RTI INTERNATIONAL | Memorandum

Date: October 24, 2008

Subject: Secondary Environmental and Energy Impacts for New HMIWI
EPA Contract No. EP-D-06-118; Work Assignment No. 2-03; SPPD No. 02/30
RTI Project No. 0210426.002.003

From: Thomas Holloway

To: Mary Johnson
OAQPS/SPPD/ESG (D243-01)
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

I. Background

The U.S. Environmental Protection Agency (EPA), under sections 111 and 129 of the Clean Air Act (CAA), is required to regulate emissions of nine pollutants from hospital/medical/infectious waste incinerators (HMIWI): hydrogen chloride (HCl), carbon monoxide (CO), lead (Pb), cadmium (Cd), mercury (Hg), particulate matter (PM), dioxins/furans (CDD/CDF), nitrogen oxides (NO_X), and sulfur dioxide (SO_2). To respond to concerns raised by the U.S. Court of Appeals for the D.C. Circuit regarding the methodology originally used to develop the regulation, EPA is re-developing the HMIWI standards. The EPA has developed a series of maximum achievable control technology (MACT) floor and beyond-the-floor (BTF) options to support that re-development. These options are discussed further in separate memoranda.[1,2] Emission control technologies and other control measures that can be used to comply with these options include wet scrubbers, fabric filters, dry scrubbers, selective noncatalytic reduction (SNCR), activated carbon injection (ACI), and various other control measures designed to obtain incremental emission reductions. The purpose of this memorandum is to determine the secondary environmental and energy impacts that would result from projected new sources using these various emission controls to comply, as well as using alternatives to compliance, specifically autoclaving and then landfilling the waste.

II. Model Impacts

The secondary environmental and energy impacts associated with bringing HMIWI into compliance include solid waste impacts, wastewater impacts, energy impacts, and secondary emissions. Solid waste impacts and wastewater impacts are the discarded solids and sewage generated by the emission controls. Energy impacts comprise the electricity and steam required to operate the emission controls, and secondary emissions include the criteria pollutant emissions (PM, CO, NO_X, SO_2) from utilities that generate the electricity.

Secondary environmental and energy impacts have been estimated for a series of model new HMIWI—large, medium, and small units—patterned after HMIWI that have been installed

over the last 10 years. Table 1 shows the basis for the development of the parameters for these model HMIWI (e.g., incinerator charge rate, stack gas flow rate, incinerator operating hours, and concentrations) were developed. Table 2 presents a summary of the model impacts for each emission control. The following sections discuss how the impacts were estimated for each emission control and present the range of model impacts.

A. Packed-Bed Wet Scrubbers

Packed-bed wet scrubbers are especially effective at reducing emissions of acid gases such as HCl, and also provide limited control of PM, metals, and SO_2 (if present at high enough concentrations). These wet scrubbers can be installed either alone or after a dry scrubber or fabric filter. Impacts are presented for each model HMIWI in Table 3.

The wastewater impacts associated with using a packed-bed wet scrubber were estimated (as shown in the following equation) by calculating the amount of sewage disposal, in gallons per year (gpy).

Wastewater impacts (gpy) = blowdown rate (gallons per minute [gpm]) x 60 minutes per hour (min/hr) x operating hours per year (hr/yr)

The sewage disposal calculation is based on algorithms in the *Model Plant Description and Control Cost Report* for HMIWI and a memo update.[3,4] The equation for blowdown rate is presented in Table 3. As shown in Table 3, the wastewater impacts associated with using a packed-bed scrubber range from 30 to 7,117 gpy.

The energy impacts associated with using a packed-bed wet scrubber were estimated (as shown in the following equation) by calculating the amount of electricity needed to operate the wet scrubber and converting that amount to million British thermal units per year (MM Btu/yr).

Energy impacts (MM Btu/yr) = [0.000181 x gas flow rate (actual cubic feet per minute [acfm]) x pressure drop (assumed 15 inches of water [in. H_2O]) + 0.000289 x water circulation rate (gpm) x water head (assumed 60 feet of H_2O)] x operating hours per year (hr/yr) x 1 Btu/0.000292875 kilowatt-hour (kWh) x 1 MM Btu/10^6 Btu

The electricity calculation is based on algorithms in the *Model Plant Description and Control Cost Report* for HMIWI and a memo update.[3,4] The equations for actual gas flow rate and water circulation are presented in Table 3. As shown in Table 3, the energy impacts associated with using a packed-bed wet scrubber range from 34 to 956 MM Btu/yr.

The secondary emissions were estimated, in pounds per year (lb/yr), by multiplying the energy impacts by emission factors for PM, CO, NO_X, and SO_2 for electricity production based on the projected generation mix for the year 2015.[5] The PM, CO, NO_X, and SO_2 emission factors were derived from new source performance standards (NSPS), AP-42 emission factors, and Clean Air Markets emission factors. The 2015 projection from the latest version of EPA's Integrated Planning Model (IPM Version 3.0) was chosen because the new sources are projected to start up within several years after promulgation of the revised standards for new HMIWI in late 2009. The projected mix is as follows: 53 percent coal, 21 percent oil and natural gas, 17 percent nuclear, 6 percent hydroelectric, 2 percent renewable, and 1 percent other.[5] No secondary air impacts were

attributed to nuclear, hydroelectric, or renewable energy generation. The secondary air impacts for "other" were assumed to be equivalent to those for natural gas.

The NO_X and SO_2 emission factors were adjusted to account for expected reductions in NO_X and SO_2 emissions by 2015, based on Clean Air Interstate Rule (CAIR) requirements—i.e., 61 percent NO_X reduction (for solid and liquid/gas fuels) and 70 percent SO_2 reduction (for solid fuels). Although CAIR has been vacated by the U.S. Court of Appeals for the D.C. Circuit, NO_X and SO_2 emission reductions similar to CAIR were assumed for 2015. The secondary emissions were estimated as follows:

Secondary PM emissions (lb/yr) = energy impacts (MM Btu/yr) x [NSPS limit for coal-fired utility boilers (0.03 lb PM/MM Btu) x 53% electricity generation using coal + AP-42 emission factor for oil/gas-fired turbines (1.9 lb PM/MM cubic feet [ft^3]) / 1,020 MM Btu/MM ft^3 of natural gas x 22% electricity generation using oil/natural gas or "other"] [6,7]

Secondary CO emissions (lb/yr) = energy impacts (MM Btu/yr) x [AP-42 emission factor for coal-fired utility boilers (5 lb CO/ton bituminous coal) / 26 MM Btu/ton bituminous coal x 53% electricity generation using coal + AP-42 emission factor for natural gas (84 lb CO/MM ft^3) / 1,020 MM Btu/MM ft^3 of natural gas x 22% electricity generation using oil/natural gas or "other"] [7,8]

Secondary NO_X emissions (lb/yr) = energy impacts (MM Btu/yr) x [Clean Air Markets emission factor for coal-fired utility boilers (0.25 lb NO_X/MM Btu) x (100% - 61%) + AP-42 emission factor for oil/gas-fired turbines (100 lb NO_X/MM ft^3) / 1,020 MM Btu/MM ft^3 natural gas x (100% - 61%) x 22% electricity generation using oil/natural gas or "other"] [7,9,10]

Secondary SO_2 emissions (lb/yr) = energy impacts (MM Btu/yr) x [Clean Air Markets emission factor for coal-fired utility boilers (0.737 lb SO_2/MM Btu)] x (100% - 70%) + AP-42 emission factor for oil/gas-fired turbines (0.6 lb SO_2/MM ft^3) / 1,020 MM Btu/MM ft^3 natural gas x 22% electricity generation using oil/natural gas or "other"] [7,9,10]

As shown in Table 3, the secondary emissions associated with using a packed-bed wet scrubber range from 0.5 to 16 lb/yr of PM, 4.0 to 114 lb/yr of CO, 2.0 to 57 lb/yr of NO_X, and 4.0 to 112 lb/yr of SO_2.

B. Dry Scrubbers

A dry scrubber can be used in concert with a fabric filter to reduce emissions of PM, as well as emissions of acid gases such as HCl. The predominant type of dry system used at HMIWI is a dry sorbent injection system followed by a fabric filter (DIFF). Table 4 presents the impacts estimated for DIFF for each model HMIWI.

The solid waste impacts associated with using DIFF were estimated (as shown in the following equation) by calculating the amount of dust disposal, in tons per year (tpy).

Dust disposal (tpy) = [(PM inlet concentration (grains per dry standard cubic foot [gr/dscf]) x gas flow rate (dry standard cubic feet per minute [dscfm]) x 60 minutes per hour (min/hr) x 1 lb/7,000 gr) + (HCl inlet concentration (parts per million by volume, dry basis [ppmvd]) x gas flow rate (dscfm) x 60 min/hr x 2.86E-7 lb/dscf)] x 1 ton/2,000 lb x operating hours per year (hr/yr)

The dust disposal calculation is based on algorithms in the *Model Plant Description and Control Cost Report* for HMIWI and a memo update.[3,11] As shown in Table 4, the solid waste impacts associated with using a DIFF range from 6.5 to 3,541 tpy.

The energy impacts associated with using a DIFF were estimated (as shown in the following equation) by calculating the amount of electricity and converting that amount to MM Btu/yr.

Energy impacts (MM Btu/yr) = 0.746 kilowatts/horsepower (kW/hp) x horsepower (hp) x operating hours per year (hr/yr) x 1 Btu/0.000292875 kWh x 1 MM Btu/10^6 Btu

The electricity calculation is based on algorithms in the *Model Plant Description and Control Cost Report* for HMIWI and a memo update.[3,11] The equation for horsepower is presented in Table 4. As shown in Table 4, the energy impacts associated with using a DIFF range from 69 to 1,681 MM Btu/yr.

The secondary emissions were estimated by multiplying the energy impacts by the aforementioned PM, CO, NO_X, and SO_2 emission factors and projected generation mix for 2015. As shown in Table 5, the secondary emissions associated with using a DIFF range from 1.1 to 27 lb/yr of PM, 8.2 to 200 lb/yr of CO, 4.2 to 101 lb/yr of NO_X, and 8.1 to 197 lb/yr of SO_2.

C. <u>Selective Noncatalytic Reduction</u>

SNCR systems have been used for NO_X emission control on industrial boilers, electric utility steam generators, thermal incinerators, and municipal solid waste energy recovery facilities.[12] NO_X reductions of 45 percent or higher are estimated for HMIWI using SNCR systems.[13] Table 5 presents the impacts estimated for SNCR for each model HMIWI.

The energy impacts associated with using SNCR systems were estimated (as shown in the following equation) by calculating the amount of electricity and converting that amount to MM Btu/yr. The amount of electricity was determined based on algorithms in the *OAQPS Control Cost Manual*.[12]

Energy impacts (MM Btu/yr) = 0.47 x kW [inlet NO_X concentration (0.28 lb/MM Btu) x incinerator charge rate (lb waste/hr) x heating value (assumed 8,500 Btu/lb waste) x 1 MM Btu/10^6 Btu / 9.5] x 1 Btu/0.000292875 kWh x 1 MM Btu/10^6 Btu x operating hours per year (hr/yr)

The algorithms are dependent on the NO_X concentration at the inlet to the SNCR system, which was estimated to be 0.28 lb/million Btu (MM Btu), based on the average of the NO_X concentration data for currently operating HMIWI. The NO_X concentration for each HMIWI was estimated (as shown in the following equation) using baseline emissions estimates developed in a separate memorandum:[14]

NO_X concentration (lb/MM Btu) = NO_X baseline emissions (lb/yr) / [operating hours per year (hr/yr) x incinerator charge rate (lb waste/hr) x heating value (8,500 Btu/lb waste)] x 10^6 Btu/MM Btu

As shown in Table 5, the energy impacts associated with using SNCR systems range from 0.1 to 5.1 MM Btu/yr. The secondary emissions were estimated by multiplying these energy

impacts by the aforementioned PM, CO, NO_X, and SO_2 emission factors and projected generation mix for 2015. As shown in Table 5, the secondary emissions associated with using SNCR systems are very low, ranging from 0.002 to 0.08 lb/yr of PM, 0.01 to 0.6 lb/yr of CO, 0.007 to 0.3 lb/yr of NO_X, and 0.01 to 0.6 lb/yr of SO_2.

D. Activated Carbon Injection System

Injecting activated carbon before the fabric filter has been demonstrated to improve the removal efficiency of both Hg and CDD/CDF from HMIWI. Table 6 presents the impacts estimated for ACI systems for each model HMIWI.

The solid waste impacts associated with using ACI systems were estimated (as shown in the following equation) by calculating the amount of dust disposal (in tpy). The dust disposal equation is based on algorithms in the *Model Plant Description and Control Cost Report* for HMIWI.[3]

Dust disposal = 0.00127 x gas flow rate (dscfm) x 1 ton/2,000 lb x operating hours per year (hr/yr)

The factor of 0.00127 in the equation is based on an ACI rate capable of producing a carbon concentration of 338 milligrams per dry standard cubic meter (mg/dscm), which is expected to achieve reductions of 90 percent for Hg and 98 percent for CDD/CDF relative to inlet levels. As shown in Table 6, the solid waste impacts associated with using ACI systems range from 1.3 to 51 tpy.

E. Incremental Controls

In some instances, it may not be necessary to install a new control system to achieve the emissions reductions necessary to meet the emission levels associated with the control options. An incremental reduction in emissions may be achievable by simply increasing the flow of activated carbon prior to the fabric filter or increasing the amount of natural gas used in the incinerator. Table 7 presents the model impacts for each of these incremental control measures, and the following sections discuss how the model impacts were estimated for each of the controls.

1. Increase activated carbon flow. As noted previously, injecting activated carbon before the fabric filter has been demonstrated to improve the removal efficiency of both Hg and CDD/CDF from HMIWI. The solid waste impacts associated with increasing activated carbon flow were estimated using the same equation employed for ACI systems, and the same results were obtained for the three model HMIWI, as shown in Table 7.

2. Increase natural gas use. One strategy to reduce CO and CDD/CDF emissions further is to increase the amount of natural gas fired in the secondary chamber and consequently increase the temperature in the secondary chamber. Carbon monoxide is a product of incomplete combustion, and increasing the temperature in the secondary chamber should subsequently increase the degree of combustion in the chamber; higher temperatures in the secondary chamber should also contribute to the decomposition of CDD/CDF compounds.[15] Combustion can be improved in other ways (e.g., tuning up burners or improving mixing in the secondary chamber), but for purposes of this memorandum, analyses were conservatively based on increased natural

gas use. The energy impacts associated with firing additional natural gas were estimated (as shown in the following equation) by calculating the amount of natural gas fired (in million cubic feet per year [MM ft^3/yr]) and converting that amount to MM Btu/yr.

Natural gas (MM Btu/yr)= 0.32 Btu/lb/°F x 28.5 lb/lb-mole x (1800 - 1700°F) temperature increase x lb-mole/385 ft^3 x ft^3/1,000 Btu x gas flow rate (dscfm)/0.9 x 60 min/hr x operating hours per year (hr/yr) x 1 MM $ft^3/10^6$ ft^3 x 1,000 MM Btu/MM ft^3

The natural gas calculation is based on algorithms in the *Model Plant Description and Control Cost Report* for HMIWI.[3] As shown in Table 7, the energy impacts associated with firing additional natural gas range from 332 to 12,634 MM Btu/yr.

The secondary emissions associated with firing additional natural gas were estimated (as shown in the following equations) by multiplying the amount of additional natural gas by the AP-42 emission factors for PM, CO, NO_X, and SO_2 associated with natural gas-fired boilers.

Secondary PM emissions (lb/yr) = [natural gas (MM ft^3/yr)] x [AP-42 emission factor (1.9 lb PM/MM ft^3)] [7]

Secondary CO emissions (lb/yr) = [natural gas (MM ft^3/yr)] x [AP-42 emission factor (84 lb CO/MM ft^3)] [7]

Secondary NO_X emissions (lb/yr) = [natural gas (MM ft^3/yr)] x [AP-42 emission factor (100 lb NO_X/MM ft^3)] [7]

Secondary SO_2 emissions (lb/yr) = [natural gas (MM ft^3/yr)] x [AP-42 emission factor (0.6 lb SO_2/MM ft^3)] [7]

As shown in Table 7, the secondary emissions associated with firing additional natural gas range from 0.6 to 24 lb/yr of PM, 28 to 1,061 lb/yr of CO, 33 to 1,263 lb/yr of NO_X, and 0.2 to 7.6 lb/yr of SO_2.

F. Autoclave/Landfill

In some instances, the cost to comply with the re-developed HMIWI regulation may lead some facilities (e.g., hospitals) to use other waste treatment and disposal methods, such as onsite autoclaving, followed by landfilling the waste. Table 8 presents the model impacts associated with autoclaving the waste.

The energy impacts associated with using an autoclave were estimated (as shown in the following equation) by taking vendor estimates of sterilizer steam usage (lb/hr of steam) and sterilizer/compactor electricity usage (kWh/hr of electricity) (see Table 9), developing equations for steam and electricity usage based on those estimates (see Figures 1 and 2), using those equations to determine steam and electricity usage for the model new HMIWI, and converting those estimates to MM Btu/yr.[16]

Energy impacts (MM Btu/yr) = [Sterilizer steam usage (lb steam/hr) x (922 Btu/lb steam) x (1 MM Btu/10^6 Btu) x H] + [sterilizer/compactor electrical usage (kWh/hr) x (1 Btu/0.000292875 kWh) x (1 MM Btu/10^6 Btu) x H]

As shown in Table 8, the energy impacts associated with using an autoclave range from 77 to 4,019 MM Btu/yr. The secondary emissions were estimated by multiplying these energy impacts by the aforementioned PM, CO, NO_X, and SO_2 emission factors and projected generation

mix for 2015. . As shown in Table 8, the secondary emissions associated with using an autoclave range from 1.2 to 66 lb/yr of PM, 9.1 to 478 lb/yr of CO, 4.6 to 241 lb/yr of NO_X, and 9.0 to 471 lb/yr of SO_2.

The solid waste impacts associated with landfilling the autoclaved waste (as opposed to landfilling the incinerated waste) were estimated (as shown in the following equation), assuming a 90 percent reduction in solid waste with incineration. Table 10 presents the model impacts associated with landfilling the waste.

Solid waste (tpy) = autoclaved waste landfilled [incinerator capacity x 67% operating factor] x [operating hours per year (hr/yr)] - incinerated waste landfilled [incinerator capacity x 67% operating factor] x [100% - 90% reduction in solid waste] x [operating hours per year (hr/yr)] x [1 ton/2,000 lb]

The methane (CH_4) and Hg secondary emissions associated with landfilling the waste were estimated using a series of equations from AP-42, as shown in Table 10.[17] The CH_4 emissions are expected to be controlled and range from 0.5 to 59 tpy. Although Hg emissions from landfills are expected to be uncontrolled, Hg emissions are estimated to be minimal, ranging from 2.89E-05 to 3.08E-03 lb/yr.

III. Nationwide Impacts

To determine nationwide secondary impacts for the three projected new HMIWI, model emission estimates for each pollutant and each new HMIWI were first compared to the MACT floor emission limits to determine which new HMIWI would potentially be impacted for a particular pollutant, and by how much. Then, the type of emission control needed to bring the HMIWI into compliance with the emission limit was determined. For example, if it appeared that a new HMIWI equipped with a DIFF would be impacted for HCl by a substantial amount, then it was determined that a packed-bed scrubber should be installed to bring the new HMIWI into compliance with the HCl limit. This approach was taken with each pollutant individually, and the results were compared across all pollutants to determine the best combination of emission controls needed to ensure the new HMIWI would be in compliance with all of the MACT floor emission limits. See Table 11 for this list of emission controls.

Once the best combination of emission controls was determined, the model secondary impacts associated with those emission controls were assigned to the impacted HMIWI, based on which size category (large, medium, small) the impacted HMIWI belonged. For example, large model secondary impacts associated with packed-bed scrubbers would be applied to the large HMIWI that needs to install that emission control to comply with the HCl emission limit. The model secondary impacts that would be applied would include the wastewater impacts, energy impacts, and secondary emissions associated with packed-bed scrubbers. Table 11 shows the secondary impacts estimates applied to each HMIWI at the floor and presents estimated nationwide totals. The MACT floor totals in Table 11 show nationwide energy impacts of 15,500 MM Btu/yr (xxx megawatt-hours per year [MWh/yr]); nationwide solid waste impacts of 60 tpy; nationwide wastewater impacts of 8,000 gpy; and nationwide secondary emissions of 3,000 lb/yr (including 50 lb/yr of PM, 1,300 lb/yr of CO, 1,500 lb/yr of NO_X, and 140 lb/yr of SO_2).

A different approach from the one described above was used to estimate secondary impacts for the BTF options. For the BTF options, the type of control assigned was determined based on the additional emission controls available (i.e., those controls not already installed at the MACT floor), and not based on a BTF emission limit. For new large HMIWI, the only additional emission control available was SNCR, so only the secondary impacts associated with SNCR were applied to the new large HMIWI. No additional emission controls were available for new medium HMIWI beyond the floor, so no secondary impacts were applied to that source. For new small HMIWI, a DIFF and ACI system were still available (i.e., not already required at the MACT floor) and could be installed beyond the floor; consequently, the secondary impacts associated with those controls were applied to the new small HMIWI. Table 12 shows the secondary impacts estimates applied to each HMIWI beyond the floor and presents estimated nationwide totals. The overall BTF totals in Table 12 show nationwide impacts approximately the same as or slightly higher than the MACT floor, including nationwide energy impacts of 15,600 MM Btu/yr (xxx MWh/yr); nationwide solid waste impacts of 60 tpy; nationwide wastewater impacts of 8,000 gpy; and nationwide secondary emissions of 3,000 lb/yr (including 50 lb/yr of PM, 1,300 lb/yr of CO, 1,500 lb/yr of NO_X, and 150 lb/yr of SO_2).

The secondary impacts associated with autoclaving and landfilling the waste were also assigned to each HMIWI, so that the impacts for this alternative option could be compared to the impacts for compliance at the floor and beyond the floor for each HMIWI. See Tables 11 and 12 for a comparison of autoclave/landfill impacts with MACT floor and BTF impacts for each HMIWI and also nationwide. As shown in Table 12, autoclave/landfill energy impacts are approximately 4,400 MM Btu/yr (xxx MWh/yr); solid waste impacts are approximately 10,300 tpy; and secondary emissions are approximately 1,440 lb/yr (including 70 lb/yr of PM, 520 lb/yr of CO, 260 lb/yr of NO_X, 520 lb/yr of SO_2, 60 lb/yr of CH_4, and 0.003 lb/yr of Hg). An estimated 1,380 lb/yr of secondary emissions comes from the autoclave and 60 lb/yr from the landfill. Compared to the MACT floor totals, the autoclave/landfill option has 28 percent of the energy impacts, 48 percent of the secondary emissions, and 180 times the solid waste impacts. Compared to the overall BTF totals, the autoclave/landfill option has 28 percent of the energy impacts, 47 percent of the secondary emissions, and 159 times the solid waste impacts.

IV. References

1. Memorandum from Thomas Holloway, RTI, to Mary Johnson, EPA. October 24, 2008. *MACT Floors, Data Variability Analysis, and Emission Limits for Existing and New HMIWI.*

2. Memorandum from Thomas Holloway, RTI, to Mary Johnson, EPA. October 24, 2008. *Beyond-the-Floor Options for Existing and New HMIWI.*

3. U.S. Environmental Protection Agency. July 1994. *Medical Waste Incinerators--Background Information for Proposed Standards and Guidelines: Model Plant Description and Cost Report for New and Existing Facilities.* Publication Number EPA-453/R-94-045a. (Docket item no. II-A-112)

4. Memorandum from Thomas Holloway, RTI, to MWI Project File. September 7, 1995. *Approach Used to Estimate the Capital and Annual Costs for MWI Wet Scrubbers.* (Docket item no. IV-B-30)

5. U.S. Environmental Protection Agency. 2006. *Clean Air Markets – Programs and Regulations; New IPM Base Case for 2006; IPM Version 3.0.* Website: http://www.epa.gov/airmarket/epa-ipm/. Accessed January 12, 2007.

6. U.S. Environmental Protection Agency. July 1, 2004. *Standards of Performance for Electric Utility Steam Generating Units for Which Construction Is Commenced After September 18, 1978*. Code of Federal Regulations. Title 40, Chapter I, Subchapter C, Part 60, Subpart Da. Washington, DC. U.S. Government Printing Office.

7. U.S. Environmental Protection Agency. January 1995. *Compilation of Air Pollution Emission Factors*. 5th Edition. Research Triangle Park, NC. Volume I: Stationary Point and Area Sources. Section 1.4: Natural Gas Combustion.

8. U.S. Environmental Protection Agency. January 1995. *Compilation of Air Pollution Emission Factors.* 5th Edition. Research Triangle Park, NC. Volume I: Stationary Point and Area Sources. Section 1.1: Bituminous and Subbituminous Coal Combustion.

9. U.S. Environmental Protection Agency. 2006. *Clean Air Markets – Progress and Results; Acid Rain Program; Preliminary Summary Emission Reports.* Website: http://www.epa.gov/airmarkets/emissions/prelimarp/index.html. Accessed December 15, 2006.

10. U.S. Environmental Protection Agency. May 12, 2005. *Rule To Reduce Interstate Transport of Fine Particulate Matter and Ozone (Clean Air Interstate Rule).* Federal Register. Volume 70, Number 91. Washington, DC. U.S. Government Printing Office.

11. Memorandum from David Randall, RTI, to Rick Copland, EPA. January 29, 1996. *Revised Costs for Dry Injection/Fabric Filter Controls for MWI's.* (Docket item no. IV-B-32)

12. U.S. Environmental Protection Agency. October 2000. *OAQPS Control Cost Manual.* Section 4.2: NO_X Post-Combustion. Chapter 1: Selective Noncatalytic Reduction. Publication Number EPA/452/B-02-001.

13. U.S. Environmental Protection Agency. November 1999. *EPA Technical Bulletin: Nitrogen Oxides (NO_X)--Why and How They Are Controlled.* Clean Air Technology Center. Publication Number EPA/456/F-99-006R.

14. Memorandum from Thomas Holloway, RTI, to Mary Johnson, EPA. October 24, 2008. *Baseline Emissions and Emissions Reductions for Existing and New HMIWI.*

15. U.S. Environmental Protection Agency. July 1994. *Medical Waste Incinerators--Background Information for Proposed Standards and Guidelines: Control Technology*

Performance Report for New and Existing Facilities. Publication Number EPA-453/R-94-044a. (Docket item no. II-A-111)

16. Contact report from Thomas Holloway, RTI, to project file. July 28, 2008. Summary of telephone conversation with Arthur McCoy, San-I-Pak, Inc. *Autoclave Cost Estimates for Large, Medium, and Small Models.*

17. U.S. Environmental Protection Agency. November 1998. *Compilation of Air Pollution Emission Factors*. 5th Edition. Research Triangle Park, NC. Volume I: Stationary Point and Area Sources. Section 2.4: Municipal Solid Waste Landfills.

Table 1. Basis for Model HMIWI Parameters

Parameters	City	State	Category	APCD code	APCD type	APCD description	Max charge rate (lb/hr)	Stack gas flow rate (dscfm)	Operating hours (hr/yr)	HCl (ppmvd)	CO (ppmvd)	Pb (mg/dscm)
Basis for Models												
Municipality of Chambers County, Resource Recovery Center, Unit 1	Anahuac	TX	L	DIFF	Dry	Secondary chamber, baghouse with virgin lime injection, urea injection, and activated carbon injection	4,167	10,031	7,896	11.0	3.96	0.019
Municipality of Chambers County, Resource Recovery Center, Unit 2	Anahuac	TX	L	DIFF	Dry	Secondary chamber, baghouse with virgin lime injection, urea injection, and activated carbon injection	4,167	9,028	7,896	5.30	2.86	0.0078
Municipality of Chambers County, Resource Recovery Center, Average	Anahuac	TX	L	DIFF	Dry	Secondary chamber, baghouse with virgin lime injection, urea injection, and activated carbon injection	4,167	9,529	7,896	8.17	3.41	0.013
Wilkes-Barre General Hospital	Wilkes-Barre	PA	M	DIFF	Dry	Secondary/tertiary chambers (1800F, 2.85 sec) and dry scrubber/baghouse with lime and activated carbon injection	400	2,063	4,472	8.95	2.08	0.0041
Centers for Disease Control and Prevention--Clifton, Building 18, Unit 3	Atlanta	GA	S	WS	Wet	Secondary chamber (1800F, 1.68 sec) and rotary atomizing wet scrubber	120	717	2,920	1.30	12.1	0.073
Models												
Facility A			L	DIFF	Dry	Secondary chamber, baghouse with virgin lime injection, urea injection, and activated carbon injection	4,000	10,000	8,000	8.17	3.41	0.013
New source MACT floor limit										0.75	2.9	0.00047
Meets limit (0 = yes, 1 = no)										1	1	1
% improvement needed										989%	18%	2714%
Facility B			M	DIFF	Dry	Secondary/tertiary chambers (1800F, 2.85 sec) and dry scrubber/baghouse with lime and activated carbon injection	400	2,000	4,500	8.95	2.08	0.0041
New source MACT floor limit										1.8	1.9	0.016
Meets limit (0 = yes, 1 = no)										1	1	0
% improvement needed										397%	10%	-75%
Facility C			S	WS	Wet	Secondary chamber (1800F, 1.68 sec) and rotary atomizing wet scrubber	100	700	3,000	1.30	12.1	0.073
New source MACT floor limit										4.5	8.2	0.18
Meets limit (0 = yes, 1 = no)										0	1	0
% improvement needed										-71%	48%	-60%

Notes:
1. Patterned new source models after those new HMIWI installed in last 10 years.
2. If emissions data unavailable, used average emissions estimates for similar units (APCD, size) to determine impact status.

Key:
Emissions data unavailable; used average

Table 1. Basis for Model HMIWI Parameters

Parameters	City	State	Category	Cd (mg/dscm)	Hg (mg/dscm)	PM (gr/dscf)	Total CDD/CDF (ng/dscm)	CDD/CDF TEQ (ng/dscm)	NO_X (ppmvd)	NO_X (lb/MMBtu)	SO_2 (ppmvd)
Basis for Models											
Municipality of Chambers County, Resource Recovery Center, Unit 1	Anahuac	TX	L	0.0013	0.0130	0.0070	0.50	0.0081	72	0.10	1.21
Municipality of Chambers County, Resource Recovery Center, Unit 2	Anahuac	TX	L	0.00089	0.0056	0.0095	0.15	0.0038	88	0.11	0.46
Municipality of Chambers County, Resource Recovery Center, Average	Anahuac	TX	L	0.0011	0.0093	0.0082	0.32	0.0059	80	0.11	0.84
Wilkes-Barre General Hospital	Wilkes-Barre	PA	M	0.0011	0.0093	0.0040	16	0.19	no data	0.28	1.90
Centers for Disease Control and Prevention--Clifton, Building 18, Unit 3	Atlanta	GA	S	0.0055	0.0029	0.0076	no data	0.0045	no data	0.28	no data
Models											
Facility A			L	0.0011	0.0093	0.0082	0.32	0.0059	80	0.11	0.84
New source MACT floor limit				0.00012	0.00093	0.0048	0.60	0.014	110		1.9
Meets limit (0 = yes, 1 = no)				1	1	1	0	0	0		0
% improvement needed				822%	900%	72%	-46%	-58%	-27%		-56%
Facility B			M	0.0011	0.0093	0.0040	16	0.19	105	0.28	1.90
New source MACT floor limit				0.0071	0.0020	0.0099	0.35	0.0097	38		0.78
Meets limit (0 = yes, 1 = no)				0	1	0	1	1	1		1
% improvement needed				-85%	363%	-60%	4557%	1885%	177%		143%
Facility C			S	0.0055	0.0029	0.0076	2.89	0.0045	105	0.28	3.52
New source MACT floor limit				0.012	0.0075	0.017	8.3	0.0080	38		0.78
Meets limit (0 = yes, 1 = no)				0	0	0	0	0	1		1
% improvement needed				-55%	-61%	-55%	-65%	-43%	177%		351%

Notes:
1. Patterned new source models after those new HMIWI installed in last 10 years.
2. If emissions data unavailable, used average emissions estimates for similar units (APCD, size) to determine impact status.

Key:
Emissions data unavailable; used average

Table 2. Summary of Model Secondary Impacts

Control option	Secondary pollutants	Large	Medium	Small
A. Solid Waste Impacts, tpy				
1. Dry injection fabric filter		3,541	592	6.5
2. Activated carbon injection system / increase carbon flow		51	5.7	1.3
3. Landfill (after autoclave)		9,648	543	90
B. Wastewater Impacts, gpy				
1. Packed-bed scrubber		7,117	877	30
C. Energy Impacts, MMBtu/yr				
1. Packed-bed scrubber		956	108	34
2. Dry injection fabric filter		1,681	221	69
3. Increase natural gas		12,634	1,421	332
4. Selective noncatalytic reduction		5.1	0.7	0.1
5. Autoclave		4,019	305	77
D. Secondary Emissions, lb/yr				
1. Packed-bed scrubber	PM	16	1.8	0.5
	CO	114	13	4.0
	NO_X	57	6.5	2.0
	SO_2	112	13	4.0
2. Dry injection fabric filter	PM	27	3.6	1.1
	CO	200	26	8.2
	NO_X	101	13	4.2
	SO_2	197	26	8.1
3. Increase natural gas	PM	24	2.7	0.6
	CO	1,061	119	28
	NO_X	1,263	142	33
	SO_2	7.6	0.9	0.2
4. Selective noncatalytic reduction	PM	0.08	0.01	0.002
	CO	0.6	0.09	0.01
	NO_X	0.3	0.04	0.007
	SO_2	0.6	0.08	0.01
5. Autoclave	PM	66	5.0	1.2
	CO	478	36	9.1
	NO_X	241	18	4.6
	SO_2	471	36	9.0
6. Landfill (after autoclave)	CH_4	59	3.3	0.5
	Hg	3.08E-03	1.73E-04	2.89E-05

Table 3. Packed Bed Scrubber Secondary Impacts

Parameters/Costs	Equation	Large	Medium	Small
A. Parameters				
1. Incinerator capacity, lb/hr (C)		4,000	400	100
2. Temperature out of FF into quench, F (T1)		300	300	130
3. Temperature out of PB to ID fan, F (T2)		130	130	130
4. Annual operating hours, hr/yr (H)		8,000	4,500	3,000
5. Exhaust gas flow rate (dry), dscfm (Qd)		10,000	2,000	700
6. Assumed moisture content in gas entering quench, % (M)		10	10	10
7. Exhaust gas flow rate, scfm (Qw)	= (Qd) / (1 - M/100)	11,111	2,222	778
8. Water added in quench, scfm (Qh)	= ((7.010 x (T1 - 77°F) - 6.958 x (T2 - 77°F)) x 0.9 + (8.154 x (T1 - 77°F) - 8.064 x (T2 - 77°F)) x 0.1) x (lb-mole/385 scf) x Qw / (1,160 Btu/lb) / (18 lb/lb-mole) x (0.7302 ft^3-atm/lb-mol-°R) x 528°R / 1 atm	647	129	0
9. Actual flow out of PB, acfm (Qa)	= (Qw + Qh) x (460°F + T2)/(528°R)	13,139	2,628	869
10. HCl concentration, ppmvd (HCl)		8.17	8.95	1.30
11. Assumed pressure drop through control system, inches of water (ΔP)		15	15	15
12. Surface area-to-volume ratio for 1" dia. Ceramic Raschig rings, ft^2/ft^3 (SAV)		58	58	58
13. Minimum packing wetting rate, ft^2/hr (WR)		1	1	1
14. Water density, lb/ft^3 (Wd)		62.4	62.4	62.4
15. Water circulation flow rate, lb/hr-ft^2 (Gs)	= SAV x Wd x WR	4,705	4,705	4,705
16. Estimated column cross-sectional area from separate analysis, ft^2 (A)		48	9.6	8.5
17. Water circulation rate, gpm (GPM)	= Gs x A x (1 hr/60 min) x (1 gal/8.33 lb)	452	90	80
18. Water head, ft of water (Head)		60	60	60
19. Wastewater (blowdown) flow, gpm (B)	= (HCl/1000000) x (Qd) x (lb-mole/385 ft^3) x (1 lb-mole NaCl/1 lb-mole HCl) x (58.2 lb NaCl/lb-mole NaCl) x (1 lb wastewater/0.1 lb NaCl) x (1 gal/8.33 lb)	0.015	0.003	0.0002
B. Secondary Impacts				
1. Energy impacts, kWh/yr				
a. kWh/yr	= (0.000181 x Qa x ΔP x H) + (0.000289 x GPM x Head x H)	279,882	31,487	9,864
b. MMBtu/yr	= [electricity (kWh/yr)] x [1 Btu/ 0.000292875 kWh] x [1 MM Btu/10^6 Btu]	956	108	34
2. Wastewater impacts, gpy	= B x (60 min/hr) x H	7,117	877	30
3. Secondary emissions				
a. PM	= [Energy impacts (MMBtu/yr)] x [solid fuel emission factor (lb/MMBtu)] x [53% energy generation from coal] + [energy impacts (MMBtu/yr)] x [natural gas emission factor (lb/MMBtu)] x [22% energy generation from oil/natural gas and other fuels]	16	1.8	0.5
b. CO		114	13	4.0
c. NO_X		57	6.5	2.0
d. SO_2		112	13	4.0

Sources:

1. Model Plant Description and Cost Report (II-A-112).
2. Wet Scrubber Cost Memorandum (IV-B-30).

Emission Factors	Value	Units
PM	1.9	lb/MM ft^3 natural gas
	0.00186275	lb/MMBtu natural gas
	0.03	lb/MMBtu solid, liquid, gaseous fuel
CO	84	lb/MM ft^3 natural gas
	0.0824	lb/MMBtu natural gas
	0.19	lb/MMBtu bituminous coal
NO_X	100	lb/MM ft^3 natural gas
	0.0382	lb/MMBtu natural gas
	0.0975	lb/MMBtu solid fuel
SO_2	0.6	lb/MM ft^3 natural gas
	0.00059	lb/MMBtu natural gas
	0.2211	lb/MMBtu solid fuel

Sources:

1. AP-42 emission factors for PM, CO, NO_X, and SO_2 for natural gas combustion.

NO_X reduced by 61% to reflect reductions similar to what CAIR would have achieved in 2015 (assuming CAIR replacement achieves similar reductions).

2. NSPS limit for PM (40 CFR part 60, subpart Da) for utility boilers.

3. AP-42 emission factor for CO for bituminous coal-fired spreader stoker boilers.

4. CAMD emission reports for NO_X and SO_2 for solid fuel-fired utility boilers. SO_2 reduced by 70% and NO_X reduced by 61% to reflect reductions similar to what CAIR would have achieved in 2015 (assuming CAIR replacement achieves similar reductions).

Assume electricity generated using the following mix (from IPM Version 3.0 for the year 2015):

Fuel	Percent of generation	Notes
Coal	53%	
Oil/natural gas	21%	
Nuclear	17%	No secondary air emissions estimated
Hydroelectric	6%	No secondary air emissions estimated
Renewable	2%	No secondary air emissions estimated
Other	1%	Assumed equivalent to natural gas

Table 4. Dry Injection Fabric Filter Secondary Impacts

Parameters/Costs	Equation	Large	Medium	Small
A. Parameters				
1. Incinerator capacity, lb/hr (C)		4,000	400	100
2. Annual operating hours, hr/yr (H)		8,000	4,500	3,000
3. Exhaust gas flow rate, dscfm (Q)		10,000	2,000	700
4. HCl concentration, ppmvd (HCl)		163	179	130
5. PM concentration, gr/dscf (PM)		10	15	0.5
B. Secondary Impacts				
1. Solid waste impacts, tpy	= [(PM x Q x 60 min/hr x 1 lb/7,000 gr) + (HCl x Q x 60 min/hr x 2.86E-7 lb/dscf)] x (1 ton/2,000 lb) x H	3,541	592	6.5
2. Energy impacts				
a. kWh/yr	= [0.746 kW/hp] x [hp (0.0079 x Q + 3.51)] x H	492,420	64,824	20,232
b. MMBtu/yr	= [Electricity (kWh/yr)] x [1 Btu / 0.000292875 kWh] x [1 MM Btu/10^6 Btu]	1,681	221	69
3. Secondary emissions, lb/yr				
a. PM	= [Energy impacts (MMBtu/yr)] x [solid fuel emission factor (lb/MMBtu)] x [53% energy generation from coal] + [energy impacts (MMBtu/yr)] x [natural gas emission factor (lb/MMBtu)] x [22% energy generation from oil/natural gas and other fuels]	27	3.6	1.1
b. CO		200	26	8.2
c. NO_X		101	13	4.2
d. SO_2		197	26	8.1

Sources:

1. Model Plant Description and Cost Report (II-A-112).
2. Dry Injection Fabric Filter Cost Memorandum (IV-B-32).

Emission Factors	Value	Units
PM	1.9	lb/MM ft^3 natural gas
	0.00186275	lb/MMBtu natural gas
	0.03	lb/MMBtu solid, liquid, gaseous fuel
CO	84	lb/MM ft^3 natural gas
	0.0824	lb/MMBtu natural gas
	0.19	lb/MMBtu bituminous coal
NO_X	100	lb/MM ft^3 natural gas
	0.0382	lb/MMBtu natural gas
	0.0975	lb/MMBtu solid fuel
SO_2	0.6	lb/MM ft^3 natural gas
	0.00059	lb/MMBtu natural gas
	0.2211	lb/MMBtu solid fuel

Sources:

1. AP-42 emission factors for PM, CO, NO_X, and SO_2 for natural gas combustion. NO_X reduced by 61% to reflect reductions similar to what CAIR would have achieved in 2015 (assuming CAIR replacement achieves similar reductions).
2. NSPS limit for PM (40 CFR part 60, subpart Da) for utility boilers.
3. AP-42 emission factor for CO for bituminous coal-fired spreader stoker boilers.
4. CAMD emission reports for NO_X and SO_2 for solid fuel-fired utility boilers. SO_2 reduced by 70% and NO_X reduced by 61% to reflect reductions similar to what CAIR would have achieved in 2015 (assuming CAIR replacement achieves similar reductions).

Assume electricity generated using the following mix (from IPM Version 3.0 for the year 2015):

Fuel	Percent of generation	Notes
Coal	53%	
Oil/natural gas	21%	
Nuclear	17%	No secondary air emissions estimated
Hydroelectric	6%	No secondary air emissions estimated
Renewable	2%	No secondary air emissions estimated
Other	1%	Assumed equivalent to natural gas

Table 5. Selective Noncatalytic Reduction Secondary Impacts

Parameters/Costs	Equation	Large	Medium	Small
A. Parameters				
1. Incinerator capacity, lb/hr (C)		4,000	400	100
2. Annual operating hours, hr/yr (H)		8,000	4,500	3,000
3. Exhaust gas flow rate, dscfm (Q)		10,000	2,000	700
4. Heating value, Btu/lb (HV)		8,500	8,500	8,500
5. NO_X concentration, lb/MMBtu (NO_X)		0.11	0.28	0.28
B. Secondary Impacts				
1. Energy impacts				
a. kWh/yr	= kW [0.47 x NO_X x (C x HV) / 10^6] / 9.5 x H	1,480	212	35
b. MMBtu/yr	= [Electricity (kWh/yr)] x [1 Btu / 0.000292875 kWh] x [1 MM Btu/10^6 Btu]	5.1	0.7	0.1
2. Secondary emissions, lb/yr				
a. PM	= [Energy impacts (MMBtu/yr)] x [solid fuel emission factor (lb/MMBtu)] x [53% energy generation from coal] + [energy impacts (MMBtu/yr)] x [natural gas emission factor (lb/MMBtu)] x [22% energy generation from oil/natural gas and other fuels]	0.08	0.01	0.002
b. CO		0.6	0.09	0.01
c. NO_X		0.3	0.04	0.007
d. SO_2		0.6	0.08	0.01

Source:

1. OAQPS Control Cost Manual. Section 4.2: NO_X Post-Combustion, Chapter 1: Selective Noncatalytic Reduction.

Emission Factors	Value	Units
PM	1.9	lb/MM ft^3 natural gas
	0.00186275	lb/MMBtu natural gas
	0.03	lb/MMBtu solid, liquid, gaseous fuel
CO	84	lb/MM ft^3 natural gas
	0.0824	lb/MMBtu natural gas
	0.19	lb/MMBtu bituminous coal
NO_X	100	lb/MM ft^3 natural gas
	0.0382	lb/MMBtu natural gas
	0.0975	lb/MMBtu solid fuel
SO_2	0.6	lb/MM ft^3 natural gas
	0.00059	lb/MMBtu natural gas
	0.2211	lb/MMBtu solid fuel

Sources:

1. AP-42 emission factors for PM, CO, NO_X, and SO_2 for natural gas combustion. NO_X reduced by 61% to reflect reductions similar to what CAIR would have achieved in 2015 (assuming CAIR replacement achieves similar reductions).
2. NSPS limit for PM (40 CFR part 60, subpart Da) for utility boilers.
3. AP-42 emission factor for CO for bituminous coal-fired spreader stoker boilers.
4. CAMD emission reports for NO_X and SO_2 for solid fuel-fired utility boilers. SO_2 reduced by 70% and NO_X reduced by 61% to reflect reductions similar to what CAIR would have achieved in 2015 (assuming CAIR replacement achieves similar reductions).

Assume electricity generated using the following mix (from IPM Version 3.0 for the year 2015):

Fuel	Percent of generation	Notes
Coal	53%	
Oil/natural gas	21%	
Nuclear	17%	No secondary air emissions estimated
Hydroelectric	6%	No secondary air emissions estimated
Renewable	2%	No secondary air emissions estimated
Other	1%	Assumed equivalent to natural gas

Table 6. Activated Carbon Injection Secondary Impacts

Parameters/Costs	Equation	Large	Medium	Small
A. Parameters				
1. Incinerator capacity, lb/hr (C)		4,000	400	100
2. Annual operating hours, hr/yr (H)		8,000	4,500	3,000
3. Exhaust gas flow rate, dscfm (Q)		10,000	2,000	700
B. Secondary Impacts				
1. Solid waste impacts, tpy	= 0.00127 x Q x [1 ton/2,000 lb] x H	51	5.7	1.3

Source:

1. Model Plant Description and Cost Report (II-A-112).

Table 7. Secondary Impacts for Incremental Controls

Parameters/Costs	Equation	Large	Medium	Small
A. Parameters				
1. Incinerator capacity, lb/hr (IC)		4,000	400	100
2. Annual operating hours, hr/yr (H)		8,000	4,500	3,000
3. Exhaust gas flow rate, dscfm (Q)		10,000	2,000	700
B. Increase Carbon Flow				
1. Solid waste impacts, tpy	= 0.00127 x Q x [1 ton/2,000 lb] x H	50.8	5.72	1.33
C. Increase Natural Gas				
1. Energy impacts (natural gas)				
a. $MMft^3$/yr	= [0.32 Btu/lb/°F] x [28.5 lb/lbmole] x [1800 - 1700°F temperature increase] x [lbmole/385 ft^3] x [ft^3/1,000 Btu] x [Q/0.9] x [60 min/hr] x H x [1 $MMft^3/10^6$ ft^3]	13	1.4	0.3
b. MMBtu/yr	= [Natural gas ($MMft^3$/yr)] x [1,000 MMBtu/$MMft^3$]	12,634	1,421	332
2. Secondary emissions, lb/yr				
a. PM	= [Natural gas ($MMft^3$/yr)] x [natural gas emission factor (lb/$MMft^3$)]	24	2.7	0.6
b. CO		1,061	119	28
c. NO_X		1,263	142	33
d. SO_2		7.6	0.9	0.2

Sources:

1. Model Plant Description and Cost Report (II-A-112)
2. Secondary Chamber Retrofit Cost Memorandum (IV-B-33)
4. Dry Injection Fabric Filter Cost Memorandum (IV-B-32)

Emission Factors	Value	Units
PM	1.9	lb/MM ft^3 natural gas
	0.00186275	lb/MMBtu natural gas
	0.03	lb/MMBtu solid, liquid, gaseous fuel
CO	84	lb/MM ft^3 natural gas
	0.0824	lb/MMBtu natural gas
	0.19	lb/MMBtu bituminous coal
NO_X	100	lb/MM ft^3 natural gas
	0.0382	lb/MMBtu natural gas
	0.0975	lb/MMBtu solid fuel
SO_2	0.6	lb/MM ft^3 natural gas
	0.00059	lb/MMBtu natural gas
	0.2211	lb/MMBtu solid fuel

Sources:

1. AP-42 emission factors for PM, CO, NO_X, and SO_2 for natural gas combustion. NO_X reduced by 61% to reflect reductions similar to what CAIR would have achieved in 2015 (assuming CAIR replacement achieves similar reductions).
2. NSPS limit for PM (40 CFR part 60, subpart Da) for utility boilers.
3. AP-42 emission factor for CO for bituminous coal-fired spreader stoker boilers.
4. CAMD emission reports for NO_X and SO_2 for solid fuel-fired utility boilers. SO_2 reduced by 70% and NO_X reduced by 61% to reflect reductions similar to what CAIR would have achieved in 2015 (assuming CAIR replacement achieves similar reductions).

Assume electricity generated using the following mix (from IPM Version 3.0 for the year 2015):

Fuel	Percent of generation	Notes
Coal	53%	
Oil/natural gas	21%	
Nuclear	17%	No secondary air emissions estimated
Hydroelectric	6%	No secondary air emissions estimated
Renewable	2%	No secondary air emissions estimated
Other	1%	Assumed equivalent to natural gas

Table 8. Autoclave Treatment Secondary Impacts

Parameters/Costs	Equation	Large	Medium	Small
A. Parameters				
1. Incinerator capacity, lb/hr (C)		4,000	400	100
2. Annual operating hours, hr/yr (H)		8,000	4,500	3,000
B. Secondary Impacts				
1. Solid waste impacts, tpy	= [autoclaved waste landfilled (C x 0.67 x H) - incinerated waste landfilled (C x 0.67 x 0.1 x H)] x (1 ton/2,000 lb)	9,648	543	90
2. Energy impacts				
a. Sterilizer steam usage, lb/hr	= 0.1316 x C + 10.561; derived from vendor quote	537	70	26
b. Sterilizer electrical usage, kWh/hr	= 0.0003 x C + 0.3228; derived from vendor quote	1.5	0.4	0.4
c. Compactor electrical usage, kWh/hr	From vendor quote	0.6	0.6	0.2
d. Total, MMBtu/yr	[Sterilizer steam usage (lb steam/hr x 922 Btu/lb steam) x (1 MM Btu/10^6 Btu) x H] + [total electrical usage kWh/hr x (1 Btu/0.000292875 kWh) x (1 MM Btu/10^6 Btu) x H]	4,019	305	77
3. Secondary emissions, lb/yr				
a. PM	= [Energy impacts (MMBtu/yr)] x [solid fuel emission factor (lb/MMBtu)] x [53% energy generation from coal] + [energy impacts (MMBtu/yr)] x [natural gas emission factor (lb/MMBtu)] x [22% energy generation from oil/natural gas and other fuels]	66	5.0	1.2
b. CO		478	36	9.1
c. NO_X		241	18	4.6
d. SO_2		471	36	9.0

Notes:

1. Assume 90% reduction in solid waste with incineration.
2. Sterilizer steam and electrical usage for large model calculated using equations derived from vendor quote (see Table 9 and Figures 1 and 2); values for medium and small models taken directly from vendor quote. Compactor electricity usage for large new source model assumed to be the same as value for large and medium existing source models.

Source:

1. San-I-Pak vendor quote.

Emission Factors	Value	Units
PM	1.9	lb/MM ft^3 natural gas
	0.00186275	lb/MMBtu natural gas
	0.03	lb/MMBtu solid, liquid, gaseous fuel
CO	84	lb/MM ft^3 natural gas
	0.0824	lb/MMBtu natural gas
	0.19	lb/MMBtu bituminous coal
NO_X	100	lb/MM ft^3 natural gas
	0.0382	lb/MMBtu natural gas
	0.0975	lb/MMBtu solid fuel
SO_2	0.6	lb/MM ft^3 natural gas
	0.00059	lb/MMBtu natural gas
	0.2211	lb/MMBtu solid fuel

Sources:

1. AP-42 emission factors for PM, CO, NO_X, and SO_2 for natural gas combustion. NO_X reduced by 61% to reflect reductions similar to what CAIR would have achieved in 2015 (assuming CAIR replacement achieves similar reductions).
2. NSPS limit for PM (40 CFR part 60, subpart Da) for utility boilers.
3. AP-42 emission factor for CO for bituminous coal-fired spreader stoker boilers.
4. CAMD emission reports for NO_X and SO_2 for solid fuel-fired utility boilers. SO_2 reduced by 70% and NO_X reduced by 61% to reflect reductions similar to what CAIR would have achieved in 2015 (assuming CAIR replacement achieves similar reductions).

Assume electricity generated using the following mix (from IPM Version 3.0 for the year 2015):

Fuel	Percent of generation	Notes
Coal	53%	
Oil/natural gas	21%	
Nuclear	17%	No secondary air emissions estimated
Hydroelectric	6%	No secondary air emissions estimated
Renewable	2%	No secondary air emissions estimated
Other	1%	Assumed equivalent to natural gas

Table 9. San-I-Pak Sterilizer Steam and Electricity Usage

Capacity, lb/hr	Sterilizer steam, lb/yr	Sterilizer electricity, kWh/hr
106	25.51	0.36
460	69.74	0.43
1,400	195.22	0.69
4,000	536.96	1.52

Figure 1. San-I-Pak Sterilizer Steam Usage

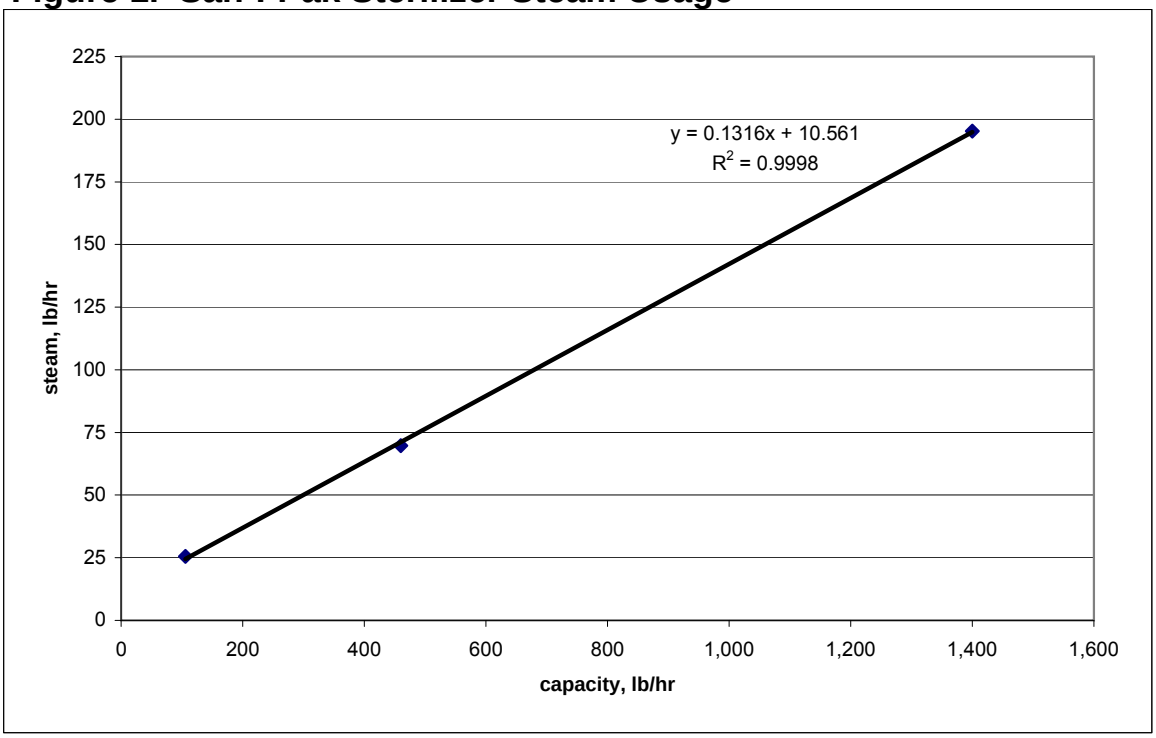

Figure 2. San-I-Pak Sterilizer Electricity Usage

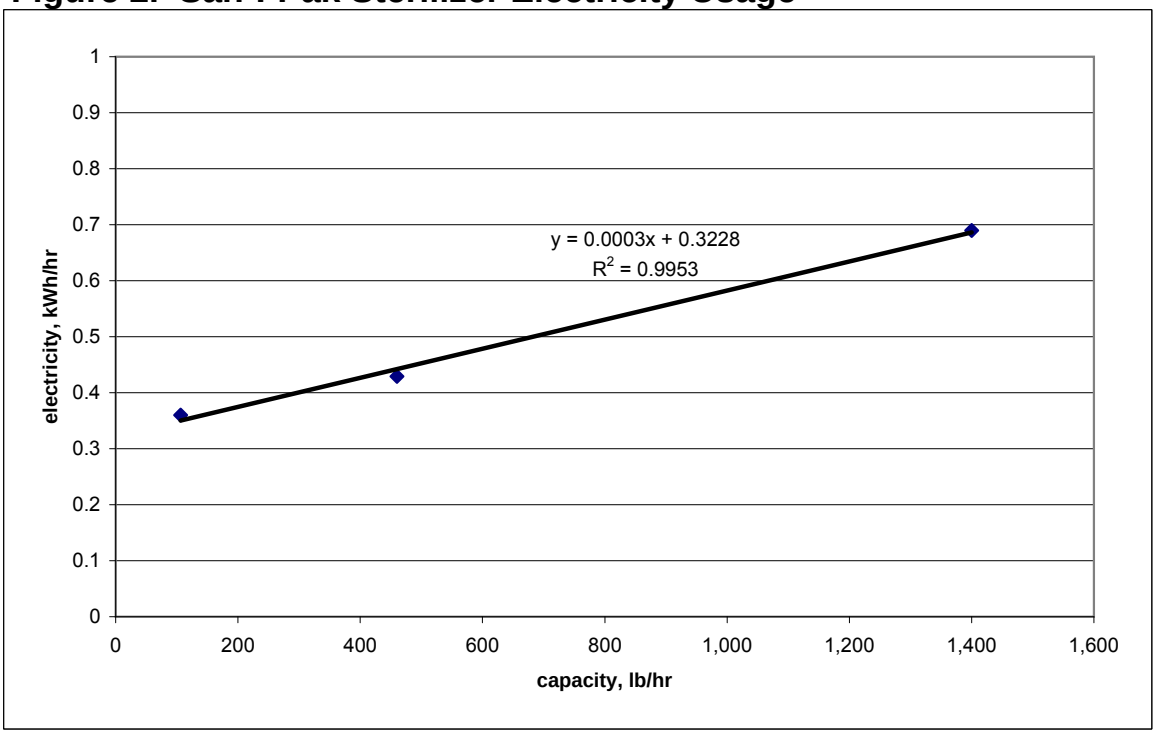

Table 10. Landfill Secondary Impacts

Parameters/Costs	Equation	Large	Medium	Small
A. Parameters				
1. Incinerator capacity, lb/hr (C)		4,000	400	100
2. Annual operating hours, hr/yr (H)		8,000	4,500	3,000
3. CH_4 generation potential, m^3/Mg (Lo)	assume Lo = 100 m^3/Mg	100	100	100
4. Average annual refuse acceptance rate, Mg/yr (R)	= [(C x 0.67)/(2,000 lb/ton)] x (0.90718 Mg/ton) x H	9,725	547	91
5. CH_4 generation constant, yr^{-1} (k)	assume k = 0.04 yr^{-1} (for areas receiving ≥25 inches/yr of rain)	0.04	0.04	0.04
6. Time since landfill closure, yr (c)	assume c = 0 yrs (for active landfills)	0	0	0
7. Time since initial refuse placement, yr (t)	assume t = 10 yrs (to reach steady state)	10	10	10
8. CH_4 molecular weight, g/g-mol (MW_{CH4})		16.05	16.05	16.05
9. Temperature of landfill gas, °C (T)	assume T = 25°C	25	25	25
10. Collection efficiency of landfill gas collection system (η_{col})	assume η_{col} = 75%	75%	75%	75%
11. Control efficiency of landfill gas control device (η_{cnt})	assume η_{cnt} = 99.7% (for flare controlling non-halogenated compounds)	99.7%	99.7%	99.7%
12. Hg concentration in landfill, (Hg)		2.92E-04	2.92E-04	2.92E-04
13. Hg molecular weight, g/g-mol (MW_{Hg})		200.59	200.59	200.59
B. Secondary Impacts				
1. Solid waste impacts, tpy	= [autoclaved waste landfilled (C x 0.67 x H) - incinerated waste landfilled (C x 0.67 x 0.1 x H)] x (1 ton/2,000 lb)	9,648	543	90
2. CH_4 secondary emissions				
a. Uncontrolled CH_4 emission rate, m^3/yr (Q_{CH4})	= Lo x R x (e^{-kc} - e^{-kt})	320,613	18,034	3,006
b. Uncontrolled CH_4 mass emissions, tpy (UM_{CH4})	= Q_{CH4} x (MW_{CH4} x 1 atm) / [(8.205E-05 m^3-atm/g-mol-°K) x (1,000 g/kg) x (273 + T)°K] x (1 ton/907.1847 kg)	232	13	2.2
b. Controlled CH_4 mass emissions, tpy (CM_{CH4})	= [UM_{CH4} x (1 - η_{col}/100)] + [UM_{CH4} x η_{col}/100 x (1 - η_{cnt}/100)]	59	3.3	0.5
3. Hg secondary emissions				
a. Uncontrolled Hg emission rate, m^3/yr (Q_{Hg})	1.82 x Q_{CH4} x Hg/(1E06)	1.70E-04	9.58E-06	1.60E-06
b. Uncontrolled Hg, mass emissions, lb/yr (UM_{Hg})	= Q_{Hg} x (MW_{Hg} x 1 atm) / [(8.205E-05 m^3-atm/g-mol-°K) x (1,000 g/kg) x (273 + T)°K] x (1 lb/0.4535924 kg)	3.08E-03	1.73E-04	2.89E-05

Notes:
1. Assume 90% reduction in solid waste with incineration.
2. Assume Hg emissions from landfill are uncontrolled.

Source:
U.S. Environmental Protection Agency. 1998. AP-42, Fifth Edition, Volume I, Section 2.4, Municipal Solid Waste Landfills. November.

Table 11. Nationwide MACT Floor Secondary Impacts for New Sources

Facility name	Category	APCD code	APCD type	APCD description	Maximum charge rate (lb/hr)	Stack gas flow rate (dscfm)	Operating hours (hr/yr)	Autoclave secondary impacts					
								Energy impacts, MMBtu/yr	PM secondary emissions, lb/yr	CO secondary emissions, lb/yr	NO_X secondary emissions, lb/yr	SO_2 secondary emissions, lb/yr	Total secondary emissions, lb/yr
Facility A	L	DIFF	Dry	Secondary chamber, baghouse with virgin lime injection, urea injection, and activated carbon injection	4,000	10,000	8,000	**4,019**	66	478	241	471	**1,256**
Facility B	M	DIFF	Dry	Secondary/tertiary chambers (1800F, 2.85 sec) and dry scrubber/baghouse with lime and activated carbon injection	400	2,000	4,500	**305**	5.0	36	18	36	**95**
Facility C	S	WS	Wet	Secondary chamber (1800F, 1.68 sec) and rotary atomizing wet scrubber	100	700	3,000	**77**	1.2	9.1	4.6	9.0	**24**
Total nationwide								**4,401**	**72**	**523**	**264**	**516**	**1,375**

Notes:
1. Patterned new source models after those new HMIWI installed in last 10 years.
2. If emissions data unavailable, used average emissions estimates for similar units (APCD, size) to determine impact status.

Table 11. Natio

Facility name	Category	Landfill secondary impacts				Meets HCl Limit	Meets CO Limit	Meets Cd Limit	Meets Pb Limit	Meets Hg Limit	Meets PM Limit	Meets Total CDD/CDF Limit	Meets CDD/CDF TEQ Limit	Meets CDD/CDF Limit (Total or TEQ)
		Solid waste impacts, tpy	CH_4 secondary emissions, tpy	Hg secondary emissions, lb/yr	Total secondary emissions, tpy									
Facility A	L	**9,648**	**59**	**0.003**	**59**	1	1	1	1	1	1	0	0	0
Facility B	M	**543**	**3.3**	**0.0002**	**3.3**	1	1	0	0	1	0	1	1	1
Facility C	S	**90**	**0.5**	**0.00003**	**0.5**	0	1	0	0	0	0	0	0	0
Total nationwide		**10,281**	**62**	**0.003**	**62**									

Notes:
1. Patterned new sourc
2. If emissions data una
units (APCD, size) to de

Table 11. Natio

Facility name	Category	Meets NO_X Limit	Meets SO_2 Limit	HCl % Improvement Needed	MACT floor HCl control	CO % Improvement Needed	MACT floor CO control	Pb % Improvement Needed	MACT floor Pb control	Cd % Improvement Needed	MACT floor Cd control	Hg % Improvement Needed
Facility A	L	0	0	989%	include packed-bed scrubber	18%	use more natural gas	2714%	install more efficient FF	822%	install more efficient FF	900%
Facility B	M	1	1	397%	include packed-bed scrubber	10%	use more natural gas	-75%	none	-85%	none	363%
Facility C	S	1	1	-71%	none	48%	use more natural gas	-60%	none	-55%	none	-61%
Total nationwide												

Notes:
1. Patterned new sourc
2. If emissions data una
units (APCD, size) to de

Table 11. Natio

Facility name	Category	MACT floor Hg control	PM % Improvement Needed	MACT floor PM control	Total CDD/CDF % Improvement Needed	MACT floor CDD/CDF control	CDD/CDF TEQ % Improvement Needed	MACT floor TEQ control	NO_X % Improvement Needed	MACT floor NO_X control	SO_2 % Improvement Needed	MACT floor SO_2 control
Facility A	L	use more activated carbon	72%	install more efficient FF	-46%	none	-58%	none	-27%	none	-56%	none
Facility B	M	use more activated carbon	-60%	none	4557%	use more activated carbon	1885%	use more activated carbon	177%	include SNCR	143%	include packed-bed scrubber
Facility C	S	none	-55%	none	-65%	none	-43%	none	177%	include SNCR	351%	include packed-bed scrubber
Total nationwide												

Notes:
1. Patterned new sourc
2. If emissions data una
units (APCD, size) to de

Table 11. Natio

Facility name	Category	Consolidated MACT floor controls	APCD code with MACT floor controls	MACT floor energy impacts, MMBtu/yr				MACT floor solid waste impacts, tpy	MACT floor wastewater impacts, gpy	MACT floor PM secondary emissions, lb/yr			
				Packed-bed scrubber	SNCR	Use more natural gas	Total MACT floor energy impacts	Use more activated carbon	Packed-bed scrubber	Packed-bed scrubber	SNCR	Use more natural gas	Total MACT floor PM secondary emissions
Facility A	L	install more efficient FF, include packed-bed scrubber, use more natural gas and activated carbon	DIFF/WS	956		12,634	**13,589**	**51**	**7,117**	16		24	**40**
Facility B	M	include packed-bed scrubber and SNCR, use more natural gas and activated carbon	DIFF/WS	108	0.7	1,421	**1,530**	**5.7**	**877**	1.8	0.01	2.7	**4.5**
Facility C	S	include packed-bed scrubber and SNCR, use more natural gas	WS	34	0.1	332	**365**		**30**	0.5	0.002	0.6	**1.2**
Total nationwide				**1,097**	**0.8**	**14,387**	**15,484**	**57**	**8,024**	**18**	**0.01**	**27**	**45**

Notes:
1. Patterned new sourc
2. If emissions data una
units (APCD, size) to de

Table 11. Natio

Facility name	Category	MACT floor CO secondary emissions, lb/yr				MACT floor NO_X secondary emissions, lb/yr				MACT floor SO_2 secondary emissions, lb/yr				Total MACT floor secondary emissions, lb/yr
		Packed-bed scrubber	SNCR	Use more natural gas	Total MACT floor CO secondary emissions	Packed-bed scrubber	SNCR	Use more natural gas	Total MACT floor NO_X secondary emissions	Packed-bed scrubber	SNCR	Use more natural gas	Total MACT floor SO_2 secondary emissions	
Facility A	L	114		1,061	**1,175**	57		1,263	**1,321**	112		7.6	**120**	**2,655**
Facility B	M	13	0.09	119	**132**	6.5	0.04	142	**149**	13	0.08	0.9	**14**	**299**
Facility C	S	4.0	0.01	28	**32**	2.0	0.007	33	**35**	4.0	0.01	0.2	**4.2**	**72**
Total nationwide		**130**	**0.1**	**1,208**	**1,339**	**66**	**0.05**	**1,439**	**1,505**	**129**	**0.1**	**8.6**	**137**	**3,026**

Notes:
1. Patterned new sourc
2. If emissions data una
units (APCD, size) to de

Table 12. Nationwide Beyond-the-Floor Secondary Impacts for New Sources

Facility name	Category	APCD code	APCD type	APCD description	Maximum charge rate (lb/hr)	Stack gas flow rate (dscfm)	Operating hours (hr/yr)	Autoclave secondary impacts					
								Energy impacts, MMBtu/yr	PM secondary emissions, lb/yr	CO secondary emissions, lb/yr	NO_X secondary emissions, lb/yr	SO_2 secondary emissions, lb/yr	Total secondary emissions, lb/yr
Facility A	L	DIFF	Dry	Secondary chamber, baghouse with virgin lime injection, urea injection, and activated carbon injection	4,000	10,000	8,000	**4,019**	66	478	241	471	**1,256**
Facility B	M	DIFF	Dry	Secondary/tertiary chambers (1800F, 2.85 sec) and dry scrubber/baghouse with lime and activated carbon injection	400	2,000	4,500	**305**	5.0	36	18	36	**95**
Facility C	S	WS	Wet	Secondary chamber (1800F, 1.68 sec) and rotary atomizing wet scrubber	100	700	3,000	**77**	1.2	9.1	4.6	9.0	**24**
Total nationwide								**4,401**	**72**	**523**	**264**	**516**	**1,375**

Notes:
1. Patterned new source models after those new HMIWI installed in last 10 years.
2. The only beyond-the-floor options available for new sources are SNCR (large HMIWI), no additional controls available (medium HMIWI), and DIFF with activated carbon (small HMIWI).

Table 12. Nation

Facility name	Category	Landfill secondary impacts				MACT floor controls	APCD code with MACT floor controls	Beyond-the-floor controls	APCD code with MACT floor and BTF controls
		Solid waste impacts, tpy	CH_4 secondary emissions, tpy	Hg secondary emissions, lb/yr	Total secondary emissions, tpy				
Facility A	L	**9,648**	**59**	**0.003**	**59**	install more efficient FF, include packed-bed scrubber, use more natural gas and activated carbon	DIFF/WS	include SNCR	DIFF/WS
Facility B	M	**543**	**3.3**	**0.0002**	**3.3**	include packed-bed scrubber and SNCR, use more natural gas and activated carbon	DIFF/WS	none	DIFF/WS
Facility C	S	**90**	**0.5**	**0.00003**	**0.5**	include packed-bed scrubber and SNCR, use more natural gas	WS	include DIFF and ACI	DIFF/WS
Total nationwide		**10,281**	**62**	**0.003**	**62**				

Notes:
1. Patterned new source
2. The only beyond-the-f
additional controls availa

Table 12. Nation

Facility name	Category	Beyond-the-floor energy impacts, MMBtu/yr				Beyond-the-floor solid waste impacts, tpy				Beyond-the-floor wastewater impacts, gpy		Beyond-the-floor PM secondary em		
		DIFF	SNCR	Total BTF energy impacts	MACT floor and BTF energy impacts	DIFF	ACI	Total BTF solid waste impacts	MACT floor and BTF solid waste impacts	Total BTF wastewater impacts	MACT floor and BTF solid waste impacts	DIFF	SNCR	Total BTF PM secondary emissions, tpy
Facility A	L		5.1	**5.1**	**13,594**			**0**	**51**	**0**	**7,117**		0.08	**0.08**
Facility B	M			**0**	**1,530**			**0**	**5.7**	**0**	**877**			**0**
Facility C	S	69		**69**	**435**	6.5	1.3	**7.9**	**7.9**	**0**	**30**	1.1		**1.1**
Total nationwide		**69**	**5.1**	**74**	**15,559**	**6.5**	**1.3**	**7.9**	**64**	**0**	**8,024**	**1.1**	**0.1**	**1.2**

Notes:
1. Patterned new source
2. The only beyond-the-f
additional controls availa

Table 12. Nation

Facility name	Category	issions, lb/yr MACT floor and BTF PM secondary emissions
Facility A	L	40
Facility B	M	4.5
Facility C	S	2.3
Total nationwide		**46**

Notes:
1. Patterned new source
2. The only beyond-the-f
additional controls availa

Table 12. Nation

Facility name	Category	Beyond-the-floor CO secondary emissions, lb/yr				Beyond-the-floor NO_X secondary emissions, lb/yr				Beyond-the-floor SO_2 secondary emissions, lb/yr			
		DIFF	SNCR	Total BTF CO secondary emissions	MACT floor and BTF CO secondary emissions	DIFF	SNCR	Total BTF NO_X secondary emissions	MACT floor and BTF NO_X secondary emissions	DIFF	SNCR	Total BTF SO_2 secondary emissions	MACT floor and BTF SO_2 secondary emissions
Facility A	L		0.6	**0.6**	**1,175**		0.3	**0.3**	**1,321**		0.6	**0.6**	**120**
Facility B	M			**0**	**132**			**0**	**149**			**0**	**14**
Facility C	S	8.2		**8.2**	**40**	4.2		**4.2**	**39**	8.1		**8.1**	**12**
Total nationwide		**8.2**	**0.6**	**8.8**	**1,348**	**4.2**	**0.3**	**4.5**	**1,509**	**8.1**	**0.6**	**8.7**	**146**

Notes:
1. Patterned new source
2. The only beyond-the-f
additional controls availa

Table 12. Nation

Facility name	Category	Total BTF secondary emissions, lb/yr	Total MACT floor and BTF secondary emissions, lb/yr
Facility A	L	1.6	2,656
Facility B	M	0	299
Facility C	S	22	94
Total nationwide		23	3,049

Notes:
1. Patterned new source
2. The only beyond-the-f
additional controls availa