United States
Environmental Protection
Agency

Office of Environmental
Engineering and Technology
Washington DC 20460

Research and Development

EPA-600/S2-81-105 July 1981

EPA

Project Summary

Evaluation of the Full-Scale Application of Anaerobic Sludge Digestion at the Blue Plains Wastewater Treatment Facility—Washington, D.C.

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This study investigates the application of a new mesophilic-thermophilic anaerobic sludge digestion process to the existing mesophilic sludge digestion system at the District of Columbia Blue Plains wastewater treatment plant. The study also evaluates improvements in the existing mesophilic digestion operation and possible application of thermophilic digestion technology. Detailed analyses in the full report are designed to facilitate the use of the approach as a case study model for other wastewater treatment facilities considering the process.

The mesophilic-thermophilic digestion process is a new two-step concept for treating municipal wastewater sludges. The first step operates under mesophilic process conditions (digestion with anaerobic microorganisms at 90 to 100°F). The second step operates under thermophilic process conditions (digestion with anaerobic microorganisms that thrive at 120 to 130°F). The mesophilic process is the most commonly used digestion process. The thermophilic process has had limited application in this country, but is used regularly in the U.S.S.R.

The development and application of the mesophilic-thermophilic process has been pioneered by the City of New York under the direction of Mr. Wilbur Torpey. Full-scale application and evaluation of its effectiveness has been undertaken by the Rockaway Pollution Control plant in New York City. Results at Rockaway indicate that the physical characteristics of mesophilic-thermophilic digested sludge are changed to the extent that the economics of dewatering are significantly improved. Moreover, the residual sludge is inert and has met the time-temperature requirements for pathogen destruction.

The Rockaway findings resulted in the desire to investigate the feasibility of applying the mesophilic-thermophilic process to a major wastewater treatment facility. The Blue Plains plant was selected because: (1) the influent wastewater is mainly domestic, as in the Rockaway influent; (2) it has anaerobic digesters in operation; (3) the same activated sludge treatment process is used; and (4) the sludge management methodology needed upgrading for operating and economic reasons.

The evaluation at Blue Plains concludes that: (1) a limited expansion of digester capacity is required to handle the entire sludge stream; (2) digester gas would be available for sale to outside interests after internal heating requirements were satisfied; and (3) the cost of sludge handling could be reduced by $24 to $31 per million gallons of influent flow (from $72/mg to $41-48/mg). The analysis also indicates that the improved characteristics of the mesophilic-thermophilic digested sludge could reduce chemical conditioning requirements so that the cost would be almost $7 less per million gallons of influent flow than mesophilic digestion and almost $4 less than thermophilic digestion. Moreover, the Rockaway results indicate that there may be additional savings during disposal because the stabilized material produced would have in effect been composted.

For any of the three anaerobic systems to process all the sludge currently being generated at Blue Plains, some capital expenditures would be required to expand or upgrade existing equipment. A detailed cost analysis was not performed. However, a unit operation analysis indicates that the capital cost would be highest for the mesophilic system and lowest for the thermophilic system. The mesophilic-thermophilic system would lie between the two.

The study concludes that, under the present circumstances, the thermophilic digestion option would require the least capital expenditure and would be the most expedient, cost-effective solution to the sludge management problem.

This Project Summary was developed by EPA's Office of Environmental Engineering and Technology, Washington, DC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

This study is an engineering evaluation of the application of a new concept in wastewate engineering to a major wastewater treatment facility. The concept involves the combination of two anaerobic digestion processes: the mesophilic process (anaerobic digestion operating at temperatures of 90 to 100°F) followed by the thermophilic process (anaerobic digestion operating at temperatures of 120 to 130°F) It is termed the mesophilic-thermophilic process. Such a system has been operated at full-scale at the Rockaway Pollution Control plant in New York City

The existing Blue Plains wastewater treatment plant in Washington, D.C. treats approximately 330 mgd and uses mesophilic anaerobic digestion as a step in disposal of the sludge produced. This step has developed operational constraints and is limited in capacity. As a result, much of the sludge generated at Blue Plains is disposed of without digestion Expansion of some sludge processing unit operations, now in progress, will increase capacity, but not enough to handle the entire sludge stream as the system now operates. Finally, related planning and engineering evaluations now in progress are considering the long-term sludge disposal options available at Blue Plains, including anaerobic digestion

Therefore, the purpose of this study is to identify the relative applicability of the mesophilic-thermophilic process compared with other anaerobic digestion processes In particular, the study evaluates the capabilities of anaerobic digestion to meet sludge processing needs at Blue Plains, the operating and equipment modifications required to handle the full sludge stream, and the monetary and energy costs associated with the systems. Of major concern was meeting the objective of being able to identify the sludge digestion process that could be implemented with no major construction

Development of the Conventional (Mesophilic) Process

Anaerobic digestion, one of the oldest wastewater treatment processes, involves the biological conversion of organic solids to methane and carbon dioxide. It is a natural process occurring in such diverse environments as swamps, stagnant bodies of water, and stomachs of cows One of its first engineered uses was in the late 19th century when septic tanks were used for wastewater treatment. In the septic tank, the solids that settle to the bottom undergo anaerobic decomposition, with the liquid passing on to a tile drainage field. Although the solids may be stabilized, the gas which evolves disturbs the sedimentation process by lifting particles into the overflow. This can cause plugging of the tile field, thus destroying the efficiency of the field and frequently resulting in malodorous conditions

In the early part of this century, Dr Karl Imhoff invented a two-story tank to deal with this septic tank deficiency. The tank design was such that the gas generated by anaerobic digestion at the tank bottom was prevented from rising to the upper zone where sedimentation occurred. The functions of digestion and sedimentation were thus effectively separated

A natural evolution of this separation of functions, which took place in the 1920's, was the construction of separate tanks for anaerobic digestion, with the solids removed in the sedimentation basin pumped to the anaerobic digester This procedure permitted the application of heating and artificial mixing to the anaerobic digester Both heating and mixing, which began to be applied in the 1930's and 40's, accelerate the rate at which the solids are converted to gas as well as increase the effective volume of tankage available for digestion Consequently, instead of the three to six months requirement for anaerobic digestion in the Imhoff tank, accelerated digestion made it possible to complete the process in one to two months The obvious result of this functional separation was a substantial decrease in required capital cost.

The application of digester mixing soon made it obvious that mixing and separation of the supernatant from the digested sludge were incompatible in much the same sense that sedimentation and digestion in the septic tank were incompatible. This led to a further separation of functions by the application of a two-stage digestion process where the biological reactions (with mixing and heating for acceleration) occur in the first stage and the digested sludge is transferred to a second stage for separation of the solids from the liquid. Two pioneers in the application of two-stage digestion were A. M. Busell and A. J Fisher. With a two-stage system, satisfactory digestion could consistently be obtained in the first tank in a nominal retention time of one month or less.

In the 1950's, New York City faced the need for expanding the capacity of the digestion systems of the various plants. It was recognized that the digestion time could be substantially decreased if a significant portion of the water could be removed from the sludge before it was fed to the digester A separate mixed raw sludge thickener was developed and placed before digestion This procedure made possible quadrupling the solids loading rate to the digesters because the loading rate on the primary digesters was doubled and the need for secondary digesters was eliminated Energy requirements for sludge heating also were substantially reduced since it was no longer necessary to heat the water that was formerly associated with the sludge

Present State of Practice of Thermophilic Anaerobic Sludge Digestion

Thermophilic anaerobic digestion is very similar to mesophilic anaerobic digestion except the temperature at which it operates is 120-130°F instead of 90-100°F. It thus takes advantage of the fact that biochemical reaction rates can be increased by increasing temperature It is only natural, therefore, that conversion of existing mesophilic digesters to thermophilic operation should be considered as a low-cost technique for increasing the sludge processing capability of wastewater treatment plants. Full-scale studies by the Metropolitan Sanitary District of Greater Chicago, Ontario Ministry of the Environment, Canada, and Moscow, U S S R have indicated that the sludge processed per unit volume of digester capacity could be doubled by converting from mesophilic to thermophilic operation

Besides its increased sludge processing capability, thermophilic operation also offers two other significant advantages over mesophilic operation improved sludge dewatering characteristics and increased destruction of pathogens.

Garber's work on the vacuum filtration of thermophilic sludge at the Hyperion plant in Los Angeles provides an example of how sludge dewatering can be improved by the thermophilic digestion. He reported a 270 percent increase in vacuum filter yields with a 48 percent decrease in coagulant dosage for thermophilic, compared to mesophilic sludge. Improved solids-liquid separation is important in land application of sludge by decreasing the quantity of wet sludge for disposal and thus lowering transportation costs

An example of the increased destruction of pathogens by thermophilic digestion is given by Popova and Bolotina in their report on the practice of thermophilic digestion in Moscow, U S S R They state "The most essential advantage of this process is the sanitary quality of the thermophilic sludge. According to the sanitary officials of the health department, viable eggs of helminths are absent from such a sludge " This improvement in sanitary quality is of special significance in light of the current trend toward land disposal of digested sludge

Although mesophilic and thermophilic anaerobic digestion are quite similar in both design and operation, there are differences which must be taken into account in adapting mesophilic digesters to thermophilic operation Among these are· (1) additional sludge heating requirements, (2) structural competency of existing digesters and piping at the higher temperatures must be checked, (3) potential odors at sludge handling areas, (4) closer attention to temperature control, (5) maintaining an optimum concentration of volatile solids in order to operate at a net energy balance, (6) higher ammonia levels due to increased protein destruction, and (7) removal of increased amounts of moisture from the digester gas

Development of the Mesophilic-Thermophilic Process

In the work at the Rockaway plant in New York City, a process was developed to overcome the potential disadvantages of thermophilic digestion as well as to improve upon the process This was accomplished by the use of a two-stage digestion system, consisting of a mesophilic stage followed by a thermophilic stage A part of the thermophilically digested sludge was also recycled through the aeration tanks to obtain additional destruction of organic solids The advantages of the thermophilic process are thus retained without the disadvantages In addition, a substantial increase in organic solids destruction is obtained, resulting in improved quality of the residual digested sludge to the extent of being comparable to a fully composted sludge

Application at Rockaway

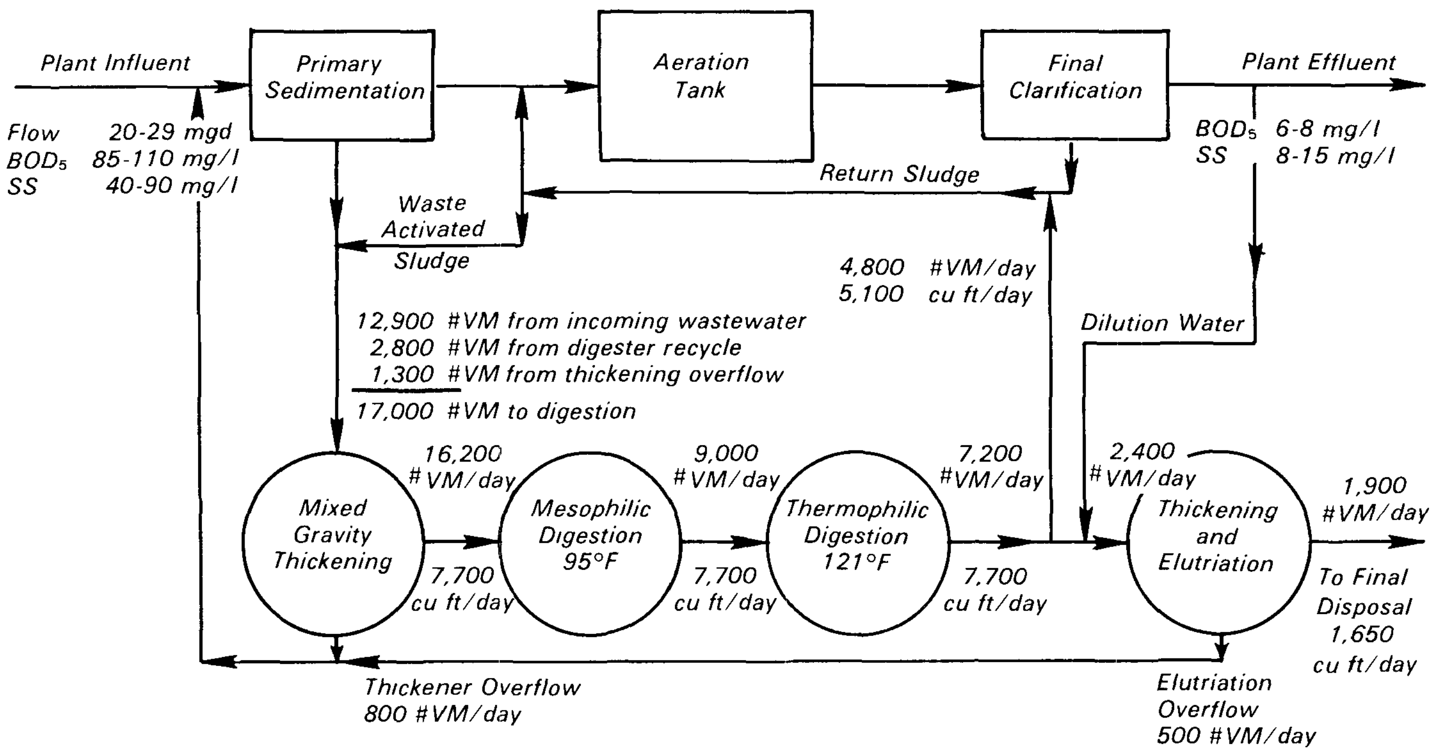
A full-scale test was conducted for five months at the Rockaway plant, which serves a population of 100,000, to evaluate a new method of reducing the amount and volume of sludge produced from the activated sludge process This method involved using high stability thermophilic digestion following mesophilic digestion and recirculating part of such thermo-digested sludge directly to and through the secondary system of the activated sludge process while the remainder was conducted to a rethickening and elutriation tank (Figure 1) Operating results (Tables 1-4) have demonstrated that the volatile matter normally transported to sea after meso-digestion was reduced by two-thirds Moreover, the volume of sludge produced was lowered by two-thirds without chemical or mechanical aids Using a laboratory scale, it was shown that the residual solids exhibited improved coagulability after having undergone thermo-digestion This change would improve the economics of all subsequent dewatering processes The treatment process performed without significant adverse effect on any accepted parameter due to the continuing recirculation of digested sludge through the activated sludge process The concentration of nutrients and metals in the final effluent were not affected.

Conclusions

1 It has been found possible to process the total waste sludge flow at the Blue Plains plant by adopting the thermophilic anaerobic digestion process to the present digestion facilities In that connection, the accumulation of grit presently in the digester tanks will not have to be removed.

2. Adoption of the thermophilic digestion option at Blue Plains requires the least capital expenditure, would be the most expedient solution to the sludge management problem, and would yield substantial operational cost savings. It also offers the potential of eliminating the need for composting because of the pathogen kill

3 The mesophilic-thermophilic digestion process would not be able to handle the entire waste sludge flow at Blue Plains without additional capital expenditures for new digester tanks and separate



Volatile Matter to Disposal

Before Thermophilic System Incorporated	After Thermophilic System Incorporated
5,700 #, 4,800 cu ft	1,900 #, 1,650 cu ft

#VM/day - Pounds Volatile Material Per Day

Summary

System Removal	12,900 #VM/day, Inf. to Effl.
Loss VM Mesophilic Digestion	7,200 #VM/day, Inf. to Effl.
Loss VM Thermophilic Digestion	1,800 #VM/day, Inf. to Effl.
Loss VM Aerator	2,000 #VM/day, Inf. to Effl.
Net	1,900 #VM/day to Disposal

Figure 1. Two-stage mesophilic-thermophilic sludge digestion wastewater treatment plant (volatile matter mass balance–daily rate).

Table 1. Monthly Average Solids Data, Rockaway, NY Pollution Control Plant, February-May 1980

Flow, mgd	25
VSS Captured @ 75% Volatile Matter, lb	12,900
Raw Thickener Pumping, cu ft/day	7,700
Volatile Matter Concentration	
Raw Thickener, %	3.4
Mesophilic Digester, %	1.9
Thermophilic Digester, %	1.5
Volatile Matter from Thickener, lb	16,200
Volatile Matter Leaving	
Mesophilic Digester, lb	9,000
Thermophilic Digester, lb	7,200
Rethickener Elutriator Underflow, lb	1,900
Rethickener Elutriator Overflow, lb	500

Table 2. Monthly Average Nutrient Data, Rockaway, NY Pollution Control Plant, (mg/l)

		Nitrogen					Phosphorus	
		NH_3	Org.	NO_3	NO_2	Total Inorg.	Total	Ortho
July-Dec 1979	Inf.	10.3	10.7	0.5	0	10.8	2.3	1.9
(Before Modification)	Eff.	4.5	7.0	3.7	0.5	8.2	1.7	1.7
Jan 1980	Inf.	9.4	9.8	0.2	0.1	9.6	2.7	1.6
(Transition)	Eff.	0.6	3.0	6.3	0	6.9	1.8	1.5
Feb-May 1980	Inf.	9.4	11.0	0.4	0	9.8	3.0	1.6
(After Modification)	Eff.	2.3	2.7	7.3	0	9.6	2.0	1.2

Table 3. *Monthly Average Gas Production, Rockaway, NY Pollution Control Plant (cu ft/day)*

	Mesophilic Digester	*Thermophilic Digester*
No Recirculation (Sept-Dec 1979)	*87,600*	*7,000*
With Recirculation (Feb-May 1980)	*83,900*	*14,000*

Note: Digester roofs were found to be leaking after this work was done.

Table 4. *Monthly Average Metal Data, Rockaway, NY Pollution Control Plant (mg/l)*

		July-Dec 1979	*Feb-May 1980*
Cu	*Inf.*	*.12*	*.088*
	Eff	*.05*	*.027*
Cr	*Inf.*	*.014*	*0047*
	Eff.	*008*	*.002*
Ni	*Inf.*	*.03*	*.0072*
	Eff.	*.02*	*.012*
Zn	*Inf.*	*.15*	*.12*
	Eff.	*.17*	*.082*
Pb	*Inf.*	*.036*	*.018*
	Eff.	*.009*	*.0035*
Fe	*Inf.*	*1.2*	*.72*
	Eff.	*.9*	*.24*
Cd	*Inf.*	*.0004*	*0018*
	Eff.	*.0004*	*0015*
Ca	*Inf.*	*30*	*16*
	Eff.	*32*	*17*
Mg	*Inf.*	*93*	*58*
	Eff.	*97*	*60*
Hg	*Inf.*	*0010*	*.0005*
	Eff.	*.0009*	*.0004*

heating systems Therefore it is not recommended at this time, even though the final product would satisfy all criteria for stabilization and disinfection comparable to effectively operated composting

4. The amount of grit passing through the existing Blue Plains grit removal facilities is substantial This grit is combined with the primary sludge and both are pumped to the digestion tanks The grit accumulates in the digestion tank and reaches equilibrium when about one-third of the tank volume is occupied by grit This grit accumulation has reduced the amount of sludge that can be processed through the existing digestion tanks by reducing the efficacy of the internal mixing process

5 The detailed solids production analysis prepared for this study can be incorporated into other sludge management evaluations performed by the District of Columbia.

Recommendations

Based on review of the anaerobic sludge digestion options and how they could be adapted to the existing facilities, the study recommends that the thermophilic anaerobic digestion process be implemented on a full-scale basis at the District of Columbia Blue Plains plant. This recommendation is based on a thorough review of the present state of practice in the U S and other countries The 30 years of successful experience in the City of Los Angeles Hyperion plant and their decision to convert the total digestion system to the thermophilic process was a consideration in making the recommendation Another factor was the successful conversion of the entire mesophilic digestion system to a higher temperature operation by the City of Denver over two and one-half years ago. The Metropolitan Sanitary District (MSD) of Greater Chicago has also shown at full scale that the capacity of a mesophilic digestion tank can be doubled by converting to thermophilic operation As a result MSD is planning to construct six additional digesters capable of being operated in the thermophilic range, as opposed to the old plan of constructing nine additional mesophilic units

Although the meso-thermophilic digestion process could be the optimum solution for other plants, the thermophilic process is recommended for Blue Plains because it could be implemented with a minimum of time and money Other significant advantages are (1) increased sludge processing capability, (2) improved sludge dewatering as to coagulant demand and yield, and (3) increased destruction of pathogens, all of which are pertinent to the needs of the Blue Plains plant

It is especially important to check the structural competency of the existing digesters and piping at the thermophilic temperatures, as well as the temperature control system prior to start-up

It is recommended that the transition from mesophilic to thermophilic operation be implemented as rapidly as possible in order to alleviate the solids handling problems in the metropolitan area. A carefully formulated transition plan should be prepared so that the transition be carried out effectively and with minimum interference with plant operations

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***James Basilico** is the EPA Project Officer (see below).*
The complete report, entitled "Evaluation of the Full-Scale Application of Anaerobic Sludge Digestion at the Blue Plains Wastewater Treatment Facility—Washington, D.C.," (Order No. PB 81-219 123; Cost: $15.50, subject to change) will be available only from:

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