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# Project Summary

# Thermal Treatment of Municipal Sewage Sludges

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**A research program on the thermal conditioning of sludge was conducted as part of an overall, long-term sludge management study for the Los Angeles and Orange County metropolitan areas. The major goal of this portion of the study was to investigate the advantages of the thermal conditioning of primary and waste-activated sludges WAS before anaerobic digestion on a continuous-flow and pilot-scale basis. The studies were designed to demonstrate whether thermal conditioning would increase gas production and volatile solids destruction during subsequent anaerobic stabilization of the sludge. Anaerobic digestion and anaerobic filtration were used for sludge stabilization. The effects of thermal conditioning on sludge dewaterability were studied by means of dewatering with a filter press, vacuum filter, scroll and basket centrifuges, and belt filter press. Other items studied were the fate of pathogens and heavy metals and the production and control of odors during the thermal conditioning process.**

**The pilot-scale thermal conditioning unit was tested under a variety of operating conditions. Temperatures and pressures were varied, and thermal conditioning was investigated with and without the use of oxygen. Two types of wastewater sludges were used—WAS and a blend of 65 percent raw primary and 35 percent WAS. An energy analysis was conducted to determine the net energy demands of including thermal conditioning in the sludge process.**

***This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, 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

In August 1976, a pilot-scale investigation of anaerobic digestion with thermal pretreatment was initiated at the Joint Water Pollution Control Plant (JWPCP) in Carson, California. The specific objectives were (1) to demonstrate on a continuous-flow, pilot-scale basis the concept of thermal treatment of primary and WAS before anaerobic digestion, (2) to determine the potential for increased methane production as a result of thermal pretreatment, (3) to determine the dewatering properties of the digested sludge; (4) to identify operational problems in the system, (5) to determine the effectiveness of a water-scrubber/carbon-adsorption system for the control of odorous off-gases, (6) to develop parameters for design and operation of a full-scale system, (7) to develop energy balances for the entire system, and (8) to demonstrate the treatment of thermally treated decant liquors with an anaerobic filter. Earlier laboratory studies at Stanford University indicated that potential toxicity problems existed in digesting sludges that had been thermally conditioned at temperatures above 177°C (350°F). This question was also to be resolved in this pilot-scale testing program.

A schematic representation of the extensive experimental program conducted is presented in Figure 1. The program was divided into three phases. The specific flow scheme investigated under Phase I incorporated thermal treatment of flotation-thickened WAS followed by (1) thermophilic anaerobic digestion and mechanical dewatering or (2) decant separation of the thermally conditioned

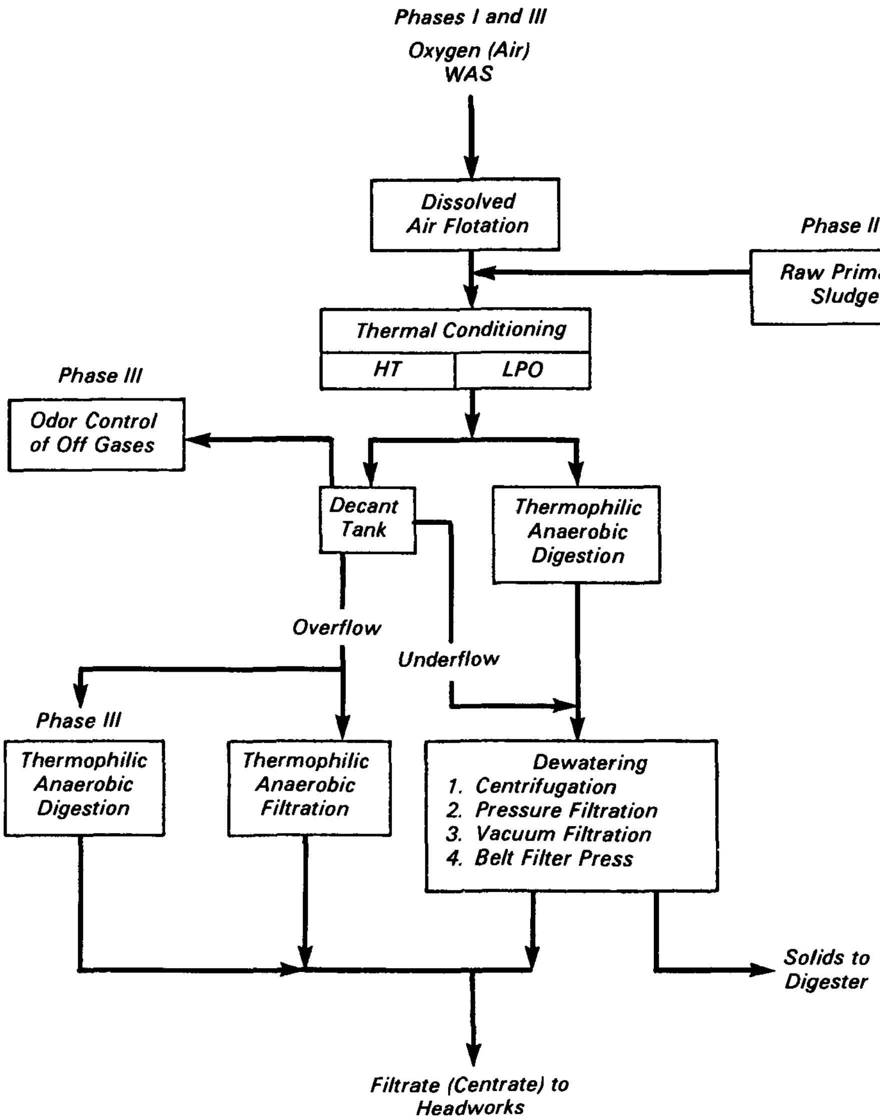


***Figure 1.*** *Schematic diagram of the sludge processing pilot facility.*

sludge with anaerobic filtration of the supernatant and mechanical dewatering of the subnatant. Phase II was identical to Phase I except that a blend of WAS and primary sludge served as the feed to the thermal-conditioning unit. A sludge blend on a dry solids basis of 65 percent raw primary sludge and 35 percent WAS was used to approximate the projected ratio at the JWPCP when full-scale secondary treatment is implemented. Phase III incorporated thermal treatment of thickened WAS followed by decant separation (thickening) of the sludge with anaerobic digestion of the supernatant and mechanical dewatering of the subnatant. Phase III was conducted primarily to study odor control techniques and to test a two-stage odor control system for decant tank off-gases.

## Pilot System

A trailer-mounted, continuous-flow, thermal-conditioning pilot plant was leased from Zimpro Inc.* as the thermal pretreatment system for these studies (Figure 2). Feed sludge passes through a grinder to reduce all particles to 0.8 cm (0.3 in.) before pumping. In the low pressure oxidation (LPO) mode, sludge and air are combined and pumped into the system. In the heat treatment (HT) mode, air is not used. With or without air, the sludge is then passed through heat exchangers and brought to the initial reaction temperature as it enters the reactor. Oxidation takes place within the reactor, and the oxidized products leaving the reactor are cooled by countercurrent heat exchange with the entering cold sludge. Steam is added directly to the reactor for startup and whenever the process is not thermally self-sustaining.

During these studies, the thermal conditioning unit was operated under either the HT mode or a modified LPO mode. The term "modified" is used here because under normal LPO conditions, enough oxygen is contained in the air added to the thermal reactor to oxidize 5 to 10 percent of the influent COD. Because one of the main objectives of these thermal pretreatment studies is to maximize gas production upon subsequent digestion, COD oxidation through the pretreatment facility must be kept to a minimum. To minimize the oxidation of organics through the thermal reactor, the quantity of air supplied was decreased from 4.7 to 7.1 L/s (10 to 15 scfm) for normal LPO conditions to 0.6 L/s (1.2 scfm) under modified operation. The theoretical degree of COD oxidation under these modified conditions approximates 1 percent and should not significantly affect methane production when the sludge is anaerobically digested. The small amount of air still provides an oxidizing environment in the reactor, and the conditioned sludge should behave in a similar manner to sludge that receives normal LPO conditioning.

Pilot-scale anaerobic digestion studies were carried out in a 45-$m^3$ (12,000-gal), single-stage digester equipped with a gas recirculation system for mixing and heat exchangers to maintain thermophilic temperatures. Anaerobic filtration studies were conducted on a filter that was 1.2 m (4 ft) in diameter and 3 m (10 ft) high (Figure 3). Feed was introduced at the top through a 1.9-cm (0.75-in.), 120° spray nozzle. The filter was loaded with three 0.6-m-deep sections (2 ft) of B.F. Goodrich plastic medium with a surface area of 144 $m^2/m^3$ (44 $ft^2/ft^3$). Liquid level in the filter was maintained to just cover the top layer of the plastic medium. To reduce the possibility of short circuiting along the

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

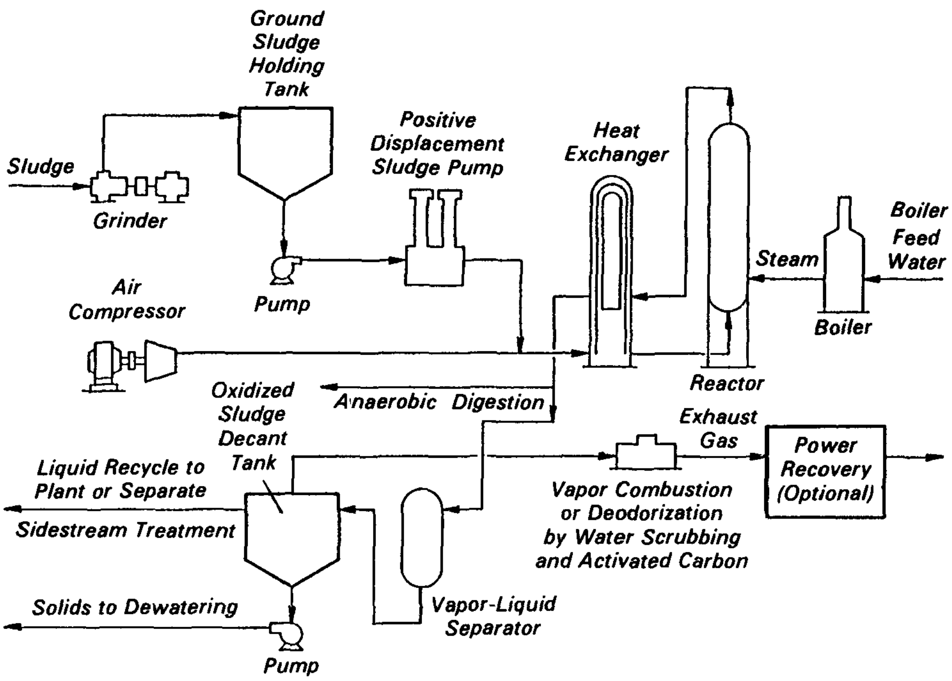


***Figure 2.*** *Schematic diagram of the Zimpro thermal conditioning process.*

wall of the filter, a 1.9-cm-wide rubber gasket (0.75 in.) was installed between the medium sections and glued securely against the inner surface of the filter wall. The filter was kept at thermophilic temperatures by means of a hot water piping system attached to the outer wall of the filter.

## Results and Conclusions

Significantly improved energy efficiency can result if thermal conditioning is performed before anaerobic digestion rather than after digestion. The major variable is the efficiency of the heat exchangers in the thermal-conditioning unit. If the efficiency is high enough, the thermal-pretreatment/anaerobic-digestion system could result in a net surplus of energy. Advantages of thermal conditioning before (rather than after) digestion appear to be (1) stable digestion with less recycling of degradable organics to the wastewater treatment plants, (2) greater methane gas recovery, (3) more positive control of odors, and (4) a reduced quantity of solids for ultimate disposal. Advantages of thermal conditioning after digestion with anaerobic treatment of liquid side streams include (1) slightly drier cake solids following dewatering and (2) reduced polymer conditioning requirements. Selection of the final mode of operation is likely to depend on site-specific factors and the ultimate disposition of the solids. Note that any type of thermal treatment results in a significantly smaller net energy surplus than when the sludge receives anaerobic digestion alone.

During the 17 months that the thermal conditioning system operated, thermophilic anaerobic digestion of the thermally conditioned WAS proved very reliable. No toxicity problems or digester upsets occurred, and digestion performance was not significantly affected by the temperature of thermal pretreatment over the range of temperatures from 170° to 220°C (340° to 425°F). The thermal-pretreatment/anaerobic-digestion system increased volatile solids destruction by 65 percent over standard mesophilic digestion and 36 percent over standard thermophilic digestion. When only those volatile solids destroyed in the digester were taken into account, the percent increases dropped to 40 and 15 percent, respectively, over standard mesophilic and thermophilic digestion of WAS. Thermal pretreatment and thermophilic digestion of the 65 percent primary/WAS blend did not produce results significantly different from standard thermophilic digestion.

Thermal conditioning with temperatures exceeding 150°C (300°F) for about 30 min should assure the complete destruction of all pathogen microorganisms. Data indicated that viable parasitic helminth ova were essentially eliminated and bacterial organisms were significantly reduced compared with levels in standard digester effluent. Regrowth of coliform organisms (and in some cases *Salmonella* sp.) was observed occasionally, possibly because of poor temperature distributions in the thermal conditioning unit. But salmonellae concentrations remained lower than those in standard digester effluent.

Thermally conditioned, digested sludges dewatered well compared with sludges receiving anaerobic digestion alone. Filtration devices generally dewatered these sludges more effectively than centrifugal devices. But prethickening of sludge was a necessary step before vacuum or pressure filtration to attain acceptable cake consistency and discharge characteristics. The mixture of primary and WAS had slightly better dewatering characteristics than WAS alone. Test runs using undigested sludges indicated that dewatering characteristics are degraded slightly by subsequent digestion. Cake solids concentrations are lowered, and polymer doses are increased. Thermal conditioning of WAS at temperatures above 190°C (380°F) was needed to produce successful dewatering.

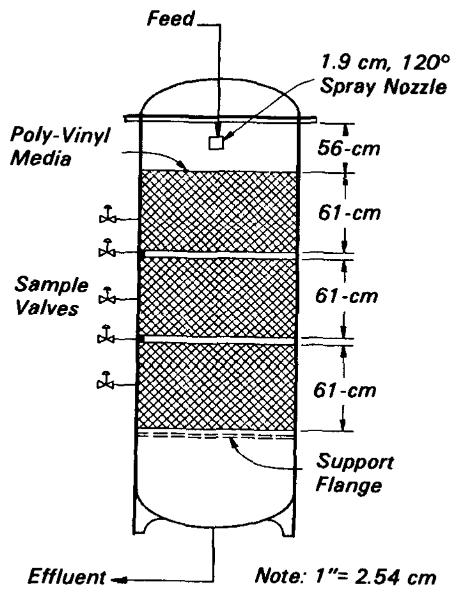


***Figure 3.*** *Schematic diagram of the pilot-scale anaerobic filter.*

A two-stage water-scrubber/carbon-adsorption unit successfully removed 97 percent of the odor concentration from the thermal conditioning decant tank exhaust gases. Alone, the water scrubber portion removed about 68 percent of the exhaust gas odor concentration.

Energy analysis data show that all thermal treatment schemes combined with the digestion step are net users of energy. The thermal treatment processes produce more biodegradable material but the increase in the gas produced from the anaerobic processes is not nearly sufficient to match the energy needed to operate the thermal conditioning unit. The least energy-efficient system was thermal treatment followed by decanting supernatant from the sludge solids with anaerobic digestion of the decant liquors only at a 15-day hydraulic detention time. Apparently, much degradable organic material still remains associated with the solids fraction of the thermally conditioned sludge. No energy credit is given to this material, since it is removed from the system before anaerobic treatment.

Net energy efficiency calculations for all systems studied are summarized in Table 1 in which the treatment systems are ranked in order of greatest to least efficiency. The data also indicate the amount of sludge solids remaining for disposal after the thermal conditioning anaerobic treatment process.

Important conclusions that can be drawn from the tabulation are as follows:

1. For any given sludge, adding any form of thermal treatment to anaerobic digestion reduces net available energy, frequently to negative values.
2. For any given process combination, there is more net available energy with the blended sludge than with WAS.
3. If thermal treatment is needed because of the demonstrated improvements it produces in dewatering properties, more net energy will be produced if the heat treatment precedes digestion rather than follows it (no experiments with thermal treatment after digestion were conducted so advice on whether thermal treatment should be conducted before or after digestion for best dewatering cannot be given).
4. Differences in net available energy between LPO conditioning and heat treatment are minor.
5. When thermal treatment is used, the net available energy depends greatly on the thermal approach attained in the heat exchangers.
6. Anaerobic digestion of the entire sludge after thermal treatment produces much more net available energy than treatment of only the decant liquors by anaerobic digestion or by the anaerobic filter.

Although net available energy is an extremely important consideration, other factors also influence process choices. Process selection should also consider capital cost and compatibility of the sludge produced with subsequent process steps and disposal choices.

The full report was submitted in fulfillment of Contract No. 14-12-150 by the Los Angeles County Sanitation Districts under the sponsorship of the U.S. Environmental Protection Agency.

***Table 1.*** *Ranking of Energy Balances for Various Thermal-Conditioning Systems*

| *System* | *Net Energy $10^9$ Joules ($10^6$ BTU)* $\Delta T$ = 22°C (40°F) | $\Delta T$ = 44°C (80°F) | *Solids Remaining for Disposal Metric Tons (Short Tons)* |
|---|---|---|---|
| *1. Digestion of blend* | *427 ( 405)* | *427 ( 405)* | *64 (70)* |
| *2. LPO conditioning—digestion of blend* | *243 ( 230)* | *95 ( 90)* | *57 (63)* |
| *3. Digestion of WAS* | *206 ( 195)* | *206 ( 195)* | *70 (77)* |
| *4. Digestion—heat treatment of blend* | *127 ( 120)* | *-95 (-90)* | *59 (65)** |
| *5. Digestion—LPO conditioning of blend* | *106 ( 100)* | *-116 (-110)* | *57 (63)** |
| *6. Heat treatment—digestion of WAS* | *95 ( 90)* | *-95 (-90)* | *55 (61)* |
| *7. LPO conditioning—digestion of WAS* | *95 ( 90)* | *-100 (-95)* | *55 (61)* |
| *8. Digestion—heat treatment of WAS* | *-179 (-170)* | *-464 (-440)* | *64 (70)** |
| *9. Digestion—LPO conditioning of WAS* | *-206 (-195)* | *-496 (-470)* | *65 (72)** |
| *10. LPO conditioning—anaerobic filtration of blend* | *-227 (-215)* | *-448 (-425)* | *79 (87)* |
| *11. LPO conditioning—anaerobic filtration of WAS* | *-280 (-265)* | *-570 (-540)* | *83 (92)* |
| *12. LPO conditioning—anaerobic digestion of WAS decant liquors* | *-353 (-335)* | *-628 (-595)* | *85 (94)* |

****Calculated assuming digested sludge behaves similar to raw sludge during thermal treatment; never confirmed by pilot testing.***



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***Irwin J. Kugelman** was the EPA Project Officer (see below).*
*The complete report, entitled "Thermal Treatment of Municipal Sewage Sludges," (Order No. PB 84-196 732; Cost: $20.50, subject to change) will be available only from:*
*National Technical Information Service*
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