. Reeser

Ownership: San Francisco Water Department

Capacity: The plant balances the load on the Hetch Hetchy aqueduct serving San Francisco and neighboring communities. It is therefore subject to rapid variations in flow. The range in flowrates has been between 8 to 80 mgd. The design flow was 40 mgd.

Influent Quality: Turbidity is highly variable, as the plant draws from surface reservoirs. During winter rains it may reach 1,500 J.T.U., while during the summer dry season turbidities of 1-2 J.T.U. are common.

Effluent Quality: Turbidity of 1 J.T.U. is expected.

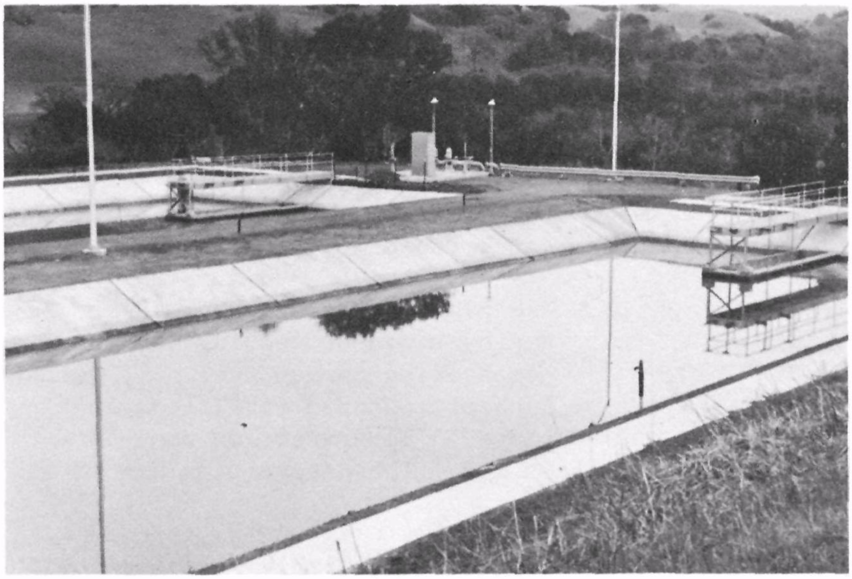
Method of Treatment: Flash mixing, flocculation, sedimentation, dual media filters; post chlorination.

Chemicals Added: Chlorine
Lime
Activiated sodium silicate
Alum during winter
Polyelectrolyte (Separan MP-10)

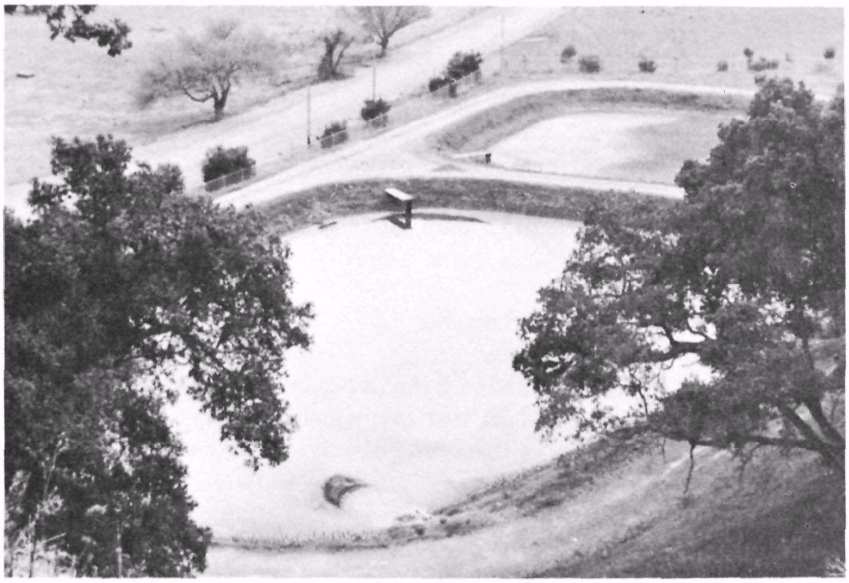
During the summer coagulation is not practiced and the polyelectrolyte is added immedialtely prior to the filters as a filter aid. Activated silica is used in

SAN FRANCISCO, CALIFORNIA

Sunol Valley Filtration Plant



Filter Washwater Recovery Basins



Alum Sludge Drying Beds

Chemicals Added: (continued)	the winter along with alum. There is insufficient alkalinity present and lime is added to the effluent for pH control.

Description of Sludge Disposal Process

Sludge from the sedimentation basins goes to two drying beds. The sludge is added continuously during the period when coagulation is practiced.

Backwash water is reclaimed by discharging it to two holding basins, allowing the solids to settle and returning the supernatant to the plant influent. The solids are drawn off intermittently and are flushed to the drying beds.

The drying beds are constructed to permit decantation of the supernatant which is discharged to a nearby creek. The floor and banks of the drying bed are natural earth with no special provision to encourage seepage.

The filling depth of the drying beds is thought to be critical. In 1966-1967 the beds were filled with 4 ft. of sludge. After 6 months in the beds (June - December), only the top 2 ft. had cracked and dried. In 1967-1968 the beds were filled to a depth of 2 ft. with sludge. After 4 months 200 $yd.^3$ was removed from one bed and 300 $yd.^3$ was removed from the other. The weight of dry solids is estimated as 250 tons.

COST OF SLUDGE DISPOSAL

Land

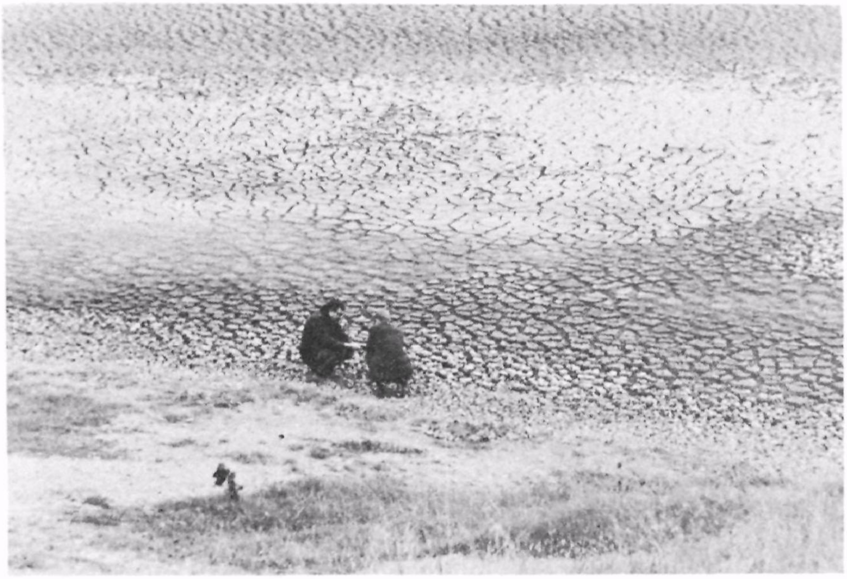
Area of the two drying beds is estimated as 8 acres. The land has been owned by the San Francisco Water Department for many years. The disposal site is also on Water Department property. Its area is estimated as 2 acres. Another acre may be assumed for access roads. Assuming a land value of $2,000 per acre results in a land value of $22,000.

Land Preparation

Construction of the drying beds and the connecting sludge lines

SAN FRANCISCO, CALIFORNIA

Sunol Valley Filtration Plant



Drying Alum Sludge

Disposal Site - Dried Alum Sludge

is estimated as $30,000.

Labor and Supervision

During regular operation this may be equivalent to one full-time man costing $9,000 per year.

Removal Costs

Removal is by outside contract. A front end loader and two trucks are needed for about one week per year. Cost is estimated to be $1,500 per annum.

Total Sludge Disposal Costs

Interest on Land ($22,000 @ 6%)	$ 1,320
(Taxes) (2% of $22,000)	(440)
Preparation of Land ($30,000 @ 6% for 25 yr.)	2,350
Labor and Supervision	9,000
Removal	1,500
Total	$ 14,170 ($14,610)

Cost / Unit

Cost per mg treated: (assume 12,000 mg/yr.)

$14,170/12,000 = $1.18/mg. ($1.22/mg)

Cost per ton of dry solids:

$14,170/250 = $56.60/ton ($58.50/ton)

Discussion of Costs

The labor and supervision cost allocation of $9,000 is thought high in that there are eight employees at the plant, but the drying beds require minimal attention during the summer. As this represents 2/3 of the cost, a change will produce a proportionate change in the cost per unit.

The removal costs would increase greatly if the sludge were applied in greater debths so that it would dry more slowly.

SOMERVILLE, NEW JERSEY

Lagoons

Superintendent: Jerry Caden

Ownership: Elizabethtown Water Co. Consol., serving 20-30 communities

Water Source: River

Flow: ave. (1967) 90.2 mgd
cap. 170 mgd

Influent Quality: (September 12, 1968 - 5 samples)

Turbidity	1-30	
Total hardness	76-130	mg/1 as $CaCO_3$
Alkalinity	58-77	mg/1 as $CaCO_3$
pH	6.7 - 8.3	
Total solids	125-240	mg/1

Method of Treatment: Flocculation, sedimentation, and rapid sand filtration; with chlorination.

Chemicals Added:

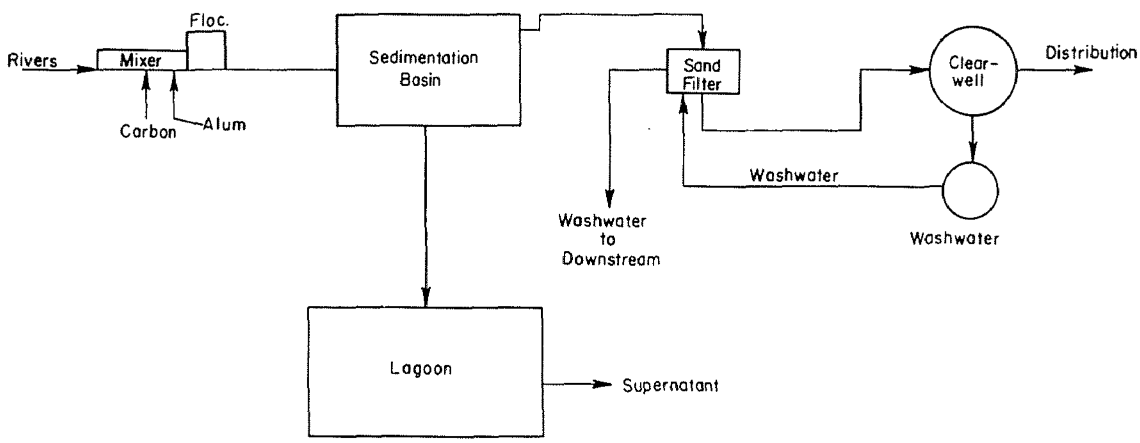
Alum	40	mg/1
Permanganate	0.85	mg/1
Chlorine	3.3	mg/1
Lime	0.89	mg/1
Ammonia	0.31	mg/1

Description of Sludge Disposal Process

The sedimentation basin is cleaned twice yearly, with the sludge pumped to a lagoon measuring 400 x 1,200 feet. The lagoon consists of previously existing roadways on three sides, with a dike as a fourth side, built about ten years ago by plant personnel. Decant

SOMMERVILLE, NEW JERSEY

Flow Diagram



SOMERVILLE, NEW JERSEY

is removed by overflow pipes. Present depth of sludge is 3½ ft. The lagoon has never been cleaned, and after the total depth of 6 feet is exhausted, cleaning or raising the dike will be necessary.

Backwash water passes directly to the river, as does the lagoon decant. As a result, the sludge has an opportunity to dry sufficiently to permit walking.

COST OF SLUDGE DISPOSAL

Construction

No cost records were kept, but it may be assumed that present cost for the construction would be on the order of $10,000.

Land

12 acres are used for the lagoon. This land is worth perhaps $10,000/acre today, or $120,000. Since estimates for cleaning of the lagoon are not available, the land is written off at 25% salvage.

Annual Costs

These are considered very small - perhaps $2,000. The life expectancy of the lagoon is greater than 20 years with slight changes to the dike.

Total Disposal Costs

(Based on 1968 throughout)

Capital recovery (6% for 25 years)	$ 700 ($7,800)*
Annual Costs	2,000
Interest on Land (6% of $30,000)	(1,800)
Taxes and Insurance (2% of $130,000)	(2,600)
Total	$2,700/year ($14,200)

Disposal Cost / Unit

Cost/mg of water treated:

$2,800/90.2·365 = $0.09/mg ($0.43)

* A municipal operation provided with free land must recover only the $10,000 investment. A private operation must, in addition, recover 75% of the cost of land.

Cost/ton of dry solids:

The basin (350' x 450' x 16') is about half filled when it is emptied. Assuming the sludge is at 1.5% solids content, the weight of dry solids produced per year is 1,180 tons. The lagoon sludge depth of 3.5 feet over 10 years at 30% solids yields 1,570 tons. An average is used.

$2,800/1,400 = $2.00/ton ($10.00)

Discussion of Cost

As expected, the major cost for private operation is the price of land. A municipal plant would have about an 80% lower disposal cost. Since this plant is privately owned, the costs in parentheses are the actual costs although one notes that 6% interest is too low a rate at the present time.

SOUTH ORANGE, NEW JERSEY

Brine Disposal to Sewer

Population: 17,000

Assistant Superintendent: Constantin Stavrou

Ownership: Municipal

Water Source: Wells

Flow: ave. (1967) 1.7 mgd

Influent Quality: Total hardness 210-220 mg/l as $CaCO_3$

Method of Treatment: Ion exchange with post-chlorination

Description of Brine Disposal Process:

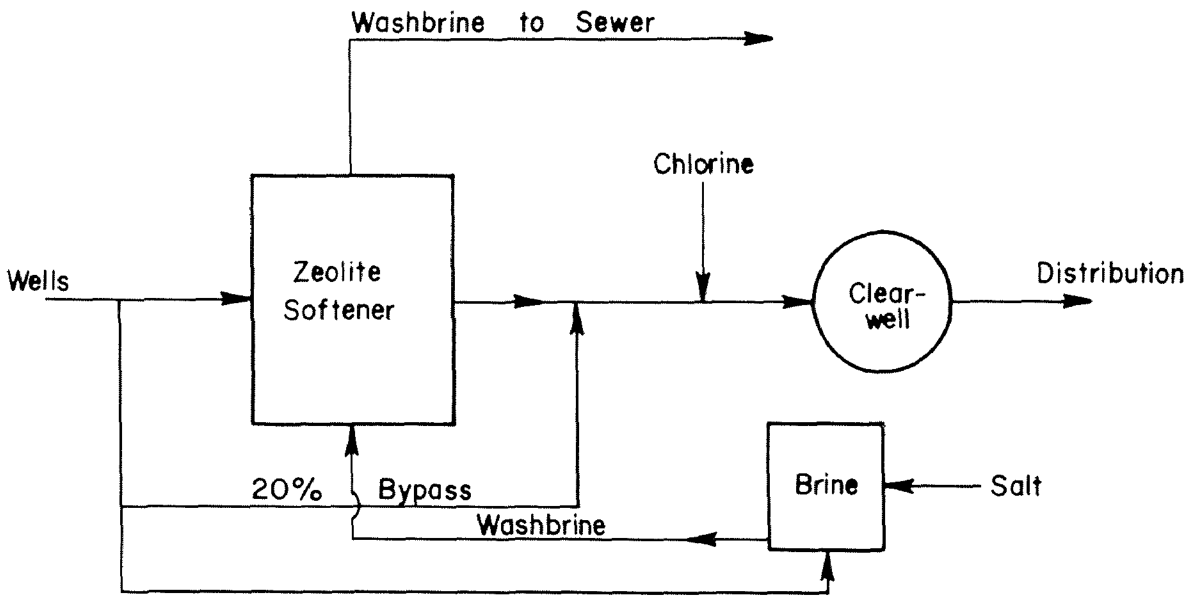
The six zeolite softeners are regenerated twice daily with a saturated salt solution. The waste brine is discharged to the sewer and thence to a large regional sewage treatment plant. Salt consumption in 1967 was 1211.5 tons.

Cost of Brine Disposal:

No charges are levied.

SOUTH ORANGE, NEW JERSEY

Flow Diagram



SOUTH ORANGE, NEW JERSEY

WILLINGBORO, NEW JERSEY

Serial Lagoons

Population: 38,000

Superintendent: Quenton M. Walton

Ownership: Municipal

Water Source: 5 wells, 3 of which require treatment

Flow: ave. consumption - 3.0 mgd (1967)
ave. treatment 2.1 mgd (1967)
Capacity of treatment - 10.0 mgd

Influent Quality: Component of concern is iron - up to 6.0 mg/l

Effluent Quality: Iron - 0.1 mg/l
pH - 7.8
Total hardness - 88 mg/l as $CaCO_3$

Method of Treatment: Coagulation, sedimentation, and rapid sand filtration; with pre- and post-chlorination and fluoridation.

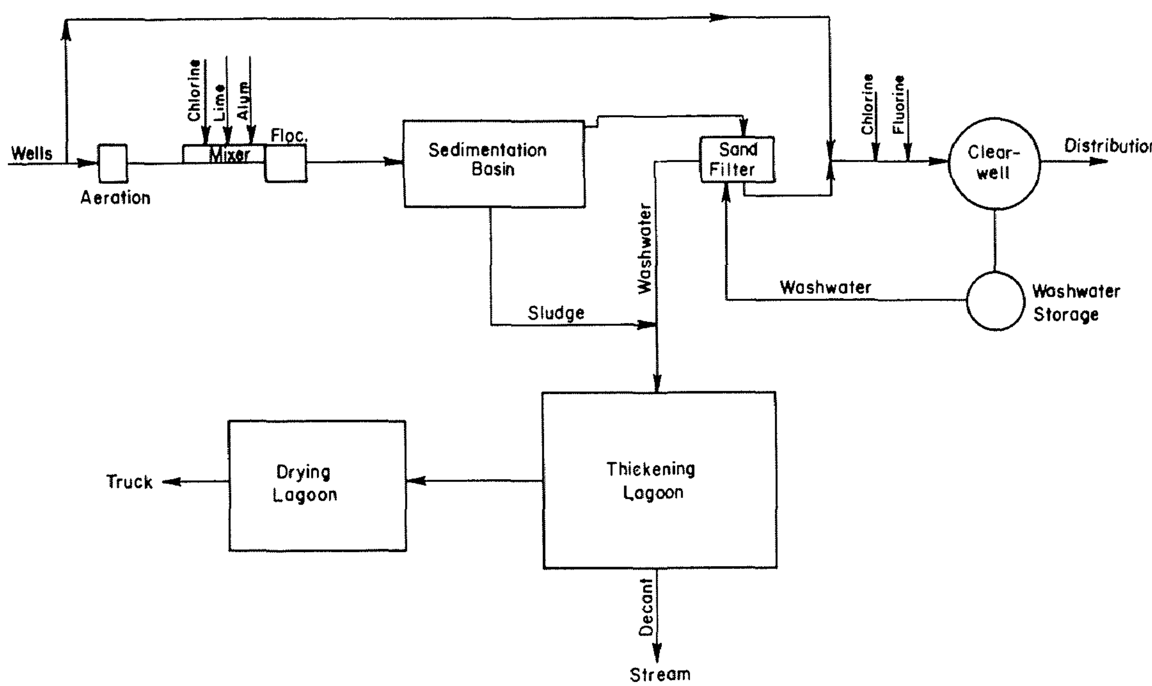
Chemicals Added:	Alum	5 mg/l
	Chlorine	7.6 mg/l
	Lime	31.7 mg/l

Method of Sludge Disposal

Sludge is removed mechanically from the settling basins and is drained into two thickening lagoons. Each lagoon is a neat exca-

WILLINGBORO, NEW JERSEY

Flow Diagram



WILLINGBORO, NEW JERSEY

vation measuring approximately 75' x 75' x 9' deep. They also receive the backwash water.

Once daily, usually at night, flashboards are removed, and supernatant decanted. The decant enters a drainage ditch leading to a small stream. About three times a year a trash pump is rented to pump the thickened sludge into a drying lagoon located 50 feet away.

This drying lagoon measures 75' x 100', and can contain a depth of 3 feet. It is built with a gravel base covered by sand. Each pumping covers a span of one week to allow for maximun drainage. Approximately every two years the sludge is removed by a front-end loader dumping into two dump trucks. The dried sludge crumbles readily and has been used for filling operations about the plant.

COST OF SLUDGE DISPOSAL

Construction

The lagoons were built in 1963 by the plant personnel. Direct costs, including materials and rental of equipment, totaled about $2,700. Assuming an indirect cost of 100% of the direct costs, the total construction cost estimates to be $5,400.

Land

The half-acre used is valued at $10,000.

Decanting

An allowance of 4 man hours/week may be made ($1,040/year). Supervision costs would raise this to perhaps $1,300/year.

Pumping

Each pumping requires about two man-weeks ($400) plus the rental

($120). Power costs are negligible. Three pumpings a year cost $1,560.

Disposal

Each cleaning and disposal is budgeted for $500 - 700. An annual cost of $500 may be assumed to allow for additional sand.

Total Disposal Costs

Capital recovery (assume 6% for 25 years)	$ 420
Annual costs	3,360
(Interest on land) (6% of $10,000)	(600)
(Taxes and insurance) (2% of $15,400)	(310)
Total	$ 3,780/year ($4,690)

Disposal Cost / Unit

Cost / mg of water treated:

$3,780/2.1·365 = $4.90/mg ($6.10)

Cost/ton of dry solids:

The amount of sludge produced is not known. An estimate may be made as follows:

Area of drying lagoon = 7,500 ft^2
x depth = 2 ft
x sludge density = 60 lbs/ft^3
x solids content = 50%

Weight of dry cake solids = 450,000 lbs = 225 tons
or 113 tons removed/year

$3,780/113 = $33.50/ton ($41.50)

Discussion of Cost

The total costs calculated are not very dependent on the construction costs which are of 1963 vintage; hence the totals of \$4.90/mg and \$4.15/ton are valid today. A private system is about 25% more expensive.

MODEL STUDIES

I. Dewatering of Alum Sludges by Vacuum Filtration

Model

Coagulation, sedimentation, and rapid sand filtration for turbidity removal using alum as a primary coagulant, and lime etc. as aids.

Flow: 10 mgd average
Labor: 10, plus 1 supervisor

Sludge is assumed to be removed continuously from either an upflow clarifier or horizontal flow sedimentation basin.

Quantity: 0.5% of influent = 50,000 gpd
Total solids: 1%

Flow Diagram

Sludge ⟶ Thickener ⟶ Vacuum filter ⟶ Land

Thickener

One thickener was chosen to provide daily batch operation, if desired. The unit chosen was a conventional circular type. Assuming 24 hrs. detention time, plus 50% excess capacity, the capacity should be 75,000 gallons. The depth was assumed to be 10 ft. The surface area is thus 1,000 ft^2, and the diameter 35 ft. This size unit, including pipes valves, fittings, and sludge pump, costs about \$29.50/ft^2, or \$29,500[1]. Operation and maintenance costs were set at \$5,200/yr.[2]

Vacuum Filter

The sludge is assumed to be at 2% solids, and thus 25,000 gpd.

This is to be dewatered in a 6-hour period. The loading rate was taken to be 0.4 lbs of dry solids/ft^2/hr,[3] using a pre-coat of diatomaceous earth.

$$\text{Area of Filter} = \frac{25{,}000 \cdot 0.02 \cdot 8.33}{6 \cdot 0.4} = 1{,}600 \text{ ft}^2$$

Cost of filter, building, and equipment[4] = \$276/ft^2, or \$458,000. Three filters would probably be used (14' x 18')

Maintenance was set at 5% of the capital cost:[3] .... \$22,900/yr.

Operation: 1½ men @ \$10,000/yr. .... \$15,000/yr.

Supervision: $\frac{1\frac{1}{2}}{10} \cdot \$15{,}000$ .... \$ 2,250/yr.

Power[5]: $\frac{6 \text{ hrs} \cdot 365}{1.34 \text{ HP/KW}}$ (1.4¢/KWH) (0.382 HP/S.F.)·1,660 ft^2 .. \$14,720/yr.

Precoat: From (3), proportioned to sludge flow .... \$17,710/yr.

Sub-Total \$72,580/yr.

Trucking

The sludge was taken to be at 25% solids. Weight of sludge: $\frac{0.01 \cdot 50{,}000 \cdot 8.33}{0.25 \cdot 2{,}000} = 8.33$ tons/day.

The annual cost for trucking and disposal could be (at \$5.00/ton): \$15,200/yr.

Land

An emergency storage lagoon of 1 acre area, plus 3 acres for the thickener, vacuum filter building, any necessary roads, etc. is assumed.

At \$5,000/acre, land cost = \$20,000.

Total of Capital Costs

Construction:	\$487,500
plus 25%	121,900
	\$609,400

Salvage value is assumed negligible.

Annual Costs

Capital recovery (6% for 25 years)	\$ 47,600
Maintenance, operating costs etc.	93,000
Taxes and insurance (2% of capital cost)	9,800
Interest on land (6% of \$20,000)	1,200
	\$150,600

Cost/ton of dry solids:

$$\frac{\$150,600}{760} = \$198.00/\text{ton}$$

Cost/mg water:

\$41.30/mg (Includes \$20/ton T.S. disposal and trucking charge)

Addendum

Assume continuous operation:

Area of filter (20 hours) = 500 ft^2

Cost of filter etc.[4] $290 \cdot \frac{1,200}{1,000} = \$348/ft^2$ or \$174,000

Note: Using (1), \$295,000 is calculated.

Maintenance [3]: \$8,700
Operation: 4½ men @ \$10,000/yr. = \$45,000
Supervision: $\frac{4\frac{1}{2}}{13}$. \$15,000 = \$ 5,200
Power and precoat, trucking: As for 1 shift operation.

The thickener need not have 50% excess capacity. Costs are reduced to \$20,200 (capital) and \$4,000 (operation and maintenance).

Annual costs

Capital recovery	\$ 19,000
Maintenance, operation etc.	110,500
Taxes and insurance	3,900
Interest on land	1,200
	\$134,600

Cost/ton of dry solids:

$\frac{\$134,600}{760}$ = \$177.00/ton T.S.

Cost/mg water: \$36.90/mg

(Includes \$20/ton T.S. disposal and trucking charge)

MODEL STUDIES

II. Dewatering of Softening Sludge by Vacuum Filtration

Model

Coagulation, clarification, and rapid sand filtration for hardness removal using lime as a primary coagulant, and sodium silicate, soda ash, etc. as aids.

Flow: 10 mgd average
Labor: 10, plus 1 supervisor

Sludge is assumed to be removed continuously from upflow clarifiers. The sludge solids produced is assumed to be 2,000 lbs/mg. at a solids content of 1%. This represents a flow of 240,000 gals/day.

Flow Diagram

Sludge ⟶ Thickener ⟶ Vacuum filter ⟶ Land

Thickener

The size of thickener necessary should provide 8 hours detention plus 50% excess capacity. An average depth of 10 feet is assumed. The dimensions would then be as follows:

Volume:	120,000 gals
Diameter:	45 feet
Area:	1,600 ft^2

From (1), this unit, including accessories (piping etc.), should cost $38,000. Operation and maintenance costs would be $6,140/yr.[2)]

Vacuum Filter

Thickened sludge (30% solids) would be dewatered during an 8-hour day, 7 days/week. The loading rate is assumed to be 40 lbs of dry solids/ft^2/hr; with an operating time of 6 hrs, the single vacuum filter should be 6 ft. in diameter and 5 ft. wide. The area is 94 ft^2.

Cost of filter, building, and equipment[6)]	$67,000
-------------	----------
Maintenance @ 5% of capital cost	$ 3,350/yr.
Labor: 1½ men @ $10,000/yr.	$15,000/yr.
Supervision: $\frac{1\frac{1}{2}}{10}$. $15,000	$ 2,250/yr.
Power[7)]: 20 HP @ 1.4¢/KWH for 6 hrs/day	$ 450/yr.
Sub-Total	$21,050/yr.

Trucking

Assume the sludge cake to be 65% solids, with a specific weight of 90 lbs/ft^3. Sludge production would be 15.4 tons of wet cake per day, assuming zero solids loss in thickening and filtration, which is reasonable if the overflow and filtrate are recycled to the head of the plant. Due to the higher density, trucking and disposal charges should be on the order of $4.00/ton, or $4,200/yr.

Land

An emergency storage lagoon of 1 acre, plus 1 acre for the building and thickener, etc. could cost $10,000.

Salvage and Contingencies

Contingencies, fees, etc. add 25% to the construction costs of $38,000 + $67,000, for a total capital cost of $131,000. Salvage is assumed at zero value in 25 years.

Annual Costs

Capital recovery ($131,000 @ 6% for 25 years) ..	$ 10,200
Operation, trucking	31,400
Taxes and Insurance (2% of $141,000)	2,800
Interest on land (6% of $10,000)	600
Total	$ 45,000

Cost/ton of dry solids:

$45,000/10·365 = $12.35/ton

Cost/mg water:

$12.35/mg (Includes $6.15/ton T.S. trucking and disposal charges)

MODEL STUDIES

III. Dewatering of Softening Sludge by Centrifugation

Model

This is identical to "II - Dewatering of Softening Sludge by Vacuum Filtration" except for the substitution of a centrifuge for the vacuum filter.

Centrifuge

Thickened sludge would be centrifuged from 30% solids to 65%, 6 hours a day, 7 days a week. The flow would be

$$\frac{240,000 \cdot 1}{30} = 8,000 \text{ gals/day},$$

or during the 6 hours, 22.2 gpm. An 18" diameter centrifuge should suffice [8)], and cost $15,000 at an ENR-Index of 800. Total cost, including installation and an ENR-Index of 1,200 would be about $60,000. The horsepower of the drive is 15.

Operating costs would be:

Maintenance	$ 3,000/yr.
Labor	15,000/yr.
Supervision	2,250/yr.
Power	340/yr.
Total	$20,590/yr.

Annual Costs

Capital recovery ($98,000 @ 6% for 25 years)	$ 7,660
Operation, trucking	30,930
Taxes and Insurance (2% of $108,000)	2,160
Interest on Land (6% of $10,000)	600
Total	$41,350

Cost/ton of dry solids:

$41,350/10·365 = $11.40/ton

Cost/mg water:

$11.40/mg. (Includes $6.15/ton T.S. trucking and disposal charges)

1) Smith, R., FWPCA Pub. WP-20-9, Preliminary Design and Simulation of Conventional Wastewater Renovation Systems Using the Digital Computer, March 1968, Fig. 9. See also Perry's Chemical Engineers Handbook, 4th Ed., p. 19-49.

2) Ibid. p. 44.

3) Long, B.W., Report No. E412-8077, Johns - Manville Research and Engineering Center, November 15, 1968.

4) Quirk, T.P., "Application of Computerized Analysis to Comparative Costs of Sludge Dewatering by Vacuum Filter and Centri fuge", Fig. 9. Note: The straight line cost function was replaced by a curvilinear relationship. A comparable value from (1) p. 41 had a considerably higher value than Quirk

$$380 \cdot \frac{1200}{812} = \$561/\text{S.F. vs. } 170 \cdot \frac{1200}{1000} = \$204/\text{S.F.}$$

5) Filter required of 0.382 HP/S.F. from (3).

6) As (4). Quirk's paper calculates a cost of $62,000; Smith, $71,000.

7) 20 HP for the unit is assumed.

8) Perry, Chem. Engrs. Handbook, 4th Ed., p. 19-92.

REPORT ON CURRENT TECHNOLOGY AND COSTS

Discussion of Report

MR. NEBIKER: To open the discussion of this report, I shall explain some of the methodology used in our investigation. We determined the location of plants employing different sludge treatment and disposal methods, and contacted officials to arrange for inspection visits.

We concentrated on establishing realistic cost data, this required a great deal of estimation, because operating records were not complete in most instances. We also attempted to determine solids balances for those plants which used mechanical processes. While we have used a fairly high percent interest rate of 6 per cent, this rate may be unrealistic today.

The cost of land and taxes has been included, we recognize many water utilities are privately operated and must consider these items. The cost figures include numbers in parentheses: the parentheses figures refer to costs of private operation.

We have reported cost figures in dollars per million gallons. This is a general way of expressing a price of water, but the price divergencies are so great that is is very difficult to generalize. We also reported costs in dollars per ton of dry solids, which is comparable to what is done in sewage treatment practice. In those instances where recalcination was practiced, we emphasized the profit or loss in dollars per ton of lime produced.

Comments on specific operating details of plants visited will be useful.

Two of the treatment plants used lagoons. We found that there is good reason for operating two lagoons in series. Note in the Willingboro, New Jersey, flow diagram that the filter washwater and the alum sludge from the sedimentation tank are discharged to a thickening lagoon, which is decanted daily. When the sludge has accumulated to a certain depth in the thickening lagoon, it is pumped by an air lift pump to a drying lagoon. There it is allowed to dry to a very high solids content, 30 per cent and above, which will hold the weight of a man.

Note in the New Britain, Conn., flow diagram, serial lagoons which also utilize thickening. Backwash water enters along with the alum sludge. The first lagoon has a canal at the bottom which, by manipulation of gates, enables gravity flow movement of the sludge from the thickening lagoon to the storage lagoon without pumping.

Several of the installations for lime sludges dewatering (at Austin, Dayton, Lansing, and Miami) use Bird centrifuges. These seem to provide a very satisfactory method of concentrating lime sludge. The rotary kiln used for recalcination of lime sludge in Miami is a very superior setup, operating fairly close to capacity. As you will note in our report, we have come to the conclusion that there is definitely a profit made by the recalcination of sludge from water softening in Miami. The installation at Dayton also uses a rotary kiln, and shows a profit in recalcination of lime sludge.

Note in the Dayton, Ohio, flow diagram the aspects concerned with heating of the sludge. The rotary kiln includes an expansion chamber and stack for the gases. The expansion chamber is used to cool and clean the gases by bringing in the thickened sludge on an impingement device. The temperature of the sludge is increased and, as a result, the settleability of the particles in the sludge during centrifugation is increased. These effects illustrate the value of a well conceived engineering design.

The Dayton plant thickens a non-heated sludge, and the Lansing plant thickens a heated sludge. Note in the Lansing, Michigan, flow diagram that a Fluo-Solids reactor is used for recalcination. Heating of the sludge is previous to thickening, so thickening performance is improved. A three-tray thickener is used in order to conserve the heat during thickening.

The building for the Lansing recalcination operation is very neat and compact. The illustration shows that all equipment is enclosed in the building except the thickener, which is on the far left background.

Note Boca Raton flow diagram. This is a very modern lime softening plant. A thickener and a vacuum filter are used. The vacuum filter dewaters lime sludge very well indeed. The thickener is loaded continuously. Sludge is removed only intermittently; that is, during the period at which the vacuum filter operates, which is some six hours a day.

During the night the lime sludge builds up to a depth of several feet, and compression makes the sludge extremely dense. In order that the scraper blades do not break, the driving mechanism has a torque control which will immediately shut off the unit if resistance from the sludge is too great. The blades can be raised and lowered to remove the top sludge layers first.

The filter cake discharged from the vacuum filter is about one-half inch thick, about 65 percent solids. The sludge is hauled out to the highway department, which utilizes it as binder for the soil on its highways.

MR. ADRIAN: I shall comment on additional plants visited. The San Francisco Water Department operates, a filter washwater recovery plant at its Sunol, Calif., treatment plant. The settled sludge from this tank is discharged by gravity to the sludge drying beds which are located at a level some two hundred feet below the plant.

The sludge drying beds have a "diving board" decant system at one end which permits the clear supernatent to be decanted continuously while the sludge is being added to the basin at the opposite end. The decant arrangement involves a vertical half culvert and a group of baffles which can be selectively lifted to decant at the correct elevation. The decant is discharged to a nearby creek. The vertical lift to the plant influent of some two hundred feet probably influenced the decision not to reclaim the decant.

Sludge from drying beds at the Sunol plant are hauled to a disposal site. Between three to six hundred cubic yards per year of solids are cleaned off the beds. Those responsible for cleaning the beds prefer the solids to be not too dry because of the dust problem. With a little moisture remaining, the volume to be hauled may be doubled, but the operators much prefer this form to a dusty cake. There is some discussion in our report concerning the optimal depth of sludge application. About two feet has been found to be a maximum value for good dewatering and drying.

Minot, North Dakota, has had several years of experience with vacuum filtration of lime sludge, using two vacuum filters. The source of water is from wells and the Mouse River. Turbidity is low much of the time. At this plant, ten feet or so of sludge cake has been dumped in the disposal site. There appears to be no difficulty in compacting the solids in the disposal site so that gravel can be spread over the top, forming a base for a truck roadway used for future hauling.

At the Rinconada, Calif. water treatment plant dewatering and drying beds were designed similar to those which are used in conventional sewage treatment operation. The illustration shows a view of a washwater recovery basin and the several dewatering and drying beds in the background. The drying beds are built so that a truck can be driven between the beds for ease in cleaning. Another illustration show that an interesting structure is formed as the sludge dries, with the cracks creating greater exposure to the air and increasing the rate of drying.

In sludge drying operations at the Sunol plant, it has been observed that if the sludge is put into the drying bed to a depth of three feet or more a great length of time is required for drying. If the sludge is applied in a lesser depth, the cracks which form penetrate to the bottom, enabling the drying to take place in about three months.

The Lompoc, Calif., employs diatomaceous earth filtration of well water and disposes of lime softened sludge to drying beds. This plant has realized quite an economy by reclaiming the decant, which is cycled back to the plant inlet. It is estimated that a savings of about $5000 a year are realized by this procedure, estimated on the basis of the cost to pump an equivalent volume of water from the well.

MR. AULTMAN: I would like to add certain comments about the Sunol plant at San Francisco. The first basin there is specifically a washwater recovery basin, which receives no settled sludge solids. After settling, the supernatent washwater is pumped back to the influent of the plant.

Solids are discharged from the sludge settling basins by gravity. The reason that the decant is not pumped back is partially because of the elevation but, also, because the water discharged to the creek is spread a short distance downstream. This decant water is recovered by existing pumping facilities. The water returns to the plant in that way. This situation was one of the reasons our engineers and the City's staff decided on that method of handling.

MR. TCHOBANOGLOUS: After reviewing the cost data in the report, I wonder if it would be possible to develop costs on some sort of continuous parametric basis rather than an point estimates?

MR. ADRIAN: We have explored this idea. We would like to be able to make estimates which would show the scale economies. Some treatment plants reported had small, and some had large flows. There are very definite scale effects evident in going over such a wide range. We would like to use something similar to that done in the Smith report - this is a report put out by Robert Smith of the Federal Water Pollution Control Administration - on a digital computor simulation of conventional waste water treatment.

MR. NEBIKER: As you may notice, our report includes three model studies. We came to no definite conclusion because the costs for lime sludge dewatering by centrifuge or vacuum filter were close. When more treatment plants are in operation it will be possible to generate simulation models. The parameter of specific resistance could apply to the vacuum filter, to the pressure filter, and to the dewatering lagoon. Another parameter would be settleability, applying to thickening and lagooning.

MR. TCHOBANOGLOUS: My thought was that, if cost estimates could be developed for 5 to 10 alternative types, the information could be broadly disseminated. Then I think the different processes would receive more attention and more action would be taken.

MR. ADRIAN: Initially, we and members of the Advisory Committee, were hard pressed to identify one operating plant example of each type of treatment process. Even today we learned that the microstrainer process is more widely used than had been thought. The operation of more plants will give more data, which will result in better cost information.

MR. DOE: We must compare like with like. The data you report for the Sunol, California, plant for dried sludge from a lagoon - if my mathematics is correct - is a sludge of 53 percent solids. Now, I think that nowhere else in the world could one get the sludge from a lagoon at 53 percent solids. I think most operators would be happy to get sludge at 20 percent solids in a lagoon. There would then be a considerable difference in the figures showing a unit cost of $56.60 per ton of dry solids for the cost; the unit cost could be perhaps $120 per ton. Parameters are an excellant idea, but may result in new problems.

MR. JOHNSON: What can you estimate as the approximate concentration of sludge solids from thickeners?

MR. NEBIKER: The only thickeners that we studied were at water softening plants: Lansing, Miami, Dayton, Boca Raton, Minot, and Austin. The thickened sludge was about 30 percent solids. One of the great variables is the solids content of sludge discharged from clarifiers. At the Miami plant the sludge is about 15 percent solids; at other locations the solids are about five percent.

MR. TCHOBANOGLOUS: Can you report the relation of the solids content to sludge thickening? For example, is it easier to thicken a five percent sludge to some given value, or is a ten percent sludge easier thicken?

MR. NEBIKER: What we saw in plant visits are not the classical types of sewage sludge thickeners with steady underflow rates. In sewage treatment, the thicker the influent sludge, the smaller the size of thickener needed.

In operating centrifuges, the thinner the sludge is, the better the solids capture. Generally, however, operators try to feed 20 percent solids into the centrifuge because they thereby reduce the number of centrifuges in operation. It might be noted that the centrifuge is ideal in removing magnesium by discharging it out in the centrate.

The vacuum filter will not throw out the magnesium. Also I should say that if a lime sludge contains a large porportion of magnesium, say 10 percent or so, its filterability is very adversely affected, and it is illogical to utilize a vacuum filter in such a case. If we consider a ground water is softened by the lime soda process and it has a low magnesium content, then recalcination is technically possible. That type of sludge is also suitable for dewatering on a vacuum filter. On the other hand, if magnesium is present in large amounts, vacuum filtration or recalcination is excluded, although centrifugation would be possible.

MR. DEAN: Getting back to the other point brought up earlier, the variation in solids content. I would refer to the study by Louis Koenig of treatment costs in small and medium sized water treatment plants, Jour. AWWA, 59:290 (Mar. 1967). He attributes a large part of costs to poor engineering. His whole range of costs was covered, I believe, by a factor of 10 when he tried to reduce it to parameters. Plant operation was important - the number of operators, the unneeded capacity available, and other factors. To establish parametric costs, we should look at the best. Most plants could do a lot better than they are now doing.

MR. NEBIKER: We have attempted to account for unused capacity, etc., in our cost calculations.

MR. ADRIAN: Additional comment may be desirable concerning the use of vacuum filters for dewatering a softening sludge. It has been reported that a few installations did not operate successfully. One may wonder why vacuum filters work well in certain installations but not in others. One explanation may be in whether or not the filter was a coil filter. The installations which did not work well apparently used a coil filter. In those installations, there was the problem of deposits forming on the coils; the deposits build up and gradually force the coils farther apart.

At the Minot, North Dakota, installation, a polypropylene belt has been used on an Eimco filter. It seems that the incrustation problem is more severe with intermittent operation. The belt replacement might be on the order of a couple hundred dollars every few years, not an excessive cost.

MR. DICK: We have studied vacuum filtration of sludge from a surface water treatment plant, which also softens. The plant has coil filters which have been sitting idle for years because their operation has been totally unsatisfactory. We have found through laboratory leaf tests of fabrics that filtration works very well with the different media. The source of the difficulty seems to be in the media selected for the initial installation, although we haven't yet evaluated possible blinding problems with the fabrics. We don't find that clogging or incrustation of the coils is the problem at this plant. The sludge just goes right through the coils, with filtrate solids as high as seven percent.

MR. KRASAUSKAS: Did you find problems of odor with the drying lagoons?

MR. ADRIAN: We noticed no odor problem. At the Sunol plant, odors were not commented upon as a problem.

MR. TCHOBANOGLOUS: To the best of my knowledge, the Rinconada plant has had no odor difficulties. The operating personnel at the Rinconada plant have found that the most successful way to operate the sludge beds is to place a thin layer of sludge on each of the beds, and progressively move down the line. This has optimized the drying time and minimized the odor problem. The lack of an odor problem is also related to the characteristics of the raw water, which contains few if any organics.

MR. AULTMAN: The water treated in each of these plants contains practically no organic matter, and there is no indication of an odor problem. No odor problems were experienced when we were discharging softening sludge from the plant of the Metropolitan Water District at La Verne. The sludge content will determine the problem

MR. WEBBER: At Toledo, Ohio, we have two 15 acre lagoons in about a half mile radius, both 20 feet deep. We have no odor problem, even though the raw water contains a considerable amount of organic matter. But we do have a dust problem. The sludge dries so thoroughly on top that we have to keep it covered with a layer of water.

MR. ADRIAN: We have brought into the laboratory a number of samples from the Bellerica, Massachussetts, plant which treats one of the worst raw waters in the United States. There have not been odors noted from sludge lagoons at this plant.

We recently brought back several barrels of sludge from Albany, New York. There was a little odor when we vigorously mixed this sludge.

MR. JOHNSON: I'd like to direct a question to Mr. Webber. How deep is the sludge in your lagoons now?

MR. WEBBER: One lagoon is about 20 feet, but during the last three years has settled back to a depth of about 17 feet. The other lagoon is kept full right up to the 20 foot mark in order to reduce wave action on the dikes.

MR. BLACK: You spoke of the need to keep the top covered with water because of dust problems. Can you tell me the percent of sludge solids in the bottom of that lagoon?

MR. WEBBER: Yes, a recent analysis at a depth of 12 feet shows about 47 percent dry solids; and four or five feet below the surface the solids are about 35 percent. At the surface, solids are 100 percent.

MR. HARTUNG: This question of sludge odor has come up several times. I can report one other experience. Sludge odor after dewatering is not a problem at the St. Louis County plant where we are treating surface water from the Meramec River. Sludge from the settling basins is discharged to a lagoon, eight feet deep. We are in the process of emptying the lagoon with crane and drag line, and hauling the sludge to a dump about one mile away. There is no odor problem. This sludge is from a clarification and lime softening plant, treating a surface water which contains considerable turbidity.

* * *

Section 3

REPORT ON WHAT IS NEEDED

CONFERENCE REPORT ON RESEARCH NEEDS

Because of the ease with which water treatment plant wastes could be discharged to streams in the past, the disposal of these wastes has not commonly been considered a problem warranting research. There is now an urgent need for dealing with wastes from water treatment plants in a way which does not deteriorate the quality of the environment.

In order to meet this need, water treatment plants must develop alternative waste treatment techniques without a background of previous experience in solving the problem. As a result, a great deal of research is needed to develop efficient and economical techniques for handling waste from water treatment plants.

Considerable expenditures of time, manpower, and money are needed for research to learn more about the nature of wastes produced by water treatment plants, to investigate means of treating these wastes, to study the alternatives for ultimate disposal of the residues, and to evaluate future water treatment and waste management technology as it relates to this problem of waste disposal.

Specific problems in these categories of research needs are listed below:

A. Nature of Wastes

In order to improve knowledge of the quality and quantity of wastes produced by water treatment processes, it is recommended that research be conducted to:

1. Identify the quantities of wastes produced by various water treatment methods

2. Characterize the physical, biological, and chemical properties of water treatment plant wastes, particularly those produced by chemical coagulation

3. Determine the manner in which the properties of raw water influence the quantity and quality of resulting wastes

4. Develop meaningful parameters to describe the properties of wastes and to permit comparisons of wastes from various plants, particularly in areas of sludge thickening, dewatering, and handling

B. Treatment of Water Plant Wastes

To improve techniques for altering properties of sludges prior to ultimate disposal, research is need to:

1. Improve techniques for gravity thickening of sludges, particularly sludges from chemical coagulation processes

2. Develop means for relating laboratory batch sedimentation results to full scale continuous thickening

3. Evaluate the applicability of flotation processes to the concentration of water treatment plant sludges

4. Develop diagnostic tests to evaluate the efficacy of various conditioning agents, particularly in selection of polymers for sludge conditioning

5. Develop polymers which are specific to conditioning needs for water treatment sludges

6. Improve understanding of the alteration of physical properties of sludges by freezing techniques

7. Improve equipment for freezing of sludges, and evaluate techniques for using natural freezing for sludge conditioning

8. Evaluate the role of heat treatment as a means for conditioning of sludges

9. Develop improved methods for dewatering sludge by centrifuges through improvement in the design and operation of centrifugation equipment

10. Develop means for obtaining centrifuge design information from laboratory study of sludge properties

11. Evaluate suitable media and precoat for vacuum filters, particularly those applicable to alum sludges

12. Obtain operational and economic data to assess the applicability of pressure filters to dewatering of water treatment plant sludges

13. Develop models for operation of lagoons to improve their dewatering ability

14. Improve techniques for solids handling, particularly in the area of emptying lagoons

15. Evaluate the basic properties of sludges which influence their behavior on sand drying beds, especially factors influencing cracking, draining, drying, and the influence of chemical conditioning agents

16. Develop models for operations of drying beds to optimize their drying behavior

C. Ultimate Disposal of Wastes

Needed research relating to the return of water treatment plant residues to the environment includes:

1. Study of the load-bearing characteristics of sludges in landfills

2. Study of means for improving load-bearing characteristics of dewatered sludges, possibly by mixing with other waste materials

3. Study the environmental effects of applying waste sludges to land, including effects on plants, soil, and ground and surface waters

4. Evaluate the influence of water treatment plants wastes on sewerage systems and on waste treatment plants.

5. Study the factors influencing the transportation of sludges by various means

6. Evaluate the ecological effect of ocean disposal of water treatment plant wastes

7. Study the reclamation and reuse of products from water treatment plant wastes, particularly clarification and softening sludges, including the reclamation of lime, alum, magnesium, and other possible usable products

D. Future Water Treatment and Waste Management Technology

The need for control of water treatment plant wastes requires reassessment of established water treatment practices, and suggests the need for research to:

1. Develop comprehensive models of water treatment with a view to evaluating the effect of process and operational changes on waste disposal problems

2. Develop new techniques for dewatering and drying water treatment plant sludges to a handleable state

3. Develop new products from sludges and new uses for sludge

4. Study the joint handling, treatment, and disposal of water treatment plant wastes together with wastewater and solid wastes

5. Consider optimization of waste managment on a regional basis through operations research studies

Committee Report by:

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CONFERENCE REPORT ON ENGINEERING NEEDS

Engineering needs related to disposal of wastes from water treatment plant currently revolve primarily around additional research on waste characteristics, existing and new methods of disposal, operating data, and costs. In particular, emphasis must be given to the need to review total management methods constantly and to develop the concept of sludge and wastewater disposal as an integral part of the treatment process. Accordingly, investigation in the following field is recommended:

A. Basic Engineering Research on Waste Characteristics

1. Concentrations and total quantities of dry solids produced

2. Biological, chemical and physical characteristics of floc, washwater, and sludge

3. Settlement characteristics

    (a) Reaction of coagulants as related to sludge production

        (1) Kinetics of reaction

        (2) Mixing intensity

        (3) Time

    (b) Sludge thickening

        (1) Mechanical means, e.g. stirring, centrifugation, filtration, pressing, etc.

        (2) Chemical conditioning, e.g. polyelectrolytes

        (3) Hindered settlement

4. Hydraulic characteristics

    (a) Torque - establishment of hydraulic equations with respect to pumping, mixing, collecting, etc.

    (b) Flow - establishment of equations with respect to hydraulics of conveyance

B. Applied Engineering Research

1. Measurement methods to determine waste flow rates
2. Solids balance
    - (a) Sludge concentrations
    - (b) Methods of measurement and sampling
        - (1) Rapid methods to determine percent solids by weight
        - (2) Relationship of turbidities and solids concentration
3. Hydraulics of sludges
    - (a) Equipment requirements
    - (b) Behavior in pipelines at varying velocities and concentrations
4. Pre-treatment (conditioning)
5. Dewatering methods, both existing and new
6. Ultimate disposal after dewatering
7. Effects of wastes on sewage treatment processes
8. Reclamation
9. Specific utilization of sludge, e.g., as soil conditioner, rubber filler, etc.
10. Wastewater reuse techniques
    - (a) Impact on treatment processes with and without treatment of wastewaters
    - (b) Treatment processes oriented for wastewater reuse

C. Assembly of Plant Operating Experience

1. Operating costs for waste disposal processes

   (a) Construction costs of sludge handling and treatment facilities

   (b) Labor, equipment and maintenance costs

2. Service charges for disposal to sewage treatment plants

3. Data gathering relating to sludge

   (a) Quantities

   (b) Concentrations

   (c) Characteristics

4. Water treatment methods used

5. Records of Performance

   (a) Variations of sludge flows and characteristics

   (b) Effect of variations in raw water influent quality.

D. Development of Design Parameters and Costs

1. Effects of variation in sludge characteristics

2. Demonstration of feasible processes

3. Development of unit costs

Finally, it is recommended that members of the Conference be invited to submit details to the AWWA Research Foundation of any specific project with which they are familiar or actually engaged upon which could yield data of the type referred to above. This exchange of information could provide the means of speedy implementation of the stated objectives during the period when demonstration projects are being set up.

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CONFERENCE REPORT ON PLANT OPERATION NEEDS

The group of Conferees directly involved in water treatment plant operation began with the premise that water treatment plant wastes can no longer be disposed of by returning them to their original source - the raw water supply. Our conclusion is that a serious problem exists in the disposal of these wastes. Accordingly, research is needed to determine improved methods for treatment sludge, and in characterization and classification of sludges for the following purposes.

First, in reclamation - for reuse by the water utility in its own water treatment plant, or for the sale of reclaimed chemicals to other wastewater treatment plants, or industrial plants. The market and potential demands for the waste sludge should be studied, as should the sludge characteristics, which make the waste products salable for water treatment purposes and for other uses, such as in manufacture of paint, building materials, and paper.

Second, for disposal to ground - as in construction of highway bases, levees, embankments or fill on sub-marginal land, in such a manner and in such condition that the value of the land is not destroyed but is enhanced if possible.

Third, for disposal to sanitary sewers, so that the sewage treatment processes are benefited, or at least not adversely affected, and a combined end product is produced which can be disposed of in one of the above methods.

Fourth, for disposal to the sea - in such form that the waste will not adversely affect biological life or recreational use.

Consider New or Modified Treatment Processes

To accomplish these purposes, water treatment processes should be reexamined and modified, if necessary, or new processes should be developed. For example, it may be necessary to separate coagulant (alum, iron, etc.) sludge from softening (lime, magnesium) sludge. The calcium carbonate may require separation from magnesium hydroxide. Conditioners may be added in the process solely to alter the character of the sludge. The use of alum (or iron salts) for coagulation may be abandoned entirely in favor of polyelectrolytes which will markedly reduce the bulk of sludge produced.

Improvement in the types of membranes now used for reverse osmosis may permit complete removal of suspended matter from water and a modest reduction in mineral content, thereby eliminating the need for coagulation and softening. Softening might be eliminated and reliance placed fully on detergents for washing purposes, and addition of additives to prevent sealing, and other adverse industrial reactions.

Precipitation processes should be modified to promote floc growth, strength, and density for more effective removal.

Methods for handling or moving sludge should be controlled so that its physical properties are not adversely affected in transportation to the place of its reuse.

Evaluate Uses and Disposal of Wastes

Much more must be learned about the properties of water treatment plant wastes to determine their suitablity for disposal or for reuse. This means that test methods for physical and chemical properties must be defined, and these properties related to methods of disposal or use of the waste.

For example, it should be determined what chemical constituents contribute to soil plasticity - or to its mechanical strength. Which physical and chemical characteristics will promote use of the waste product for agricultural purposes? What properties will determine its suitability for use in embankments of landfill? What properties enhance its flow characteristics?

What laboratory tests will permit evaluation of the suitability of wastes for the above and other uses? Standard methods should be developed to accomplish this. Possibly a system of classifications such as the construction engineers use would be adaptable. The properties measured and used in classification of soils are: maximum dry weight, cohesion, specific gravity, plasticity, liquid and plastic limits, permeability, resistivity, particle size, organic characteristics, etc.

Modification or conditioning of wastes to make them suitable for disposal or reuse may include freezing, heating, filtration (mixed media, rapid sand, vacuum, pressure, etc.) centrifuging, admixing.

Addition of silicates or other chemicals to enhance mechanical strength and suitability for use as fill or structural material.

Determine Economics of Improved Operations

The committee recognizes that the cost of water treatment plant waste disposal must be borne by the ultimate consumer of the water. Therefore, waste disposal and conditioning methods must be economically feasible and justifiable. It would be fruitless to develop processes which would be rejected because of costs substantially in excess of the benefits obtained.

It must be recognized, however, that the level of cost justifying sludge disposal methods are not the same for all waste sludge generating agencies. And what at first inspection might seem unfeasible, might be found feasible after more or less research has been done.

In summation, the principal needs are to find effective and economical means, through research, to dispose of water treatment plant wastes by direct treatment of sludge, or by eliminating undesirable chemicals, such as alum, through changes in water treatment methods. This need applies both to clarification and softening of surface and well waters.

An important instrument of research should be a central service operating to gather, document, and disseminate data on plant operations that are pertinent to the subject.

Committee Report by:

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CONFERENCE REPORT ON REGULATORY NEEDS

General Statement

It is general knowledge in today's society that needs are increasing in all quarters for protection and enhancement of the quality of our water resources. To this end, all waste water discharges must be carefully controlled to insure attainment of that goal.

The water works industry has a most critical stake in the quality of our water resources and clearly should adopt a role of leadership in their protection for all beneficial uses. Accordingly, the conception, design, construction, maintenance, and operation of any water supply facility must be considered as inadequate if it does not incorporate the important principles of water quality management, including acceptable disposal of waste.

The Committee feels that the water works industry, individually and collectively, has an obligation to conform with all requirements for water quality control which are applicable to industrial and municipal wastes. Furthermore, the Committee feels that attainment of that goal would be greatly facilitated by regulatory action establishing clear policies for treatment and disposal of wastes from water supply facilities.

Sources of Wastes

Wastes from water treatment plants can no longer be discharged without satisfactory control, including the following:

1. Waste filter washwater, including diatomaceous earth
2. Sludge from settling units, including softening sludges
3. "Red" or "black" wastewater from iron or manganese removal plants
4. Waste brine from ion exchange plants
5. Sanitary wastes
6. Other wastes, including silt during construction
7. Operating practices which may be detrimental to the water resources

The water works industry should assist regulatory agencies and cooperate in providing information relative to water pollution control. Specific needs are:

For existing water treatment plants

1. Evaluate practices and potential water pollution problems. As pollution from municipal and obvious industrial sources is abated, the tendency will be for official and public attention to turn to other discharges - including those from water treatment plants.

2. Consider opportunities and factors affecting inclusion of sedimentation sludges with municipal or other industrial wastes.

3. Consider other methods and factors affecting reclamation of coagulants, water softening chemicals and other chemicals or substances useful in water treatment processes.

4. Consider opportunities for using softening sludges or other waste discharges for alleviating natural or man-made water pollution problems.

5. Consider opportunities for using wastes in land reclamation, highway construction, and other beneficial uses.

6. Consider factors affecting ultimate disposal of sludges or other waste residual on soil, or at sea. Consider also the total effect of waste disposal on the environment.

7. The utility should have operating responsibilities for monitoring, recording, and reporting waste and receiving stream characteristics.

For new water treatment plants

1. Waste management should be an integral consideration in the design or expansion of water treatment facilities. With proper weighting, waste management should have direct influence upon the selection of unit processes and the location of the water treatment plant.

Summary Statement

The Committee feels the need for development of substantial detailed information concerning the technology of treatment and disposal of wastes originating from water treatment practices. This information is vital for rational regulation of the industry. Because of the unusual size and complexity of the industry, the Committee discerns great difficulty in planning efficient and economical research and development programs and in dissemination of information from those programs.

Accordingly, the Committee believes that the AWWA Research Foundation could render valuable service both to the industry and to regulatory agencies by assuming active leadership in planning and coordinating research activities for the nation. Specifically, the Committee believes that a central clearing house for information on the disposal of wastes from water treatment plants should be established as a function of the AWWA Research Foundation.

Committee Report by:

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CONFERENCE CONCLUDING STATEMENT

J. C. Lamb, III

This Conference has summarized, in a series of reports and discussions, our state of knowledge about the disposal of wastes from water treatment plants. I would like to review what has been presented by suggesting that our water utilities are an industry. As an industry, they have an industrial waste problem.

We may examine this industrial waste problem as we would that of any other industry. Perhaps, from this viewpoint, we may discover clues which will assist researchers, engineers, plant operators, and regulatory agencies who endeavor to solve the problem.

The first question we ask is always "What is the problem?" To answer it, we need to know about the characteristics of the waste. We need to identify the specific constituents, their concentrations, and the ranges which occur in practice. We need to recognize that, as in other industries, the character of the waste will not remain constant.

The data we collect will help to define the problem in broad terms but, like textbook information, is inadequate for plant design or regulatory purposes. In many alum coagulation plants or lime softening plants, while wastes are similar, they are not identical, and the technology required to solve treatment problems will not be identical.

This situation makes it evident that there is a limit to the value of information obtained on the basis of averages. No one plant, or very few plants, will produce wastes close to the national average. Our need, then, is for general quality measurements, general ranges of concentrations, and specific departures from normal values.

Our second concern must be with the pollutional effects of wastes from the water treatment industry. Apparently, very little study has been made of this subject. We do need to substantiate the fact that there are such problems, and we need to evaluate them. To do this, we must collect information, coordinate it, and document the problem.

Having determined that there is a problem, we next look for solutions. No one solution is ideal to solve a problem, even for a single industry. Treatment is only one solution and, in a good industrial waste investigation, may be the last one to examine - because others provide a more reasonable chance of realizing major savings.

We should, for example, consider dilution. In certain situations, good engineering may permit impounding and the discharge of wastes seasonally or in proportion to stream flow. If such discharge does not contravene legitimate uses of a stream, this becomes a rational method for attacking the problem.

Another approach, already noted in one Conference report, suggests the change of treatment processes, to reduce or eliminate the waste. Changing from lime softening to ion exchange softening will radically affect the character of a waste. This may solve the waste problem but only, perhaps, if the plant wastes can be discharged to the ocean.

Similarly, the use of polyelectrolytes is intriguing. Coagulation by substances other than alum might mean that the waste problem could be solved by new technology.

We might even give consideration to profitable reclamation and sale of a waste by-product. This possibility should be approached with cautious skepticism, but should not be eliminated.

The next approach is to discharge the water treatment plant wastes into a municipal wastewater system. There are, apparently, many uncertainties about the harmful effects that could result. Properly done, it also appears that there could be beneficial effects from this method of disposal.

Finally, we come to discuss the treatment processes. These are not as simple as they might appear. Some available sewage treatment processes might apply here. In order to apply them, we need to know much more about the differences in design parameters operating conditions, and economics.

RESEARCH DIRECTIONS

Obviously, there are many legitimate areas of needed research. Our research should, properly, be divided into two general areas. The first is concerned with questions of general applicability. For example: questions involving the quantities and characteristics of waste, their pollutional effects, and the applicability of treatment processes for different types of water treatment wastes.

The second area of research is concerned with questions involved in solving specific problems. In this area, we need to develop adequate technology and uniform methodology to be used on individual plants. For example: questions dealing with methods for properly evaluating the dewaterability of sludges, using different treatment processes. Uniform methods of this type would provide tools which engineers, plant operators, and regulatory agencies could apply to the solution of specific problems.

We are then faced with the question: "Who is to do all this research?" I think that many different groups must contribute. For example: research of different types can be done in academic institutions, federal and regulatory agency laboratories, commercial laboratories, and by consulting engineers, plant operators, and equipment manufacturers. All of these have something to contribute.

The next question is then: "Who is to pay for this research?" We find that, for broadly applicable basic and applied research projects, and demonstration projects having industry-wide utility, some support may be provided by a federal agency. Regulatory groups at the state level should develop more research support than they have in the past.

I submit that support for much research of this nature must come from within the water industry. We have learned at this Conference that a number of utilities already have substantial projects under way. They are working to solve their own problems.

RESEARCH COORDINATION

We come now to the long-range goal of this Conference. That is, how knowledge derived from research and investigation is to be applied to the solution of specific problems of the water industry.

The first step will be taken when the AWWA Research Foundation publishes its project report on the disposal of wastes from water treatment plants. This report will summarize in some detail what we know and what we need to know about the problem.

During our Conference discussions, it has repeatedly been suggested that a central service - a clearing house - is needed to provide information on continuing research and demonstration projects.

The Conference committee reports, prepared to outline what we need to know, emphasize the need for an information clearing house. These reports recommend that the AWWA Research Foundation undertake to collect and disseminate such information.

In this activity, the Foundation would, with an appropriate advisory committee, assume a role of leadership in planning and coordinating research and demonstration projects. Coordination could significantly stimulate the rate of progress in solving problems of waste disposal.

We should recognize another important function which the Research Foundation could serve. This would be to interpret and translate research results, which must frequently be put into terms useful for plant operators.

The concept of a clearing house, and the important functions it could serve, certainly represent a challenge to the AWWA Research Foundation. This activity would benefit the entire water industry in solving its problem of treatment plant waste disposal.

* * *

Section 4

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Section 5

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BIBLIOGRAPHIC: American Water Works Association Research Foundation, Disposal of Wastes from Water Treatment Plants, FWPCA, Water Pollution Control Research Series, ORD-2, 1969.

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A series of four status reports describe in detail what is known of the research, engineering, plant operation, and regulatory aspects of the problem. A special report reviews current technology and analyzes costs of disposal methods, based on data collected from fifteen operating plants. A conference was organized to provide expert evaluation of each report and to extend the data available.

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Committee reports also recommend establishment of a central service to promote the planning of research and development, and to implement effective programs of new or improved technology. The service would collect, coordinate, and disseminate data on all aspects of water treatment plant waste disposal problems.

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