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Project Summary

Fuel-Efficient Sewage Sludge Incineration

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A study was performed to evaluate the status of incineration with low fuel use as a sludge disposal technology. The energy requirements, life-cycle costs, operation and maintenance requirements, and process capabilities of four sludge incineration facilities were evaluated. These facilities used a range of sludge thickening, conditioning, dewatering, and incineration technologies.

The results provided realistic cost and energy requirements for a fuel-efficient sludge incineration facility and highlighted operational, managerial, and design features that contributed to the fuel efficiency of the incineration process. This information provides a basis for evaluating both the applicability of sludge incineration in future facilities and the cost and energy efficiency of existing incineration facilities.

This Project Summary was developed by EPA's Risk Reduction Engineering 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

To be considered an alternative sludge technology under the U.S. EPA's Construction Grants program, an incineration system is required to be "self-sustaining" or a net energy producer. In determining if a system is a net energy producer, the energy used for sludge dewatering, combustion, and pollution control equipment is included. The purpose of this study was to determine if, in fact, a fuel-efficient, well-operated sludge incineration system could be "self-sustaining."

The energy requirements, life-cycle costs, operation and maintenance (O&M) requirements, and process capabilities of four sludge incineration facilities were evaluated to determine the status of incineration with low fuel use. The four facilities used a variety of sludge thickening, conditioning, dewatering, and incineration technologies.

Plant Information

Detailed information for the following four facilities is included as appendices in the Project Report.

Upper Blackstone WPCF

The Upper Blackstone Water Pollution Control Facility (WPCF) in Millbury, MA is a secondary wastewater treatment facility with an average capacity of 2,400 L/s (56 mgd). Currently, the facility treats an average of 1,400 L/s (33 mgd) and processes approximately 27 dry metric tonnes (30 dry tons) of dewatered sludge cake per day.

The solids handling processes include flotation thickening of the waste activated sludge (WAS), storage and mixing of the WAS and primary sludge, polymer conditioning, belt filter press dewatering, multiple-hearth (MH) incineration, and ash disposal by landfilling. The MH does not include an afterburner chamber or any means of waste heat recovery.

Metropolitan WPCF

The Metro facility in St. Paul, MN is a secondary wastewater treatment facility with an average capacity of 11,000 L/s (250 mgd). The plant currently receives an average of 9,600 L/s (220 mgd). Approximately 163 dry metric tonnes (180 dry tons) of dewatered sludge cake are processed at the plant daily.

Sludge handling processes include gravity thickening of the primary sludge, flotation thickening of the WAS, sludge storage, heat conditioning (Zimpro*) and decanting of the WAS, blending of the primary sludge and WAS, polymer conditioning, roll press dewatering, and MH incineration. The MH incineration system includes a waste heat boiler system for heat recovery and a zero hearth afterburner chamber for air emission control. Auxiliary fuel is not added to the afterburner chamber.

Duffin Creek WPCP

The Duffin Creek Water Pollution Control Plant (WPCP) in Pickering, Ontario is a secondary wastewater treatment plant with an average capacity of 2,100 L/s (48 mgd). Currently, the plant treats an average of 2,100 L/s (47 mgd) and processes about 24 dry metric tonnes (27 dry tons) per day of dewatered sludge cake.

WAS is returned to the primary clarifiers and co-settled with the primary sludge. The solids handling processes include two-stage anaerobic digestion, sludge storage, polymer conditioning, diaphragm filter press dewatering, fluidized bed (FB) incineration, and ash disposal by landfilling. The incineration system has a hot windbox design and includes a waste heat boiler system for energy recovery.

Cranston WPCF

The Cranston, Rhode Island WPCF is a secondary wastewater treatment facility with an average capacity of 1000 L/s (23 mgd). The plant currently receives an average of 400 L/s (10 mgd) and processes about 8 dry metric tonnes (9 dry tons) of dewatered sludge cake daily.

The solids handling processes include dissolved air flotation thickening of WAS, gravity thickening of primary sludge, sludge storage and blending, chemical conditioning, dewatering with fixed-volume filter presses, and MH incineration. The MH system includes an external afterburner chamber and a separate scrubbing and heat recovery system. The furnaces were designed for operation in the pyrolysis (starved air) mode but have only operated in this manner during start-up. No auxiliary fuel is added to the afterburner chamber.

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

Cost and Energy Consumption

The estimates of cost and energy consumption presented here reflect plant operation under current emission control regulations. Changes in these regulations could significantly affect the cost and energy efficiency of the incineration process. Exhaust gas temperatures for the three MH furnaces ranged from 480°C (900°F) to 590°C (1100°F). None of the MH systems employs afterburning of the furnaces exhaust gas stream, although two of the installations have an afterburner chamber incorporated into the incineration system. Each of these facilities employs a venturi wet scrubbing system. If new air emission regulations require operation of an afterburner for all MH systems, cost and energy requirements for MH incineration will increase significantly. Requirements for more sophisticated emissions control technologies will also increase the capital, labor, and power costs for sludge incineration.

Basis of Analysis

For the purpose of this evaluation, the solids handling train included all processes following the clarifiers through the incineration system, including air emission control and waste heat recovery systems. The cost of energy consumption required to treat the sidestream flow that is returned to the head of the plant was considered essentially equal at each facility and therefore was not included in this evaluation. However, at the Metro facility, the sidestream flow is of much higher strength due to the heat conditioning process and must be treated to reduce its strength before it can be returned to the head of the plant. Because this additional level of sidestream treatment represents an additional cost to the solids handling system, costs and energy consumption associated with the rotating biological contactors used for sidestream treatment at the Metro facility were included in this evaluation.

Plants with waste heat recovery systems must have an auxiliary boiler system to supplement steam generation from the waste heat boilers during periods of low sludge production or high steam demand. The auxiliary boiler system is considered a part of the incineration/heat recovery system; therefore, energy, fuel, and costs associated with auxiliary boilers were accounted for under the incineration system.

Raw data for each facility were obtained through a review of available plant records and discussions with plant staff. For the purposes of the economic evaluation, both capital cost and O&M cost data were obtained for each unit process, and O&M cost data were further broken down into six components: (1) labor; (2) electricity; (3) fuel (either fuel oil or natural gas); (4) chemicals; (5) materials and supplies; and (6) contracted services.

Because of the lack of complete data regarding actual metered electrical consumption, electrical consumption at each facility was estimated by using a combination of available plant data and typical consumption figures presented in industry publications.

Economic Evaluation

Variations in the unit costs for labor, electricity, fuel, and other consumables among the four facilities were accounted for by converting O&M costs to a common set of unit costs. Original capital costs were updated to 1988 dollars using the Engineering News Record cost index. Updated capital costs were amortized assuming a 40 year useful life for all structures, a 20 year useful life for all equipment, and a discount rate of 8%.

The actual load on a plant (versus design capacity) can significantly affect O&M costs. For this reason, a facility operating at design capacity should not be compared directly with a facility that is in the early stages of its design life. Because of the influence of the difference between load and capacity, costs were evaluated for operation at current loads and for operation at capacity. To estimate the costs at capacity, the capacity of each solids handling system was estimated, and costs for operation at capacity were developed.

The capacity of each solids train was taken to be the maximum amount of sludge that the solids train could process while maintaining a reasonable amount of standby capacity.

Each facility's expenditures for labor, electricity, chemicals, and other consumables were scaled up to reflect operation at capacity. Costs were scaled up based upon the percent increase in sludge production, the increase in the number of units on-line under average conditions, or some other appropriate parameter.

All costs presented below are on the basis of dewatered sludge cake, and are expressed as dollars per dry metric tonne (per dry ton). Based on the methodology presented above, the following ranges represent a reasonable estimate of capital and O&M costs for a well-operated sludge incineration system operating at capacity, including furnaces, heat recovery system, air pollution control system, and ash disposal system.

Annual O&M	$ 77 to $ 99	($ 70 to $ 90)
Amortized Capital	$110 to $138	($100 to $125)
Total Annual Cost	$187 to $237	($170 to $215)

The following ranges represent a reasonable estimate of capital and O&M costs for a complete, well-operated incineration solids train operating at capacity, when the thickening and dewatering processes are also included.

Annual O&M	$198 to $220	($180 to $200)
Amortized Capital	$220 to $253	($200 to $230
Total Annual Cost	$418 to $473	($380 to $430)

Limitations on Cost Estimates

It is important to recognize the limits of these cost estimates. Capital costs are presented on the basis of dollars per ton of installed capacity, allowing for a reasonable amount of reserve capacity. It must be recognized that capital costs can vary significantly due to site-specific factors such as subsurface conditions, local materials costs, size constraints, constructions market conditions, and the amount of redundancy built into the system. These factors make it difficult to generalize about capital costs; therefore the capital costs figures presented here should be applied carefully.

Estimates of O&M costs were based upon operation at system capacity. O&M costs can vary significantly over the life of a facility depending on the difference between initial and design year sludge quantities, the use of multiple units rather than one large unit in equipment selection, and other design factors. A system that operates at a fairly constant sludge feed throughout its design life will see little change in per ton O&M costs.

Actual per ton O&M costs for sludge incineration at the four subject facilities ranged from 6% to 186% greater than the per ton costs estimated for operation at capacity. The fluctuation in per ton costs over the design life of an incineration system should be considered when using the figures presented in this study.

Energy Evaluation Summary

Energy efficiency was examined on several levels, which were defined by how energy inputs and outputs for the system were defined. The following generalizations were made regarding the energy consumption of a well-operated facility.

Level A --

Based on the auxiliary fuel consumed within the furnaces only.

- Total annual auxiliary fuel consumption within the furnace itself should range from 29 to 38 L fuel/dry metric tonne of sludge cake processed (7 to 9 gal/dry ton).
- Frequent downtime (whether scheduled or unscheduled) increased the auxiliary fuel consumption by a factor of 10.

Level B --

In addition to Level A, auxiliary fuel use by the heat/auxiliary boiler equipment, the emission control equipment, and the ash disposal system was included. When steam was produced and used outside of the incineration system, it was included as an energy output.

- When a waste heat recovery system was included in the incineration system, the incineration system could be a net energy producer when only auxiliary fuel (no electricity) was considered an energy input to the system.

Level C --

In addition to Level B, electricity for equipment was also included as an energy input.

- An incineration system with a waste heat recovery system could still be energy producer when operated at a maximum efficiency. Two facilities approached the goal of being a net producer at their current loading rates. It is possible that, if these facilities were operating at capacity, the increase in energy efficiency that results from complete equipment utilization might make those facilities net energy producers.

Level D --

In addition to Level C, energy inputs to the sludge conditioning/ dewatering system were included.

- When the definition of the incineration system was expanded to include the sludge conditioning/dewatering system, the goal of net energy production by the incineration system did not appear achievable.

Level E --

In addition to Level D, energy to the entire solids handling train was included. Auxiliary fuel, electricity for equipment, and electricity for general building requirements were considered energy inputs.

- Total energy consumption for a solids train using sludge incineration varied widely depending on the thickening and dewatering technologies employed. Total energy consumption for a well-operated solids train ranged from 5.8 to 10.4 million kJ/dry metric tonne (5 to 9 million Btu/dry ton) of sludge cake processed.

Overall, a variety of technologies could achieve energy-efficient sludge incineration. The most complex systems proved to be very energy efficient under each set of conditions evaluated. The simplest system also proved to be very energy efficient, especially in terms of overall energy consumption by the entire solids train.

Keys to Fuel-Efficient Operation

Although each of the facilities had several features that contributed to the success of its own sludge incineration process, there were some common operational and management features that operators at each facility agreed were essential to a fuel-efficient sludge incineration system.

Sludge Equalization

A uniform flow of sludge to the incineration system was essential, both in terms of quantity and quality. Each time the quality or quantity of the furnace feed changed, the operator had to adjust the excess air level, rabble arm rotation speed, auxiliary fuel use, or some other operational variable to maintain complete combustion conditions instead of concentrate on fine tuning the incineration system.

To create a uniform furnace feed, some sludge storage and mixing should be provided within the solids train. Sludge storage also allows the incineration system to be taken off-line for regular maintenance and equipment calibration.

Staff Motivation/Training

The real key to a successful sludge incineration facility was in the plant O&M staff. An incineration system is a relatively complex system to operate and maintain. The operations staff had to understand the effect that changes in operational variables had on the combustion process, and the effect that the performance of the preceding solids handling processes had on the furnace's operation. The maintenance staff had to have the manpower and skill to provide regular maintenance on a variety of equipment. Management had to create a positive working environment that motivated the plant staff.

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Communication among the operators of all of the solids handling processes regarding changing sludge conditions was essential. Management encouraged this by implementing programs such as a rotating employee program or by forming problem solving committees comprised of engineers, operators and maintenance personnel from throughout the solids handling facility.

Management should encourage the plant staff to pursue advanced levels of training through in-house programs, operator certification programs, graduate level engineering programs, and activity in professional organizations and societies.

Maintenance Program

A strong maintenance program increased the cost-effectiveness and energy efficiency of the incineration process; it:

- reduced auxiliary fuel use by minimizing unscheduled maintenance shutdowns;
- minimized costs by extending the useful life of furnace components; and
- provided the operators with accurate information by keeping the instrumentation and monitoring equipment operable and up-to-date.

Over the life of a facility, it appeared to be more economical to pay the annual cost of proper preventive maintenance than to pay for major repairs on a periodic basis.

Conclusions

1. If all energy inputs were considered (Level D), none of the incineration systems studied could be defined as "self-sustaining." These systems did, however, provide several keys to fuel-efficient operation:
   - A uniform sludge flow to the incineration system was essential, both in terms of quantity and quality.
   - the real key to a successful sludge incineration facility was in the plant operations and maintenance staff.
   - a strong maintenance program increased the cost-effectiveness and energy efficiency of the incineration process.
2. For a well operated system, total annual auxiliary fuel consumption within the furnace itself should range from 29 to 38 L fuel/dry metric tonne of sludge cake processed (7 to 9 gal/dry ton). Frequent downtime (whether scheduled or unscheduled), however, increased the auxiliary fuel consumption by a factor of 10.
3. A reasonable estimate of total annual cost (including amortized capital and O&M) for a well-operated sludge incineration system operating at capacity, including furnaces, heat recovery system, air pollution control system, and ash disposal system ranged from $187 to $237 per dry metric tonne ($170 to $215 per dry ton) (see note on limitations above).
4. A reasonable estimate of total annual cost (including amortized capital and O&M) for a complete well-operated solids train, operating at capacity, including thickening, dewatering, and incineration, ranged from $418 to $473 per dry metric tonne ($380 to $430 per dry ton) (see note on limitations above).

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The complete report, entitled "Fuel-Efficient Sewage Sludge Incineration" (Order No. PB90-261 827/AS ; Cost: $39.00 , subject to change) will be available only from:
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