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Project Summary

Evaluation of a Fluidized-Bed Sewage Sludge Incinerator Using Wood Chips for Fuel

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An environmental and technical evaluation was conducted for the Western Lake Superior Sanitary District (WLSSD) waste treatment plant, which uses wood chips to incinerate sewage sludge in fluidized-bed combustors. The most important environmental factors for evaluation were the metal contents of the particulate stack emissions and of various influent and effluent streams for the incinerator and the incinerator air pollution abatement system.

The technical evaluation used data collected over the life of the facility to develop a mathematical model of the incineration and energy recovery system. The model was coded in the form of a computer program and can rapidly evaluate a wide variety of possible situations in which such an energy recovery approach might be taken. Thus the technical evaluation is presented in a widely usable and understandable form.

This Project Summary was developed by EPA's Water Engineering 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

Background

The WLSSD serves the 500-square mile area surrounding Duluth, Minnesota, which is a major port on Lake Superior. The District provides wastewater treatment (44 million gal/day) and solid waste disposal (280 tons/day) for approximately 135,000 area residents.

The WLSSD waste treatment plant was designed in 1975 to incorporate several new and innovative technologies for accomplishing the co-incineration of solid wastes and sewage sludge. The incineration facility (completed in 1979) was designed to use shredded solid waste as fuel to augment the combustion of the sewate sludge in one of two fluidized-bed combustors, each rated at 100 million Btu/hr. A major portion of the energy required to operate the facility was provided by a waste-heat boiler that produces steam from energy in the hot combustion gases.

The original study was undertaken in 1978 to compile information on the technical, environmental, and economic performance of this innovative co-disposal system. However, because of prolonged technical difficulties encountered at the facility, the evaluation was not performed until 1984. Up until that point, constant problems were experienced with the solid waste processing system; but the fluidized-bed combustors were operating well using wood or bark chips as the auxiliary fuel. Since the study had already been delayed for 5 yr, a decision was made to complete as much of the evaluation as possible with the system in its present configuration.

Objectives

The original study objectives were to perform a technical, environmental, and economic evaluation of the refuse/sludge combustion process at WLSSD. Because of the 5-yr delay, these goals were modified to focus primarily on the environmental and technical issues. The results of the evaluation provide technical and environmental information about sludge combustion with wood chips that will allow others to replicate WLSSD's successes and to avoid their problems.

Because the energy-recovery, co-combustion system has a very limited number of effluent streams, it was decided that the most important environmental factors were the metal contents of the particulate stack emissions and the metal contents of the various influent and effluent streams to the combustor scrubber system. Because the scrubber and wastewater treatment plant would be in a closed-loop mode when operated as designed, it is conceivable that the facility could accumulate metal concentrations that could be toxic to the biological processes in the wastewater treatment operation. Thus the fate of metals in the process became the most important consideration in the environmental evaluation of this process.

As a result of the extensive evaluation performed on the combustion process over the life of the facility, much of the information needed to perform a technical evaluation was already available. Thus it was decided that this information could best be used by developing a mathematical model of the incineration and energy recovery system and to code this model in the form of a computer program. This model could readily be used by WLSSD personnel and by others in the technical community. By varying several of the input parameters (e.g., fuel characteristics, sludge characteristics, and energy demand), it is possible to use this model to perform rapid technical evaluation of a wide variety of possible situations in which such an energy recovery approach might be taken. Actual operating data were used as the basis for developing this model, and the performance of the combustor for various operating scenarios can be predicted through the use of this model. This approach presents the technical evaluation of the combustion and energy recovery system in a widely usable and understandable form.

Procedures

Figure 1 illustrates the current configuration of the WLSSD incineration system. To collect metals data, sewage sludge was cofired with wood bark chips in the fluidized-bed reactor under the same set of normal operating conditions on April 10, 11, and 12, 1984. Representative hourly samples of each of seven major process streams were acquired over a 6-hr test period during the 3 days. Hourly samples of each process stream were composited to provide one representative daily sample of each stream for metal analyses. The mass flow rate of each process stream was measured or calculated, and the metal concentrations within each stream were calculated. In addition, operating logs of 1982, 1983, and 1984 were analyzed to produce the data needed to design those equations that describe the mass and energy flows of the incineration and heat recovery system.

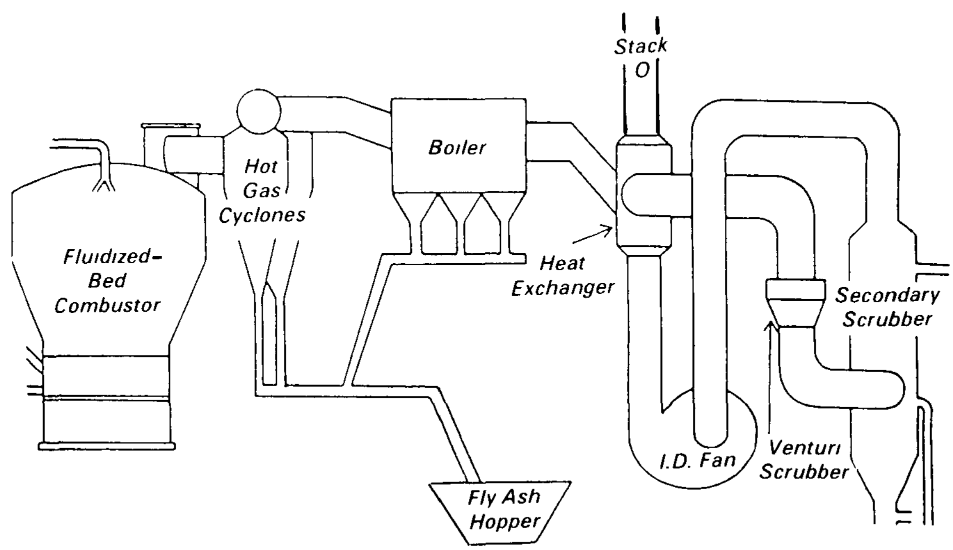

Figure 1. WLSSD process schematic.

Results

Average Metal Mass Rates

Table 1 presents the average mass rates of metals detected within the various process streams. Elements entering the system with the sludge filter cake (SC), wood chips (WC), and the fluidizing-bed sand (SA) are summed in the (Σ In) column. The elements are listed in decreasing order of magnitude of total system input. Exponential notation has been used to allow quick scanning for order of magnitude differences.

Metals leave the incineration system via the fly ash (FA), the scrubber effluent (ΔS), and the stack particulate (PF and IC). The net scrubber discharge is the result of subtracting the mass rate of metals entering the scrubber via the scrubber influent (SI) from the mass rate of metals in the scrubber overflow (SO) and the scrubber discharge (SD). Thus

$$\Delta S = (SO + SD) - SI$$

The total mass rate of metals leaving the system is then

$$\Sigma \text{ Out} = FA + \Delta S + PF + IC.$$

The results of the metal analyses shown in Table 1 must be viewed in relation to the designed operating mode of the plant. The scrubber and wastewater treatment system are designed to operate in a closed loop, and therefore the WLSSD process is probably concentrating metals.

Mathematical Model of the Combustor System

The computer model "HEATBAL" was designed to simulate the operation of the fluidized-bed combustors at WLSSD. The source code of the model is written in HP-3000 Fortran. The source code is divided into modules and subroutines with numerous comment lines and long, descriptive variable names. Efficiency and elegance have been sacrificed to make the source code easy to understand and easy to modify by another programmer.

The object code resulting from the compilation of this source code can be stored for interactive execution from a video terminal. Successive runs of the program are possible in the same session without terminating the program and restarting.

Upon initiating a run of this program, users will first be asked if they want a list of the available modes of analysis. The following list will then be displayed if a user responds "Y":

1. Maximum steam production
2. Minimum auxiliary fuel usage
3. Specified steam production
4. Exhaust temperature (heatwork)
5. An economizer with any mode
6. An air preheater with any mode

Table 1. *Summary of Average Metal Mass Rates (g/hr)*

Element	*Sludge Filter Cake*	*Wood Chips*	*Bed Sand*	*Σ In*	*Fly Ash*	*Scrubber Water Influent*	*Scrubber Overflow*	*Scrubber Discharge*	*Net Scrubber Discharge*	*Particulate Filtrable*	*Impinger Catch*	*Σ Out*
Ca	2.16E04*	4.14E04	1.15E03	6.42E04	2.09E04	1.56E04	3.69E03	2.22E04	1.03E04	—†	—	3.12E04
Al	3.13E04	3.40E02	1.07E03	3.27E04	2.70E04	4.66E01	2.29E01	1.15E02	9.13E01	—	2.19E00	2.71E04
P	1.43E04	1.30E03	1.24E01	1.56E04	3.80E03	—	—	—	—	9.54E-01	—	3.80E03
K	7.20E03	6.15E03	2.86E02	1.36E04	1.35E04	1.19E03	2.90E02	1.16E03	2.60E02	2.24E00	—	1.38E04
Ti	1.23E04	4.91E01	1.55E02	1.25E04	1.87E03	—	—	2.11E01	—	1.72E-01	—	1.89E03
Fe	9.23E03	5.78E02	1.15E03	1.10E04	9.91E03	1.79E02	2.16E02	1.59E02	1.96E02	1.69E-01	—	1.01E04
S	9.51E03	1.52E03	9.16E00	1.10E04	8.86E02	4.63E03	1.21E03	8.80E03	5.38E03	1.59E00	3.49E01	6.30E03
Mg	6.13E03	2.59E03	3.44E02	9.06E03	5.33E03	3.32E03	7.92E02	3.55E03	1.02E03	—	—	6.35E03
Na	3.02E03	8.57E02	2.67E02	4.14E03	2.60E03	3.80E04	8.73E03	3.00E04	7.30E02	—	1.60E01	3.44E03
Zn	1.26E03	3.26E02	1.81E00	1.59E03	8.91E02	6.53E00	2.22E00	1.89E01	1.46E01	—	—	9.06E02
Ba	5.15E02	1.89E02	7.25E02	7.11E02	3.54E02	1.96E01	5.45E00	4.49E01	3.08E01	3.19E-02	2.86E-02	3.85E02
Mn	3.64E02	1.44E02	1.78E01	5.26E02	3.15E02	4.72E01	1.69E01	7.77E01	4.74E01	3.41E-02	—	3.62E02
Cu	2.02E02	1.11E01	1.47E00	2.15E02	1.13E02	—	—	9.63E00	9.63E00	—	—	1.23E02
Pb	1.44E02	—	5.54E-01	1.45E02	—	—	—	—	—	—	—	—
Sr	6.88E01	5.71E01	2.67E00	1.29E00	6.75E01	2.35E01	5.58E00	3.11E01	1.32E01	4.49E-03	—	8.07E01
Cr	3.91E01	—	2.67E00	4.18E01	3.90E01	—	—	—	—	—	—	3.90E01
V	3.84E01	—	3.44E00	4.18E01	2.01E01	—	—	—	—	—	—	2.01E01
Ni	3.39E01	—	1.22E00	3.50E01	2.21E01	—	—	—	—	1.45E-02	—	2.21E01
Co	2.99E01	—	8.40E-01	3.07E01	8.73E00	—	—	—	—	—	—	8.73E00
Si	2.34E01	—	1.36E00	2.48E01	3.79E02	1.73E03	4.27E02	2.39E03	1.09E03	1.26E00	4.23E01	1.51E03
Mo	1.20E01	—	1.87E-01	1.22E01	1.48E00	—	—	—	—	—	—	1.48E00
B	—	—	3.82E00	3.82E00	5.76E01	—	—	—	—	—	—	5.76E01
Li	—	—	—	2.75E00	—	—	—	—	—	—	—	2.75E00
Be	7.09E-01	—	—	7.09E-01	—	—	—	—	—	—	—	—
Cd	—	—	1.91E-01	1.91E-01	—	—	—	—	—	—	—	—

**Results reported in computer notation, e.g., 2.16E04 = 2.16 x 10^4 = 21,600.*
†Dashes indicate that the concentration of the reported element was below the detection limit in one, two, or all three of the samples analyzed.

The user must then specify the mode of analysis desired for this run.

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The complete report, entitled "Evaluation of a Fluidized-Bed Sewage Sludge Incinerator Using Wood Chips for Fuel," (Order No. PB 86-183 092/AS; Cost: $11.95, subject to change) will be available only from:
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