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Project Summary

Total Hydrocarbon Emission Testing of Wastewater Sludge Incinerators

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The U.S. Environmental Protection Agency (EPA) is considering a regulatory requirement for continuous monitoring of total hydrocarbon (THC) emissions from all wastewater sludge incinerators. This study was conducted to determine the reliability of total hydrocarbon analyzers (THCAs) in this application.

Continuous monitors for oxygen (O_2), carbon monoxide (CO), THC, and temperature were installed at two municipal wastewater sludge incinerators. The O_2 data were used to normalize the measured THC concentrations to 7% O_2. CO was measured to determine if it could be used as a surrogate for THC measurements.

The two THCAs performed very well, achieving 94% and 90% on-line availability at the two sampling sites, respectively. The O_2 and CO analyzers also worked well. There were initial problems with the sample conditioning system that is necessary for the CO and O_2 monitors, but successful operation was achieved after it was modified. The average hourly THC concentrations, normalized to 7% O_2, were 108 and 88 parts per million by volume (ppmv) for the two sites.

The corresponding CO concentrations were 1,071 and 1,091 ppmv. The CO and THC data showed a poor correlation. Several short runs were made under high turbulence firing conditions, and others were made with the use of an afterburner. These short runs ranged from 15 min to about 5 hr and achieved O_2 normalized THC concentrations of less than 30 ppmv.

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

The EPA Office of Water (OW) drafted risk-based sludge regulations (for incineration and a variety of other options) under Section 405d of the Clean Water Act. The proposed regulations were published for public comment in the *Federal Register*.* Being considered for the final regulation is a provision for continuously monitoring THC emissions as a method of controlling organic emissions from sludge incineration. The monitoring would have to demonstrate that the THC stack emissions were not exceeding a concentration limit.

To evaluate THC monitoring the EPA Risk Reduction Engineering Laboratory (RREL) implemented a study for OW to operate total hydrocarbon analyzers (THCAs) over a 3-mo period at two municipal wastewater sludge incineration facilities. Continuous analyzers for THC, CO, and O_2 were installed and operated at the two facilities, (Site THC-1 and Site THC-2) both of which employed multiple-hearth furnaces (MHFs) to incinerate wastewater sludge. In addition, EPA requested an evaluation of the use of these monitors to assist with improving incinerator operation.

* Fed. Reg., 54 (23): 5746-5902, Feb. 6, 1989.

Description of Facilities

Site THC-1 had been previously studied by the EPA. The results of that study are contained in EPA report "Emissions of Metals, Chromium and Nickel Species, and Organics From Municipal Wastewater Sludge Incinerators, Volume III: Site 6 Emission Test Report"†. Site THC-2 had also been previously studied, but different incinerators were tested in that EPA study.

Site THC-1 is a publicly operated treatment works (POTW) that processes an average of 30 million gallons per day (mgd) of wastewater. The sludge furnace operates 24 hr per day, 5-3/4 days per week. Sludge is dewatered before incineration to reduce sludge-cake water content to 70% to 75% by weight. A gravity thickener is used to increase the percentage of solids in the primary sludge, and a flotation thickener processes the secondary sludge. Lime slurry and ferric chloride solution are used to condition the sludge drawn from a storage tank. Four recessed-plate filter presses are used to dewater the conditioned sludge before transport to the furnaces.

Site THC-1 has two identical Nichols* eight-hearth, MHFs; only one is operated at a time. Sludge is screw fed into the side of Hearth #1. The air pollution control system consists of an adjustable-throat venturi scrubber, followed by a two-plate impingement tray scrubber.

The project at Site THC-1 was conducted under normal plant and incinerator operating conditions. During the test program, the unit operated a total of 1,690 hr out of a total of 2,232 possible hr, representing a 76% on-line operation.

Site THC-2 is a POTW treating approximately 40 mgd of primarily domestic wastewater. Solids processes at the facility are: gravity thickening of chemically treated (ferric chloride) primary sludge; flotation thickening of waste-activated sludge; mixing/storage of thickened sludges; chemical conditioning/dewatering of sludge by a combination of a vacuum filter, belt press, and membrane-type filter press; and incineration using multiple hearth incinerators.

Site THC-2 has two identical MHFs, only one of which is operated at a time. During this study, both furnaces were used. The furnaces are eight-hearth units, approximately 22 ft diameter, built in 1979 by Nichols Engineering.

†EPA 600/R-32/003c, PB 92-151570/AS. March 1992.

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

Throughout most of this study, tests at Site THC-2 were conducted under normal plant and incinerator operating conditions. Because of ongoing plant modifications, however, several problems were encountered. These problems related to changes in the dewatering system and modifications to the burner control circuit. Other problems at Site THC-2 included the failure of an induced draft (ID) fan bearing and a fire in the sludge conveyor and control wiring. During the test program, Site THC-2 operated a total of 1,533 hours out of a possible 2,184 hours, representing a 70% on-line operation.

Procedures

Sampling sites at both facilities were located in a transition section between the ID fan and the outlet stack, downstream of the scrubber and demister but upstream of the shaft cooling air point of entry. Detailed descriptions of each sampling site are presented in the report.

Continuous emission monitors (CEMs) were used to monitor THC, CO, and O_2 in the sludge incinerator exhaust gases. Exhaust gas temperature was monitored with a thermocouple. The analyzer and thermocouple outputs were recorded on a computer with the use of an electronic data acquisition system. The analyzer outputs were also recorded on strip charts.

The THCA sampling system for both sites consisted of a probe, a three-way calibration valve, and a heated sample line. The heated sample line connected directly to the oven section of the THC as manufactured by J.U.M. Engineering. Inside the oven, which was maintained at 190°C, was a sample filter, a pump, a sample flow control capillary, and a flame ionization detector.

The O_2/CO sampling system was more complex. The initial system had a sintered stainless steel filter attached to the probe inlet. This system suffered repeated blockage of the sintered stainless steel filter. The redesigned system had a 1/4-in. OD stainless steel probe that was open at the inlet.

At Site THC-1, a Wilkerson compressed air line water trap was attached to the three-way valve, which was connected to a Nutech heated filter box and glass filter holder. The outlet of the filter holder was connected to a heated sample line.

At Site THC-2, a Gast model V400G filter jar was attached to the three-way valve, and the heated line was attached to the filter jar. This water knockout trap had a 7 oz capacity whereas the one at Site THC-1 held 32 oz. The varying complexity of the two systems demonstrated how different water knockout/filter designs can be used, depending on the amount of contamination in the sampled gas. The rest of the O_2/CO sample acquisition system was the same at both sites, including a two-pass refrigeration unit.

A thermocouple was installed in the refrigeration unit outlet line to monitor the gas stream temperature. Linearized output from the temperature readout was fed to the data logger. The THCA unit at Site THC-1 was a model VE-7AP, and the unit at Site THC-2 was a model VE-7 with an add-on autopurge module. The THC analyzers were calibrated by using propane in air standards prepared by Scott Specialty Gases.

Servomex model 1420 O_2 analyzers measured the O_2 content of the exhaust gas at the THC sampling location. These analyzers utilize the paramagnetic measurement technique.

Milton Roy Corporation model 3300 analyzers measured the CO concentration in the exhaust gases. These analyzers use a nondispersive infrared technique to measure gas concentration. The exhaust gas temperature was measured with an Omega Engineering, Inc., model KQ55-14G Type K thermocouple connected to an Omega model TAC-30 analog converter. The thermocouple produces a voltage proportional to temperature, and the analog converter provides electronic reference junction compensation and a linearized output so that 1 millivolt equals 1 degree.

Outputs from the THC, CO, and O_2 analyzers and the various thermocouples were recorded on an Odessa model DSM 3260 data acquisition/data reduction system. The Odessa was connected to a Walkabout 386-SX laptop computer.

Most data processing was performed by DEECO, Inc., as DEECO had processed continuous monitoring data from other EPA test sites. Data from this study were recorded in the same format used in previous studies so EPA could enter the data into its THC database. THC concentrations, measured on a wet basis, were converted to a dry basis.

Columns were created in the data spreadsheets for: THC concentrations corrected to 7% O_2; hourly average O_2 concentrations; hourly average CO concentrations with off-scale data; hourly average CO concentrations with no off-scale data; hourly average O_2-corrected THC concentrations with off-scale data; and hourly average O_2-corrected THC concentrations with no off-scale data.

A comprehensive quality assurance/quality control (QA/QC) program was implemented for this testing project to as-

sess the data quality and to establish limitations on the ultimate use of the data. The objective of this QA/QC program was to optimize precision, accuracy, completeness, comparability, and representativeness for each major measurement parameter of the test program. Data quality objectives for the THC, CO, and O_2 continuous monitors are presented in Table 1.

Table 1. *Summary of Estimated Precision, Accuracy, and Completeness Objectives*

Parameter	*Objective*
Precision	*± 20%**
Accuracy	*± 20%†*
Completeness	*90%‡*

* *Coefficient of variation (CV) determined from periodic analyses of a control sample, where*

$$\%\ CV = \frac{\text{Stand Deviation} \times 100}{\text{Mean}}$$

† *Relative accuracy (RA) determined from the difference between the known concentration of the cylinder gases and the concentrations indicated by the CEMs, where RA = |difference/actual concentration x 100|*

‡ *Valid data percentage of total hours sampled.*

Four-point calibration error (linearity) checks were made at the beginning and end of the study and each time a new or modified analyzer was installed. Collected data show that the analyzers were routinely well within the allowable ±3% of span. The maximum error observed for any of the linearity checks was 1.6% for CO, 0.87% for O_2, and 1.0% for THC.

Bias checks were conducted at the beginning and end of the study and periodically during the study when the sampling line was disassembled to ensure that the sampling system was not leaking. All bias checks were below the allowable ±5% of the control gas value. The maximum bias check error observed was 1.6%.

Zero and span drift checks were performed throughout the study. The allowable zero and span drift error, calculated as a percentage of the span, was ±5%. The maximum zero and span drift observed were 0.6% and 2.0%, respectively.

Because different coefficient of variation had to be calculated for each span gas used during the study, there was more than one value for each analyzer. All of the coefficient of variation results were well below the maximum allowable ±20%.

The relative accuracy of the continuous monitors was determined from the analysis of special audit gases. The results were all well below the ±20% maximum allowable. The largest relative accuracy error was 2.35%.

Results

At Site THC-1, data collection began on June 8, 1991, and ended on September 9, 1991. At Site THC-2, monitoring ran from June 11, 1991, to September 10, 1991.

During the study, the various analyzers worked well with a minimum of maintenance under a wide range of operating conditions. Concentrations of THC and CO were, however, often much higher than anticipated.

Significant problems occurred at the beginning of the study with the sample conditioning system for the O_2 and CO analyzers. The initial sample conditioning system design was prone to plugging, but after the system was redesigned, satisfactory operation was achieved.

In future applications, it appears that problems associated with particulate and liquid water removal can be solved with relatively simple water knockouts and filters. Water vapor removal, however, requires more complicated mechanical equipment that will increase maintenance requirements by plant personnel.

The EPA criteria for determining THCA analyzer reliability was on-line availability of the analyzers. These results are presented in Table 2.

Table 2. *THCA On-Line Availability*

Site	*Furnace Operating Hours*	*THCA Operating Hours*	*THCA Availability (%)*
THC-1	*1,681*	*1,579*	*94*
THC-2	*1,508*	*1,355*	*90*

The target of having the THCAs operating at least 90% of the time that the plant was operating was achieved at both sites. At Site THC-1, 94% availability was achieved and at Site THC-2, 90%.

A THCA failed to reignite on nine occasions after an automatic backpurge cycle. Six of these occurrences, at Site THC-1 during August, resulted in 53 hr of lost data. The problem was corrected by adjusting the flame-out potentiometer inside the analyzer. The THCA failed to reignite three times at Site THC-2, and 184 hr of data were lost. These failures occurred in July, August, and September.

Had the flameout been noticed sooner during routine inspection, the analyzer could have been repaired more quickly, and Site THC-2's availability would have been considerably better. No other repairs or maintenance had to be performed other than the flame-out potentiometer adjustment and a sample line clean out. A total of 3 hr and 15 min were spent maintaining the two THCAs.

THC concentrations were initially significantly higher than had been anticipated and resulted in stack gas concentrations that exceeded the designated range of the THCAs. Operating ranges of the THCAs were subsequently expanded to compensate for this problem. THC concentrations were normalized to 7% O_2. Daily averages were calculated for those days that had 13 or more hours of data.

Neither plant achieved a O_2-normalized THC concentration of 30 ppmv or less. Most were considerably higher. At Site THC-1, concentrations of less than 30 ppmv or less were achieved for only 100 hr and at Site THC-2 for 51 hr.

The overall average hourly concentration at THC-1 was ≥108 ppmv and at THC-2, ≥88 ppmv. The average daily concentration: (1) for days with all data on scale was 81 ppmv for THC-1 (10 days) and 74 ppmv for THC-2 (29 days); (2) for days with off-scale data was ≥117 ppmv for THC-1 (25 days) and ≥118 ppmv for THC-2 (5 days); and (3) as an overall average was ≥107 ppmv for THC-1 and ≥81 ppmv for THC-2. The maximum daily concentration for THC-1 was ≥272 ppmv and for THC-2 ≥188; the minimum daily concentration for THC-1 was 40 ppmv and for THC-2, 44. For periods with off-scale values, the maximum scale reading was used for calculation of these averages, yielding equal-to-or-greater-than values.

The CO monitors worked very well during the study, and there was one serious problem and two minor problems with the O_2 monitors. The O_2 monitor at Site THC-1 had a loose output connector that caused lost data in July, and in September, the analyzer failed completely. A replacement analyzer was obtained, and the failed unit was returned for repair.

Another minor problem was encountered with the Site THC-2 O_2 monitor, when the dumbbell inside the unit became stuck. The dumbell deflects in a varing magnetic field to provide a reading proportional to O_2 concentration. Tapping the side of the case released the stuck dumbell, and no other problems occurred.

The CO data from both sites had frequent off-scale excursions. The concentrations were higher than had been encountered on previous EPA tests. Thus, expanded-range analyzers were installed at Site THC-1 on August 15 and at Site THC-2 on August 5. Even with the higher range, both sites still had a number of off-scale excursions. The overall average hourly concentration for the THC-1 was 1,071 ppmv and for THC-2, 1,091 ppmv.

In comments to EPA, CO was suggested as a surrogate for THC measurements. This led to a second objective of the project—to determine correlations between THC and CO concentrations. Data from August were chosen for these analyses because both the analyzers and the furnaces performed best during that time period. For meaningful analysis, it is also important that the correlation be determined for values near the expected emission standard. Results of the linear regression analyses for data ranging from 10 to 50 ppmv are shown in Table 3. The correlations developed for both sites do not appear to support the use of CO concentrations for estimating THC concentrations.

The use of breaching temperature as a possible surrogate for THC concentrations was also suggested. These correlation analyses were also performed with August data. Results of the analyses for Sites THC-1 and THC-2 (Table 4) do not reflect a strong correlation between THC and breaching temperature.

Several operations test runs were conducted at Site THC-2 during the weeks of August 5 and August 12, 1991, to determine if lower THC emissions could be obtained with relatively minor changes in furnace hardware or operating conditions, or both. Two different scenarios were tried. One involved inducing more turbulence within the hearths with special air-fuel mixing valves (i.e., a high turbulence [HT] run). In addition to this analysis, several runs were made using the afterburner to evaluate THC and CO reduction at different afterburner temperatures.

The HT run was achieved during a 5-hr period between August 8 and August 9, 1991. THC concentrations were shown to vary between 10 and 25 ppmv normalized to 7% O_2 during this 5-hr test, with the exceptions of a spike condition resulting in a value of approximately 65 ppmv (normalized). The spike condition was caused by a momentary stoppage in the sludge feed.

A second series of runs, on August 14, 1991, evaluated the use of an afterburner to achieve desired emission limits. These tests were at an afterburner temperature of 1400°F. During this series of runs, THC emissions decreased from an observed value of approximately 50 ppmv before starting afterburner to approximately 5 to 10 ppmv whenever the afterburner was on.

On August 16, 1991, a second analysis of afterburner effectiveness was conducted at temperatures between 1100°F and 1400°F. These test runs showed an inverse relationship of afterburner temperature to THC emissions. Under these reduced afterburner temperatures, emissions varied between 7 to 21 ppmv.

Table 3. *Correlation of THC and CO*

Site	Linear Regression Equation	Number of Observations	R^2
THC-1	CO = (20.4)(THC) + 247	3,028	0.525
THC-2	CO = (22.0)(THC) + 232	8,190	0.455

Table 4. *Correlation of THC and Breaching Temperature*

Site	Linear Regression Equation	Number of Observations	R^2
THC-1	Temp. = (-1.102)(THC) + 929	3,028	0.012
THC-2	Temp. = (-1.316)(THC) + 867	8,190	0.085

Conclusions

In terms of equipment operation, the two J.U.M. Engineering THCAs worked reliably at both MHF wastewater sludge incinerators. It is believed that the success of these analyzers was significantly affected by the unique sample filtering and backpurging system used by J.U.M. The CO analyzers also performed very well. No downtime was caused by analyzer failure; rather all downtime was caused by failures of the sample acquisition/conditioning system, which was external to the analyzers. The Servomex O_2 analyzers performed well, despite two analyzer-related problems.

Based on the data collected in this study, there was poor correlation between THC and CO concentrations, and there was essentially no correlation between THC concentration and breaching temperature. As indicated in this summary, sample conditioning systems are critical to acquisition of reliable CO and O_2 data when using extractive monitors. If not properly designed, or maintained, or both, such sample conditioning systems can cause significant operating problems. For O_2 monitors, the sample conditioning system can be eliminated by using an *in-situ* monitor rather than an extractive monitor.

On a limited basis, the study examined operating the incinerator afterburner at lower temperatures and also examined two potentially less expensive process modifications (that might offer an alternative to afterburners). External afterburners are effective in reducing CO and THC emissions, and it appeared that emissions less than 30 ppmv may be achieved at temperatures less than 1,400°F. Only a short demonstration of this was possible during this study, however. A limited test program also demonstrated that lower THC emissions may be achieved by increasing the gas phase turbulence within the hearths while simultaneously raising the exhaust temperature by firing most of the auxiliary fuel above the combustion hearth. It was beyond the scope of this study, however, to demonstrate that these techniques are viable for long-term operation.

The test program reverified that an MHF is inherently unstable. The extremely wide variation in CO and THC emissions shown in this study indicates that substantial changes in operating procedures probably will be required to comply with the new regulations. For many plants, equipment modifications may also be necessary.

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The complete report, entitled "Total Hydrocarbon Emission Testing of Wastewater Sludge Incinerators," (Order No. PB92-197086/AS; Cost: $19.00; subject to change) will be available only from:
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