Air emission studies of sewage sludge incinerators at the Western Branch wastewater treatment plant

Lawrence H. Hentz, Jr., Floyd B. Johnson, Allen Baturay

ABSTRACT: ... ensive air emission tests were conducted on ... multiple-he... erators equipped with venturi scrubbers, af... and ... afterburners. A pilot wet electrostatic precip... was also ... its ability to reduce emissions from existing ... Partic..., metals, organics, and acid gas emissions were ... by rig... procedures. Tests of existing systems indicated ... equipm... pable of reducing particulate emissions to less ... 0.38 kg... udge input. More than half of the particulate ... penetrati... g equipment was less than 0.6 μm in diameter. ... indica... bmicron particles were enriched with volatile ... The ex... ment demonstrated cadmium and lead control ... that ... icantly higher than those assumed in proposed ... ations. I... sludge concentrations and high site-specific ... efficien... ic and cadmium emissions will exceed limits ... ed in re... ions. Dispersion factor corrections or reductions ... admium a... emissions will be needed to satisfy proposed ... ations. En... s indicated that a wet electrostatic precipitator ... greatly enh... removal of particulate matter, metals, and total ... carbons t... rated the existing systems. *Water Environ. Res.*, ... 1 (1992)

KEYWORDS: ... missions, electrostatic precipitator, incineration, ... regulation... udge, volatile organic compounds.

National regulations specific to air emissions from sewage sludge incinerators have been limited to standards for particulate matter (PM) and opacity since 1974 (U. S. EPA, 1974). Today, the public is demanding a higher level of control of air emissions. The public wants assurances that air emissions do not pose an unacceptable risk to public health and are environmentally safe. As a result, the U. S. Environmental Protection Agency (EPA) has recently begun revising and proposing regulations intended to protect human health and the environment.

One of the first revisions to sewage sludge incinerator regulations was promulgated on October 6, 1988. On that date, the EPA issued "Standards of Performance for New Stationary Sources; Sewage Treatment Plants" (1988). These regulations are commonly referred to as New Source Performance Standards (NSPS). These regulations limit PM emissions to 0.65 kg/Mg (1.3 lb/ton) of dry sludge input and specify monitoring, recording, and reporting requirements for incinerators constructed after June 11, 1973. In addition, the regulations require performance tests to measure PM and metal emissions. Certain monitoring, recording, and reporting requirements are waived if the PM emissions during the performance test are less than 0.38 kg/Mg (0.75 lb/ton) of dry sludge input.

The most recent sewage sludge incinerator regulations were proposed on February 6, 1989, when the EPA issued "Standards for the Disposal of Sewage Sludge; Proposed Rule" (1989a). These regulations are commonly referred to as the proposed Part 503 regulations. Subpart G of the proposed Part 503 regulations establishes limits for metal and organic emissions from sewage sludge incinerators. Total hydrocarbon concentrations (THC) are limited in the combustion gas from incinerators. Arsenic, beryllium, cadmium, chromium, lead, mercury, and nickel emissions are controlled by limiting their concentrations in the sludge entering the incinerator.

The proposed Part 503 regulations are based on limiting health risks to a most exposed individual (MEI) inhaling emissions downwind of an incinerator. The maximum allowable metal concentration in the sludge is calculated using conservative dispersion factors and assumed emission control efficiencies. Control efficiency is defined as the effectiveness of an incinerator and associated emission control equipment to prevent the release of a contaminant. Except for beryllium and mercury, assumed control efficiencies are based on the lowest tenth percentile control efficiencies of wastewater sludge incinerators in EPA's database. Beryllium and mercury concentrations are based on National Emission Standards for Hazardous Air Pollutants (NESHAPs). The proposed Part 503 regulations allow for increasing the maximum metal concentration in the sludge if site-specific control efficiencies are determined during performance tests. The proposed Part 503 regulations also allow site-specific dispersion factors if they are determined by an approved air dispersion model.

EPA projected that 122 of 194 sewage sludge incinerator facilities would fail to comply with numerical limits proposed in the Part 503 regulations. This assessment was based on assumed control efficiencies and dispersion factors. In general, most existing sewage sludge incinerators have not been tested to determine specific control efficiencies for regulated contaminants. The database used by the EPA to establish emissions control efficiencies is small and is not normalized according to the type of incinerator or air emission control device. Therefore, it is difficult for owners, operators, and designers of incinerators to determine the effects of the proposed regulations on existing or proposed incinerators. Also, few data are available on sewage sludge emission control efficiencies for newer air emission control equipment such as electrostatic precipitators, scrubbers, and baghouses. Therefore, site-specific air emission tests are necessary to determine the facilities and equipment capable of complying with proposed regulations.

The Washington Suburban Sanitary Commission (WSSC) owns and operates two wastewater sludge incinerators at the Western Branch Wastewater Treatment Plant (WWTP). The Western Branch WWTP is an advanced wastewater treatment facility designed to treat 113 ML/d (30 mgd) of domestic wastewater. The solids-handling facilities at the Western Branch WWTP include dissolved air flotation thickeners, thermal conditioning equipment, three centrifuges, and two multiple-hearth furnaces (MHFs). The MHFs consist of seven hearths that are 4.27 m (14 ft) in diameter. Each of the MHFs is designed to process 23.6 dry metric tons per day (dmtpd) of heat-treated sludge at approximately 35% dry solids. The MHFs are equipped with venturi scrubbers and impingement plate aftercoolers.

When the recent regulations were issued, the WSSC was considering improvements to increase the capacity of existing incinerators. In response to numerous odor complaints, the WSSC had decommissioned the thermal conditioning equipment in 1984 and converted the top hearth of each incinerator to a "zero" hearth afterburner. Although this reduced odors considerably, the solids destruction capability of each incinerator was significantly diminished. The shut-down of the thermal conditioning system caused the sludge solids entering the incinerators to drop to approximately 21% dry solids. The increased water added to the MHFs and the conversion of the top hearth to an afterburner reduced the available burn area within each incinerator. As a result, the solids destruction capability of each incinerator was reduced to approximately 50% (11.8 dmtpd) of its design capacity. Therefore, the WSSC investigated various improvements to restore the capacity of the incinerators.

As WSSC became familiar with the requirements of the new regulations, it became apparent that there were insufficient data to determine the effects of these regulations on existing MHF operations and proposed improvements. A preliminary assessment using assumed control efficiencies indicated that cadmium and total hydrocarbon concentrations could be higher than permitted by proposed Part 503 regulations. For this and other reasons, improvements to the incinerators were delayed pending an analysis of the necessary data. The performance test required by the NSPS regulations provided the opportunity to collect the necessary data and investigate methods of reducing metal and organic emissions. Thus, a testing program was established with the following objectives:

- To conduct a performance test of the incinerators as specified in the NSPS regulations,
- To determine THC emissions and metal control efficiencies for the existing incinerators and emission control equipment, and
- To pilot test a wet electrostatic precipitator (WESP) and determine its ability to reduce air emissions from the existing incineration systems.

Methods and Materials

Comprehensive tests of both incinerator systems and a pilot WESP (SonicKleen Model 12-8H10, Sonic Environmental Systems, Parsippany, N. J.) were conducted September 19–23, 1989, by a laboratory specializing in atmospheric emissions testing. The pilot WESP was sized to treat a nominal gas flow of 43 actual m^3/min (1500 acfm) at saturated conditions. The WESP was provided flue gas from incinerator No. 2 by way of a 20-cm slipstream inserted into the existing scrubber exit stack. Figure 1 shows the placement of the pilot WESP system in the existing incineration system. A reversed nozzle was inserted into the incinerator stack to collect a representative sample of flue gas. The

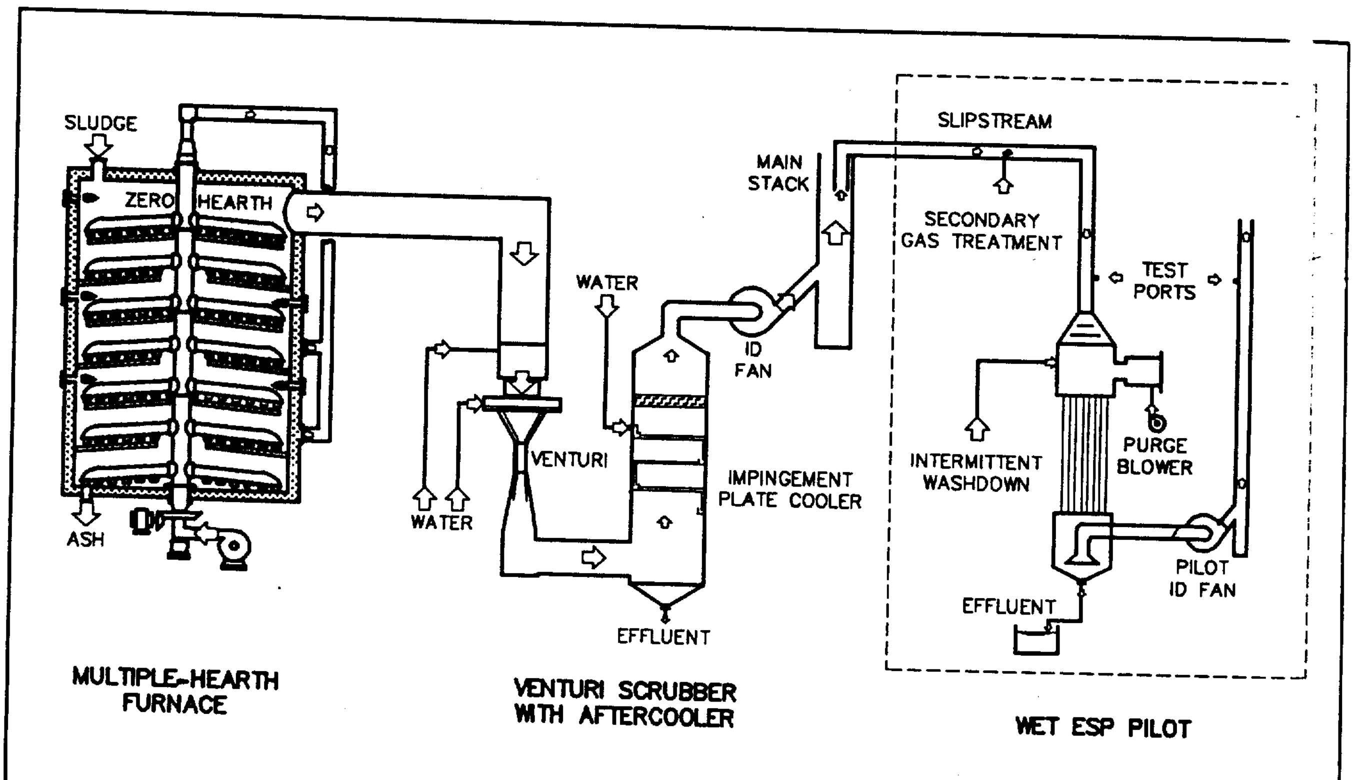


Figure 1—Air emission control systems.

... to the WESP was approximately 25% of the total gas ... the incinerator stack. Stack sampling was conducted simultaneously at the WESP inlet and outlet.

The pilot WESP was a vertical, downflow tube-type unit ... with rigid mast precipitating electrodes, hexagonal ... electrode tubes, gas distribution devices, and intermittent fog irrigating water sprays. Figure 2 provides a cut-away ... of the WESP. The pilot WESP was delivered in three preassembled sections. The sections included necessary piping, wiring, equipment, and controls necessary to operate the unit. The pilot ... required 60 ... amps of power at 480 volts, 57 L/min (15 gpm) ... water for intermittent washdown and flush, and 0.4 m^3/min ... compressed ... for operating the spray washdown nozzles.

Each incinerator was tested in accordance with NSPS regulations. Flue gas velocity, temperature, composition, and molecular weight measurements were taken as required by EPA ... methods ... 3 (U. S. EPA, 1987). Particulate emissions ... were ... ically conducted in accordance with test ... 5 (U. S. EPA, 1987). After gravimetric determinations ... particulate ... er, the samples were digested and analyzed ... arsenic, ... m, cadmium, chromium, copper, lead, mercury, nickel ... um, and zinc by using inductively coupled ... and ... absorption analytical techniques. Sludge feed samples were ... cted at 30-minute intervals during the particulate ... ion tests. Metals in the particulate and sludge ... samples ... determined by digestion and analytical procedures as ... bed in "Test Methods for Evaluating Solid Waste" (U. S. EPA, 1986). Sludge feed samples were also analyzed for ... t moisture and percent volatiles by methods ... 216 (M... Determination, 1980) and 2540G (Standard Methods, ... respectively.

Data rec... for the proposed Part 503 regulations were also collected. ... valent chromium samples were collected in a method 1... ample train (U. S. EPA, 1987). Each sample was analyzed by methods 3060 and 7196 (U. S. EPA, 1982). These methods ent... extraction with an alkaline solution and determination by the diphenylcarbazide colorimetric method. Continuous THC measurements were conducted in accordance with ... method 25A (U. S. EPA, 1987) at the incinerator outlets and the WESP inlet and outlet. Flue gas carbon monoxide (CO) content was determined by test method 10 (U. S. EPA, 1987) using a Bendix (Baltimore, Md.) nondispersive infrared analyzer.

Additional data relevant to the performance of the existing incinerators and WESP were also collected. WESP flush water and bottom residue were analyzed for metals in accordance with procedures used for sludge feed samples. WESP flush water was also analyzed for pH, chloride, and sulfate concentrations (Methods for Chemical Analysis, 1983). Nitrogen oxides (NO_x) and sulfur dioxide (SO_x) in the flue gas from incinerator No. 1 were measured according to EPA test methods 7A and 6, respectively (U. S. EPA, 1987). Particulate size distribution measurements were collected at the inlet to the WESP using an Andersen Mark III impactor (Atlanta, Ga.). Eight cut-point stages and a glass-fiber backup were used to gravimetrically determine particulate size. Cut-points for the impactor stages were calculated by computer program (South. Res. Inst., 1980). All particle sizes are based on a particle density of 1 g/cm^3.

Results and Discussion

NSPS tests. The first set of stack tests were conducted in accordance with NSPS regulations. In addition, the NSPS tests were observed by representatives of the Maryland Air Management Administration. Each incinerator was operated at peak sludge capacity (14.6 dmtpd) and controlled to achieve the lowest possible emission rates. The zero hearth afterburners were operated at approximately 760°C (1400°F) and the venturi scrubbers were operated with a maximum sustainable pressure drop of 44 cm (17 in.) water column. Table 1 indicates the operating conditions for incinerator No. 1. Data provided in Table 1 represent an average of three separate measurements. Each measurement is based on samples collected over a 1-hour time period. Each measurement was generally within 10% of the average. Operating conditions and results for incinerator No. 2 were similar.

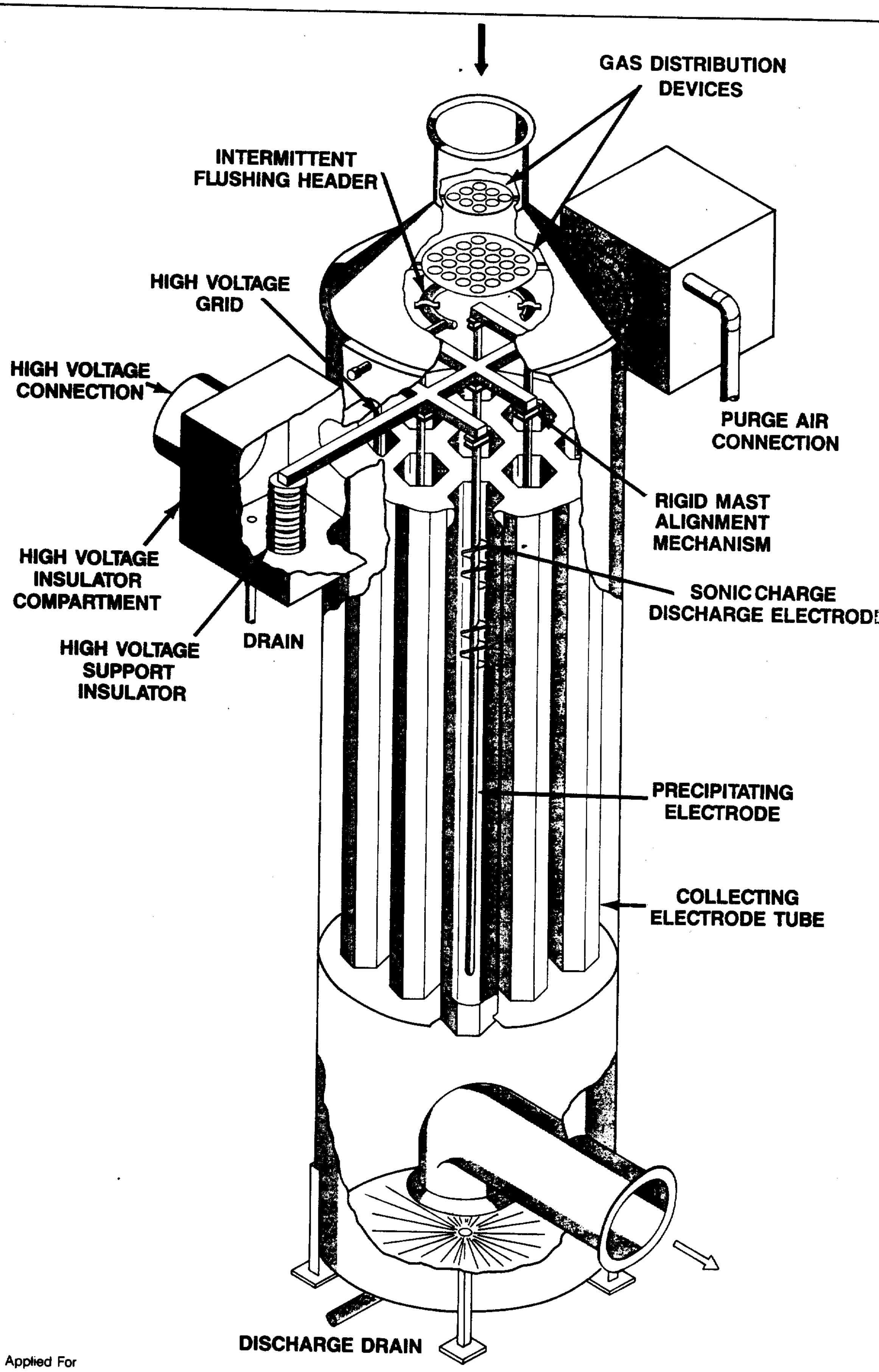
The NSPS tests demonstrated that both multiple-hearth furnaces emit particulate matter less than 0.38 kg/Mg (0.75 lb/dry ton) of dry sludge input. During the NSPS performance tests, the PM in the flue gas from incinerators 1 and 2 averaged 33.9 mg/m^3 (0.014 8 gr/dscf) and 36.6 mg/m^3 (0.016 0 gr/dscf), respectively. These measurements are corrected to 12% carbon dioxide. These data are similar to measurements made by Western Branch laboratory personnel on a monthly basis for the past 5 years. At the sludge feed rates experienced during the NSPS tests, these PM concentrations equate to emissions of 0.253 kg/Mg (0.506 lb/dry ton) and 0.22 kg/Mg (0.440 lb/dry ton) of dry sludge input, respectively.

Low PM emissions measured during the NSPS tests reduced the continuous monitoring and recording requirements at Western Branch. In accordance with NSPS regulations, continuous monitoring at Western Branch is limited to venturi pressure drop and flue gas oxygen content. Reporting requirements are limited to deviations from the test level pressure drop and oxygen content by more than 30% and 3 percentage points, respectively. These deviations must be maintained for 15 minutes and 1 hour, respectively, before a report is required. If the PM emissions during the NSPS tests were greater than 0.38 kg/Mg, continuous monitoring of hearth temperature, fuel usage, sludge flow, sludge moisture, and sludge volatility would be required. In addition, reports would be required if the venturi pressure drop deviated by 17%.

Although low PM emissions significantly reduced the monitoring, recording, and reporting requirements for the Western Branch facility, the WSSC installed a computer monitoring system to assist in data handling and report generation. From January 1, 1990, to June 30, 1991, Western Branch incinerators were operated 14 841 hours. During that period, incinerators were operated within the NSPS pressure drop and oxygen limits 99.1% of the time. Most of these limited excursions were due to high oxygen levels in the flue gas.

NSPS stack tests also indicated that the existing venturi and aftercooler equipment significantly reduced metal emissions. Table 2 provides average metal emission rates and control efficiencies for incinerator No. 1. In general, average control efficiencies were better than or equal to those assumed in the proposed Part 503 regulations. Cadmium and lead control efficiencies were considerably higher than those assumed in the proposed Part 503 regulations. This is significant because all of the noncarcinogenic aggregate human health effects attributed by EPA to current incineration practices were due to lead and cadmium emissions (U. S. EPA, 1989b). EPA projected that incineration of sewage sludge is currently causing the blood levels of 129 835 people in the U. S. to exceed 10 μg/dL of lead. This concentration

SonicKleen™ Wet Electrostatic Precipitator



Patent Applied For

Figure 2—SonicKleen™ wet electrostatic precipitator.

—Incinerator No. 1 average operating conditions.

Process conditions		Flue gas conditions	
ed rate,	2315	Volumetric flow rate	
		Actual, m^3/min	155.4
composition			(5490 acfm)
re, %	73.7	Dry standard,	
es, % of solids	71.5	m^3/min	125.7
O, N, % of	41, 7, 20, 4		(4440 dscfm)
ds		Temperature, °C	82.8
alue, kcal/kg	4283	Moisture, %	3.34
		Oxygen, %	11.8
ressure drop,	44.2	Carbon dioxide, %	7.3
H_2O			
ressure drop,	32.8		
H_2O			
, L/min	1.36		
emperatures, °C			
h 0	739		
h 2	669		
h 4	753		
h 6	418		

ablished as the level for concern for infants, children, and nsive adults. EPA also concluded that 794 people would d the reference dose (RfD) for cadmium. This baseline assessment assumed incinerator control efficiencies of and 74.61% for lead and cadmium, respectively. As seen ble 2, Western Branch control efficiencies were 98.4 and , respectively. Therefore, the Western Branch test results rt evaluations by the Association of Metropolitan Sewerage cies, which found EPA's assumed control efficiencies to be d by a few atypical incinerator operations (AMSA, 1989). health effects attributed to incineration may be exagger-

ble 2 also provides data on hexavalent chromium, copper, um, and zinc. These metals do not currently have emission limits in the proposed Part 503 regulations. However, EPA established total chromium limits, assuming that 1% of total chromium emissions are in the hexavalent form. Test results at Western Branch indicate that there was more hexavalent chromium than total chromium. Because this is not possible, the hexavalent chromium tests are suspect. EPA is currently refining hexavalent chromium procedures and evaluating emissions from additional incinerators. Because the amount of chromium is small in Western Branch sludge, future tests should sample for a longer period than 1 hour.

The concentrations of metals in the sludge that was fed to incinerator No. 1 during NSPS tests are provided in Table 3. These results match metal analyses that have been performed at Western Branch on a monthly basis. Sludge metal concentrations are also compared to mean concentrations in the "40 City Survey" (U. S. EPA, 1989c) and the National Sewage Sludge Survey (NSSS) (U. S. EPA, 1990). The 40 city survey concentrations are typical of sludges with little or no industrial contributions. The NSSS concentrations are for plants with flows from 38 to 380 ML/d (10 to 100 mgd). As seen in Table 3, Western Branch sludge is relatively clean. Chromium concentrations are approximately 12% of the NSSS national mean. Arsenic, cadmium, lead, nickel, and zinc concentrations are approximately 35% of the NSSS national mean.

Table 3 also compares Western Branch sludge metal concentrations with maximum allowable concentrations as calculated by proposed Part 503 equations. The maximum allowable sludge metal concentrations have been calculated using EPA default control efficiencies and site-specific control efficiencies measured during the NSPS tests. In both calculations, the dispersion factor is based on the existing stack height of 16 m and a maximum sludge loading of 23.6 dmtpd to the incinerator. Comparing columns 1 and 5 shows that measured sludge cadmium and arsenic concentrations exceed the maximum allowed by the proposed Part 503 regulations. Thus, the WSSC could not incinerate the Western Branch sludge unless it improves air emissions, reduces sludge input, or determines site-specific dispersion factors. These efforts will be required despite low sludge cadmium

2—Incinerator No. 1 particulate and metals emissions.

	Venturi/aftercooler			Venturi/aftercooler/WESP			
Analyte	Average mass emission rate, 10^{-6} kg/h	Average control efficiency, %	Part 503 control efficiency, %	Inlet mass emission rate, 10^{-6} kg/h	Outlet mass emission rate, 10^{-6} kg/h	Removal efficiency,[a] %	Improved control efficiency, %
iculate	154 700	0.253[b]	No limit	39 920	689	98.3	99.88
enic	160	94.5	96	74	7.7	89.6	99.4
ryllium	<8	>97.1	99	No data	No data	—	—
dmium	770	84.0	65	712	23.6	96.7	99.5
xavalent chromium	112	>96.0	None	No data	No data	—	—
tal chromium	50	99.7	96	6.8	6.8	0	99.7
pper	300	99.9	None	254	8.2	96.8	99.9
ad	640	98.4	67	735	53.5	92.7	>99.9
ckel	<42	>99.6	95	3.5	<1.7	>50.8	99.8
lenium	39	98.0	None	No data	No data	—	—
nc	2 700	99.3	None	1 680	122	92.7	99.9

[a]Removal efficiency = 1 − (mass out/mass in).
[b]Units = kg/Mg dry sludge.

Table 3—Incinerator No. 1 sludge metal concentrations.

	Average sludge concentration, dry mg/kg	Forty city survey median concentration, dry mg/kg	NSSS median concentration, dry mg/kg	Part 503[a] maximum allowable concentration, dry mg/kg	Existing system[b] maximum allowable concentration, dry mg/kg	WESP addition[c] maximum allowable concentration, dry mg/kg
Arsenic	4.8	4.4	12.08	6.3	4.6	44
Beryllium	0.5	0.8	0.37	42.3	14.4	No data
Cadmium	8.3	11.2	22.84	1.8	3.9	120
Total chromium	29.4	248.2	281.4	233.9	3192.1	3 200
Copper	455.8	411.0	746.8	No limit	No limit	No limit
Lead	63.9	265.7	243.4	125.1	2503.0	34 000
Mercury	2.3	1.7	2.94	135.5	No data	No data
Nickel	16.7	70.1	81.96	72.6	892.0	1 800
Selenium	3.3	1.4	5.21	No limit	No limit	No limit
Zinc	597.8	979.8	1584.9	No limit	No limit	No limit

[a] Assumes EPA default control efficiencies and dispersion factor = 33.24 and sludge loading = 23.6 mt/d.
[b] Based on site-specific control efficiency from Table 2.
[c] Based on site-specific control efficiency and WESP removal efficiency from Table 2.

and arsenic concentrations and high site-specific control efficiencies.

WESP tests. The addition of a WESP was considered the most practical and economic method of improving air emissions from the existing incineration system. Because the WESP is a fine particulate collection device, it usually requires a coarse particulate scrubber upstream. The existing venturi and aftercooler at Western Branch are especially appropriate because volatile metals must be condensed to solid particles to be collected. In addition, a WESP has a low pressure drop (2 to 5 cm water), which allows it to be retrofitted into the existing emission control systems without costly changes to the induced draft off-gas system. Although WESPs have been used in other fields, their use in sewage sludge incinerators is limited. Therefore, a test of a pilot WESP was performed immediately after the NSPS tests.

The pilot WESP was operated at 34 to 43 actual m^3/min. This equates to a specific collection area loading rate of 330 to 475 m^2/1000 actual m^3/min (100 to 150 sq ft/1000 acfm). Table 2 and Figure 3 show the results of WESP tests. Data are based on 27-hour tests covering 3 days of operation. Data indicate that the WESP is capable of removing substantial amounts of PM and metals that escape the existing venturi and aftercooler. Particulate matter removal efficiency averaged 98.3% for the 3 days of testing. Removal efficiencies of approximately 90% or better were achieved for all metals except chromium and nickel. Although the reasons for unexpectedly low chromium recoveries are not fully understood at this time, possible explanations include analytical interferences and corrosion of the WESP stainless steel collector tubes. The inconsistency of chromium data supports the first postulate and the low flush water pH promotes the second postulate.

During the WESP test, the pressure drop across the unit did not exceed 3.6 cm water. No stack plume was visible during the operation of the unit and no reentrainment of particulate matter was observed. Effluent discharge from the unit averaged 4.5 to 11 L/min per 1000 m^3/min (2 to 5 gph/1000 acfm), which includes water from the fog spray and intermittent washdown.

Table 4 provides an evaluation of the flush water and residue collected in the bottom of the WESP after the unit was drained. The flush water was black and had a pH of 2.18. Sulfate and chloride concentrations were significant. Table 4 shows that residue bottoms contained considerable amounts of metals, especially lead. Treatment and disposal of this flush water and residue bottoms must be considered to prevent recycle of metals back to the wastewater treatment process.

The last columns of Tables 2 and 3 demonstrate the improved system performance if a WESP were to be added to the existing system. For all sampled metals, control efficiencies would increase to more than 99.4%. These improved control efficiencies would raise the maximum allowable sludge metal concentrations to more than those measured in the sludge feed to the incinerators during the NSPS tests. Thus, the WESP would be a suitable retrofit to satisfy the requirements of proposed Part 503 regulations.

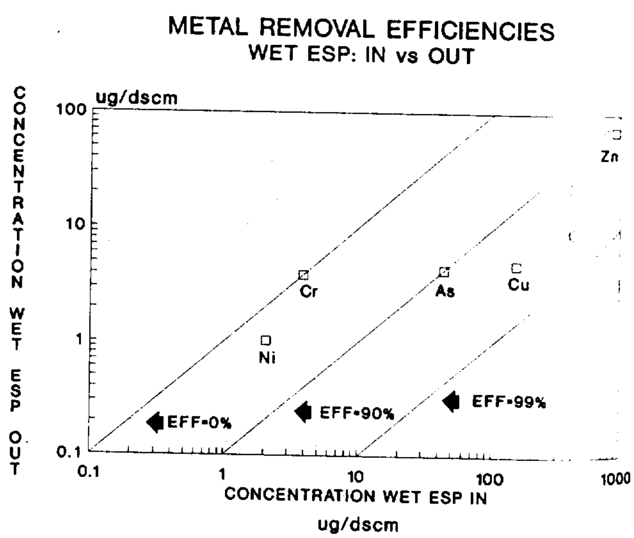


Figure 3—WESP metal removal efficiencies.

4—WESP flush water/residue samples.

Analyte	Flush water: Test day 1 composite, mg/L	Test day 2 composite, mg/L	Test day 3 composite, mg/L	Average, mg/L	Residue (bottoms): Test day 2 composite, mg/L
[illegible]	2.15	2.33	2.02	2.16	41.50
[illegible]ium	6.66	8.13	5.22	6.67	12.90
[illegible]ium	0.28	0.16	0.072	0.17	4.33
[illegible]	2.26	3.21	1.81	2.42	5.63
[illegible]	10.20	13.00	11.60	11.60	1030.00
[illegible]	0.53	0.43	0.35	0.44	<1.51
[illegible]	34.50	53.30	43.80	43.87	81.80
[illegible]	—	2.18	—	—	—
[illegible]ride	—	53.70	—	—	—
[illegible]ate	—	667.00	—	—	—

[illegible]ons an[illegible] considerable margin should the regulations [illegible]ome [illegible]gent.

Other [illegible]atile metals (such as arsenic, cadmium, and [illegible] are [illegible] the most difficult metals to remove from air [illegible]ssions [illegible]videnced by EPA's assumed control efficien[illegible] and [illegible]ficiencies measured at Western Branch. Dif[illegible] in [illegible] volatile metals has been attributed to metal [illegible]densa[illegible]ng gas cooling in scrubbers and aftercoolers [illegible]ms [illegible]38). It has been postulated that most of the [illegible]atile [illegible]dense within the scrubbers as small submicron [illegible]ticles [illegible]all submicron particles are thus enriched with [illegible]atile m[illegible]d are not effectively removed by impact scrub[illegible] such [illegible]nturi or aftercooler.

Submi[illegible]rticle metal enrichment was examined during [illegible] test o[illegible]ESP. Particle-size measurements and metal de[illegible]terminati[illegible]re conducted on the inlet to the WESP (Figure [illegible]). In gen[illegible]ore than half of the particulate mass penetrating [illegible] existi[illegible]nturi and aftercooler was less than 0.6 μm in di[illegible]ameter. Ap[illegible]ximately 70% of the metals were less than 0.3 μm. [illegible]us, the W[illegible]stern Branch tests support the enrichment of sub[illegible]icron particles by volatile metals.

THC and CO emissions were also measured in the gas exiting [illegible] existing aftercoolers. Table 5 shows that these measurements were highly variable. As can be seen, THC concentrations ranged [illegible]om 3.4 to 33.2 ppmv as propane corrected to 7% oxygen. Flue [illegible] CO concentrations ranged from less than 20 to 154 ppmv. [illegible]he highest THC concentration occurred during an upset of [illegible]inerator No. 1. The upset was due to a loss of sludge feed to [illegible] incinerator. Unfortunately, no other measurements were [illegible]ing performed during this upset. Data show that the existing [illegible]cinerators can meet the proposed national THC limit of 20 [illegible]pmv when carefully operated. However, there will be excursions [illegible]hat exceed this limit, even with an afterburner. The existing MHFs cannot meet a national CO limit of 100 ppmv, even [illegible]uring careful operation. There does not appear to be a corre[illegible]ation between THC and CO emissions for the Western Branch MHFs. Simultaneous THC tests across the WESP indicated a THC reduction of approximately 50%. This is probably due to [illegible] removal of organics bound to particulate matter.

Table 6 provides data on the measurement of NO_x and SO_x emissions from incinerator No. 1. These data were collected in anticipation of possible reductions considered in the Clean Air Act. Data indicate that NO_x emissions are variable and averaged 157 ppmv. This concentration equates to an average emission rate of 3.4 kg/Mg (6.7 lb/ton) of dry sludge input. SO_x emissions were also variable and averaged 9.32 ppmv. This equates to an average emission rate of 0.3 kg/Mg (0.55 lb/ton) of dry sludge input. These emission rates are slightly less than reported for similar facilities (Engineering-Science, 1986). Measured sulfate concentrations in the WESP flush water indicate that the WESP is capable of reducing SO_x emissions.

Summary and Conclusions

Air emission studies were conducted on two MHFs and a pilot WESP at the Western Branch WWTP. The pilot WESP was tested for its ability to reduce air emissions from gas exiting venturi and aftercooler scrubbers. These studies were performed to satisfy the requirements of recently promulgated NSPS and proposed Part 503 regulations. Comprehensive tests of particulate, metal, organic, and acid gas emissions were conducted on each MHF and the pilot WESP, resulting in the following conclusions.

Existing MHFs with venturi and aftercooler scrubbers at Western Branch emit particulate matter at less than 0.38 kg/Mg of dry sludge input. This low emission rate reduces the mon-

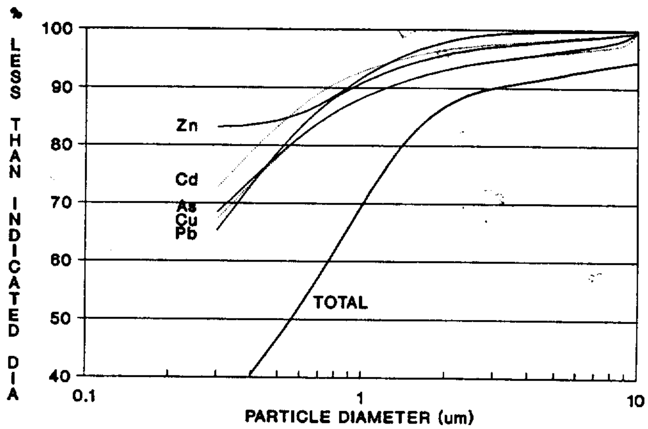


Figure 4—Particle size distribution.

Table 5—Total hydrocarbons and carbon monoxide emissions.

		Total hydrocarbons		Carbon monoxide	
Day	Sample hour	Wet concentration, ppmv as methane	Dry concentration, ppmv as propane	Wet concentration, ppmv	Dry concentra ppmv
Incinerator No. 1					
1	1000	7.0	3.4	149	154
1	1100	7.0	3.4	126	130
1	1500	21.9	—	—	—
1	1600	17.1	8.1	—	—
1	1700	51.9	24.5	—	—
1	1800	70.0	33.2	—	—
2	1500	12.0	7.1	<17.4	<18
Incinerator No. 2					
1	1255	11.0	—	<17.3	<18
2	0845	19.0	9.8	—	—
2	0945	18.0	9.3	<17.2	<18
2	1528	—	—	108	114
WESP					
2	Inlet	20.9	—	—	—
2	Outlet	10.0	—	—	—

itoring, recording, and reporting as required by the NSPS regulations.

Western Branch sludge is a relatively clean sludge as evidenced by cadmium and chromium concentrations that are 12% of the national mean.

Existing MHFs and associated emission control equipment demonstrate cadmium and lead control efficiencies of 84.0 and 98.4%, respectively. These are significantly higher than those assumed in the proposed Part 503 regulations (65 and 67%).

Despite low sludge metal concentrations, the site-specific control efficiencies of the existing MHFs and ancillary equipment could not satisfy proposed Part 503 arsenic and cadmium limits. Dispersion factor corrections or a reduction in air emissions will be needed to satisfy Part 503 requirements.

Emissions tests indicate that a WESP is a good method of reducing air emissions from the existing MHF system. The WESP removes 98% of particulate matter penetrating the existing emission control equipment. Except for chromium and nickel, the WESP removes more than 90% of the penetrating metals.

More than 50% of the particulate mass penetrating existing scrubbers was less than 0.6 μm in diameter. More than 70% of the metals penetrating existing scrubbers were less than 0.3 μm

Table 6—Incinerator No. 1 acid gas emissions.

Parameter	Units	Nitrogen oxides	Sulfur dioxides
Sample time	min	15	20
Number samples	#	12	6
Average concentration	ppmv	157	9.32
Average mass emission rate	kg/h	2.07	0.17
Minimum concentration	ppmv	67.7	1.51
Maximum concentration	ppmv	218	34.62

in size. This indicates the enrichment of small submi on par- ticles by volatile metals.

THC emissions from the existing MHF systems ca chieve a national THC limit of 20 ppmv if carefully operated. wever, excursions significantly higher than this limit were served even with existing afterburners operating at 760°C (00°F). A WESP can remove approximately 50% of the THC

The existing MHF system cannot achieve a national) limit of 100 ppmv. A correlation between THC and CO was found at Western Branch.

NO_x and SO_x emissions from the existing system were riable. However, the average emission rate is consistent with ata reported on similar facilities.

Acknowledgments

Credits. The authors would like to thank the oper rs, engineers, and project team members that participated in e tests at the Western Branch WWTP. Ernie Carlson, Rud Chow, Mohammad Habibian, Avi Jain, and John Sands co ibuted to this effort. Chuck Bruffey of PEI, Cincinnati, Ohio, nd Bill McCoy of Malcolm Pirnie, Inc., Newport News, Virgi a, conducted and managed the tests, respectively.

Authors. Lawrence H. Hentz, Jr., P.E., is Principal Process Engineer at the Washington Suburban Sanitary Commission. Floyd B. Johnson is Plant Superintendent at the Western Branch WWTP. Allen Baturay is Principal of Carlson Associates. Correspondence should be directed to Lawrence H. Hentz, Jr., Washington Suburban Sanitary Commission, 8103 Sandy Spring Road, Laurel, MD 20707.

Submitted for publication December 7, 1990; revised manuscript submitted August 2, 1991; accepted for publication August 7, 1991. The deadline for discussions of this paper is July 15, 1992. Discussions should be submitted to the Executive Editor.

authors will be invited to prepare a single Closure for all ...ussions received before that date.

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