EMISSION ESTIMATES FOR MODERN RESOURCE RECOVERY FACILITIES

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ABSTRACT

This paper presents a refined method of deriving emission estimates for modern mass-burn facilities equipped with dry scrubber/baghouse pollution control systems. Given the sensitivity of environmental issues, emission estimates are critical components of a resource recovery project. Resource recovery full service operators and preparers of environmental impact reports need to estimate emissions as carefully as possible. Overestimating emissions can jeopardize projects for environmental reasons. Underestimating emissions can jeopardize projects if the vendor is unable to meet permit conditions. A significant recent development is the willingness of some air pollution control system vendors to guarantee maximum emissions of trace metals.

NOMENCLATURE

ACFM = actual cubic feet per minute

Baghouse = component of modern air pollution control systems which removes particulates from flue gases by impact and filtration

Btu = British thermal unit

Corrected = refers to "correcting" volumes of flue gas to a standard oxygen or carbon dioxide content as required by emission limitations

Dry Scrubber = component of modern air pollution control systems which reduces acid gas emissions by spraying a slurry of hydrated lime into flue gases, and producing a dry reaction product

Emissions = products of combustion of solid waste which are contained in the flue gases emitted from a facility's stack

Emission Factors = unit masses of products of combustion emitted per unit mass of solid waste combusted, usually expressed in terms of pounds of pollutant per ton of solid waste

gr = grain; 7000 grains equal 1 lb

Mass Burn = solid waste combustion technology which involves combustion of waste as-received, with little or no front-end separation or processing

PAH = polycyclic aromatic hydrocarbons

PCDD = polychlorinated-dibenzo-dioxin

PCDF = polychlorinated-dibenzo-furan

MSW = municipal solid waste

nm^3 = normal cubic meter

PPMDV = parts per million by volume on a dry basis

SCFM = standard cubic feet per minute

STD = standard deviation of the data set

TCDD = tetrachlorodibenzo-dioxin

TCDF = tetrachlorodibenzo-furan

INTRODUCTION

Emission estimates for resource recovery facilities are typically developed in the proposal stage of a project, often without vendor emission guarantees. The estimates are used for preliminary environmental permitting, and cannot be increased later to specific vendor guarantees without reconsideration of environmental impacts. It is therefore critical for these emission estimates to be derived on a not-to-exceed basis. The basis for preliminary emission estimates should include emission limitations established by local, state and federal regulatory agencies, and emissions test data from similar facilities. One major problem is the lack of emissions test data from facilities with modern dry scrubber/baghouse pollution control systems for use in deriving emission estimates. This paper presents a method for deriving preliminary emission estimates on a not-to-exceed basis using statistical analysis of existing test data and State of New Jersey emissions guidelines.

Full-service vendors for a variety of reasons may choose to guarantee emissions lower than the preliminary factors, particularly if the facility site is in an area designated as nonattainment for one or more pollutants. Full service vendors in turn generally request guarantees from combustion system manufacturers for maximum emissions of carbon monoxide, nitrogen oxides, and hydrocarbons, and from air pollution control system manufacturers for maximum emissions of acid gases and particulates. Emission estimates for other pollutants such as trace metals and dioxins are generally based solely on test data from existing facilities. However, a significant recent development toward additional confidence in these emission estimates is the willingness of some air pollution control system vendors to guarantee maximum emissions of trace metals.

Emission concentration limitations assumed as the basis for the regulated pollutant emission estimates in this paper are from the State of New Jersey Air Pollution Control Guidelines for Resource Recovery Facilities, Addendum 2, April 1987. For the purpose of this paper, regulated pollutants include carbon monoxide, nitrogen oxides, sulfur dioxide, particulates, nonmethane hydrocarbons, and hydrogen chloride, for which there are flue gas concentration limitations. New Jersey regulations provide a useful example due to the state's high level of resource recovery activity and advanced regulatory framework for resource recovery.

In addition to the concentration limitations for regulated pollutants, New Jersey facilities must also demonstrate compliance with specified emission rates for seven trace metals (mercury, lead, arsenic, beryllium, cadmium, chromium, and nickel); for organic substances (2, 3, 7, 8 TCDD; total PCDD; and total PCDF) as well as for other substances (hydrogen fluoride and sulfuric acid). However, trace metals, organics, and other substances have no specified emission concentrations required for compliance on which to base emission estimates. Emission estimates for trace metals, organic substances, and other substances are therefore established based on statistical analysis of test data from similar facilities.

A typical mass-burning facility schematic is presented in Fig. 1, which includes a dry scrubbing system for control of acid gas emissions and a baghouse for control of particulate emissions. Scrubbing equipment is currently a federal requirement for resource recovery facilities, and at low particulate control levels, such as required in New Jersey, economics generally favor use of baghouses instead of electrostatic precipitators. De-NO_x technologies have not been considered since they are less well developed, and usually are not required by regulatory agencies although California is a notable exception. Dry scrubber and baghouse pollution control systems typically comprise 12–15% of a facility's equipment cost, and also add significantly to operating costs due to normal maintenance, consumption of lime and water, and the production of added residue. The dry scrubbing system consists of a quench reactor in which lime slurry is sprayed into the flue gases to effect removal of sulfur dioxide (SO_2) and other acid gases (HCl, HF and H_2SO_4). Particulates are removed from the flue gases by filtration or impact in the fabric filter baghouse. Each combustion train generally has its own dry scrubbing system, fabric filter system, induced-draft fan, and stack flue.

SOURCES OF AIR POLLUTANTS AND EMISSION FACTORS

Regulated Pollutants

For the purpose of this paper, regulated pollutants are defined as the six pollutants for which there are regulatory limits in the New Jersey Guidelines on the allowable concentrations in flue gases. Therefore, emissions factors for regulated pollutants are all established based on the concentration limitation and density of the specific pollutant together with a peak corrected flue gas flow rate.

Use of a peak gas flow rate in conjunction with the emission limitation concentrations is necessary since emission factors for preliminary environmental assessments are to be not-to-exceed values. For this reason,
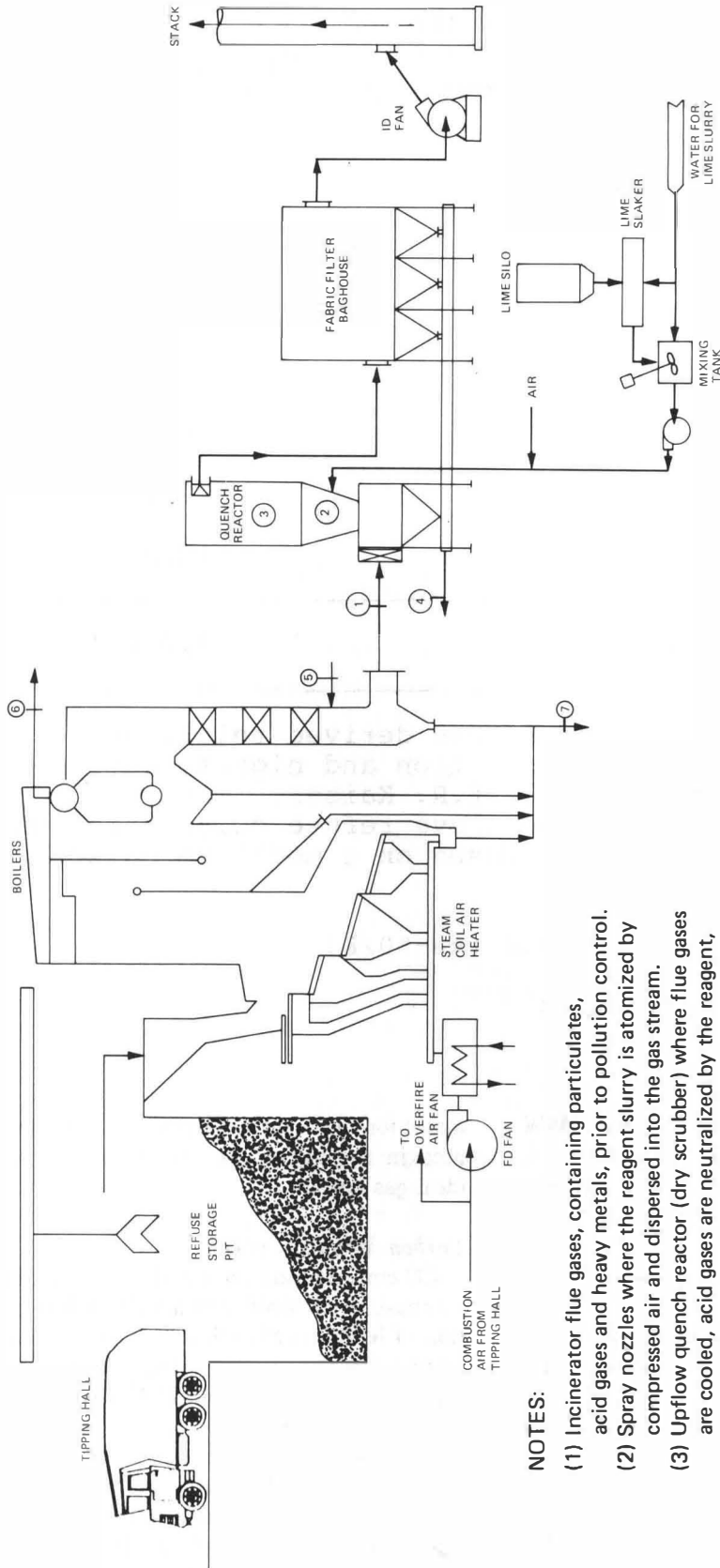
NOTES:

(1) Incinerator flue gases, containing particulates, acid gases and heavy metals, prior to pollution control.

(2) Spray nozzles where the reagent slurry is atomized by compressed air and dispersed into the gas stream.

(3) Upflow quench reactor (dry scrubber) where flue gases are cooled, acid gases are neutralized by the reagent, and dry product is generated for subsequent collection

(4) Flyash and reaction products to disposal

(5) Feedwater to economizer.

(6) Superheated steam to turbine-generator.

(7) Residue to disposal.

FIG. 1 TYPICAL MASS-BURNING FACILITY SCHEMATIC WITH DRY SCRUBBER AND BAGHOUSE

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TABLE 1 REFUSE ULTIMATE ANALYSIS

Component	Percent By Weight
Carbon	31.65
Hydrogen	4.21
Sulfur	0.15
Oxygen	22.89
Nitrogen	0.49
Chlorine	0.50
Moisture	22.00
Ash/Inerts	18.11
Higher Heating Value, Btu/lb	5,600[1]

Note: (1) Several researchers have derived relationships between refuse composition and higher heating values, most notably E.R. Kaiser. The relationship that applies to the above refuse composition was assumed as follows based on a modified Kaiser equation:

$$HHV = 151 \ (\%C) + 610 \ (\%H - \%O/8)$$

$$= 5,602 \ Btu/lb$$

emission factors presented herein are based on an MSW higher heating value (HHV) of 5600 Btu/lb, which is a typical peak design HHV at a given rated throughput for a resource recovery facility. Emission factors are therefore derived based on the peak flue gas flow rate corresponding to the peak thermal capacity of a resource recovery facility.

The combination of combustion and emissions calculations can easily be combined in a spread-sheet computer format. Table 1 presents a typical ultimate analysis for refuse with an HHV of 5600 Btu/lb. Table 2 presents a summary of a spread-sheet combustion and mass balance calculation, including the flue gas composition after the pollution control system used in calculating regulated pollutant emission estimates. Table 3 presents a tabular calculation of emission esti-

mates for the regulated pollutants. Pollutant densities used in the calculation are calculated based on the ideal gas law.

Carbon Monoxide (CO)

CO emissions are produced as a result of incomplete combustion of MSW and are dependent on composition of MSW, combustion technology, and boiler operation. Possible causes of high CO emissions include high moisture content of MSW, low and nonuniform combustion temperatures, an improper overfire air ratio, and poorly designed overfire air jets.

The emission factor used in projecting emissions, 1.259 lb/ton MSW, is based on the assumed regulatory limitation of 100 ppmdv (four-day rolling average) at 7% oxygen, and the calculation presented in Table 3.

TABLE 2 SUMMARY OF COMPUTERIZED COMBUSTION CALCULATIONS

FLUE GAS COMPONENT	PERCENT BEFORE SCRUBBER	BY VOLUME STACK EXIT[2]
Carbon Dioxide	8.207	7.145
Moisture	12.483	16.428
Sulfur Dioxide[3]	0.007	0.001
Oxygen	9.297	9.652
Nitrogen	69.970	66.771
Hydrogen Chloride[3]	0.036	0.003
Temperature, °F	425	268
ACF/Ton MSW	400,620	353,342
DSCF/Ton MSW[4]	-	214,170
DSCF/Ton MSW @ 12% CO_2	-	127,520
DSCF/Ton MSW at 7% O_2	-	173,308

Notes: (1) Flue gas compositions based on standard combustion calculations with 100 percent excess air rate and the 5,600 Btu/lb MSW from Table 1.

(2) Flue gas composition at stack exit includes nozzle air and moisture added for removal of acid gases.

(3) Sulfur dioxide and hydrogen chloride concentrations at stack exit are based on 80 and 90 percent removal and the assumed sulfur and chlorine contents of the waste, and are not used as the basis for emission estimates.

(4) Standardized at 20°C, or 68°F.

(5) Correction factor to 7% O_2 determined as follows:

$$CF = \frac{20.9 - \% \ O_2}{20.9 - 7.0}$$

TABLE 3   REGULATED POLLUTANT EMISSION FACTORS

REGULATED POLLUTANT	CONCENTRATION LIMITATION (PPMDV AT 7% O_2)	DENSITY[1] (LB/SCF)	EMISSION[3] FACTOR (LB/TON MSW)
Carbon Monoxide	100	0.07262	1.259
Nitrogen Oxides	350	0.11931	7.24
Sulfur Dioxide	100	0.16600	2.88
Non-Methane Hydrocarbons	70	0.3891	0.472
Hydrogen Chloride	50	0.09467	0.820
Particulates	0.015[4]	7000[5]	0.371

Notes:

(1) Densities calculated from the ideal gas law based on 385.6 ft^3/lb-mol.

(2) Emission factors are based on the peak gas flow of 140,198 dscf/ton MSW at 7 percent oxygen, developed in Table 1.

(3) To convert to SI units of g/kg MSW, multiply lb/ton MSW by 2.0.

(4) Concentration limitation for particulates is expresed in gr/dscf at 7 percent oxygen.

(5) Density for particulates is expressed in grains/lb.

(6) Example calculation:

$$\frac{LB\ CO}{Ton\ MSW} = \frac{100}{10^6} \times 173,308\ \frac{DSCF}{Ton} \times 0.07262\ \frac{LB}{SCF}$$

$$= 1.259\ lb/ton$$

Nitrogen Oxides (NO$_x$)

Nitrogen oxides are produced during combustion by conversion of nitrogen in the fuel and atmospheric nitrogen to NO_x at high temperatures. NO_x emissions are precursors to ozone, a prominent constituent of smog. It is believed that nitrogen oxide (NO) is formed mainly on the flame front where temperature is high and oxygen is available. The NO formed in the furnace subsequently oxidizes to nitrogen dioxide (NO_2) in the atmosphere. Generally, NO_x emissions from MSW boilers are low compared to other combustion sources due to lower combustion temperatures.

The nitrogen oxides emission factor, 7.24 lb/ton MSW, is based on the assumed regulatory limitation of 350 ppmdv (hourly average) at 7% oxygen, and the calculation presented in Table 3.

Sulfur Dioxide (SO$_2$)

Emissions of SO_2 are primarily dependent on the MSW sulfur content. However, only a fraction of the sulfur in the MSW is emitted as gaseous SO_2, because emissions are also dependent on the form and chemical bonding of the sulfur contained in the MSW. Sulfur appears in MSW as organic sulfur, sulfates and to a

lesser degree as sulfides. The sulfates do not readily oxidize, and generally become part of the incinerator ash. Primarily the organic sulfur oxidizes to gaseous SO_2 and SO_3, some of which exits the incinerator and some of which reacts to produce additional sulfates.

The sulfur content of waste is typically assumed to be 0.15–0.30%, and an uncontrolled emission factor of 3.0–6.0 lb/ton MSW would result from the assumption that approximately 50% of the sulfur in the waste is available for oxidation. However, the not-to-exceed emission factor of 2.88 lb/ton MSW is based on the assumed regulatory limitation of 100 ppmdv (3 hr average), and the calculation presented in Table 3.

Particulates

Uncontrolled emissions of particulate are related to the degree of turbulence in the combustion chamber. The controlled emission factor of 0.371 lb/ton MSW is based on the assumed regulatory limitation of 0.015 gr/dscf at 7% oxygen, and the calculation presented in Table 3.

Nonmethane Hydrocarbons (NMHC) as Methane

Hydrocarbons are another product of incomplete combustion. Primarily in the form of low-molecular-weight hydrocarbons, aldehydes and organic acids, hydrocarbons combine with NO_x to form photochemical oxidants, or smog, under warm, sunny conditions. Hydrocarbons are also precursors to ozone. Although there is no specific control device for hydrocarbons, combustion controls to control CO emissions generally also control hydrocarbon emissions.

The nonmethane hydrocarbon emission factor of 0.472 lb/ton MSW is derived based on the assumed regulatory limitation of 70 ppmdv at 7% O_2 and the calculation presented in Table 3.

Hydrogen Chloride (HCl)

Hydrogen chloride is a by-product of combustion formed primarily from the organic chlorine fraction of the MSW. Major sources of organic chlorine are chlorinated plastics, and rubber and leather products. Inorganic chlorine, such as that contained in paper, will end up largely in the bottom ash.

The HCl emission factor of 0.820 lb/ton MSW is based on the assumed regulatory limitation of 50 ppmdv at 7% oxygen and the calculation presented in Table 3. It should be noted that controlled emissions are not expected to exceed 50 ppmdv, although this is allowable provided the minimum 90% reduction of unabated emissions is achieved. Therefore, the not-to-exceed emission factor is calculated based on the 50 ppmdv concentration limitation.

Trace Metals

Mercury (Hg)

The emission factor for mercury is calculated separately from the other trace metals due to its low vapor pressure. Controlled and uncontrolled Hg emission factors are generally assumed to be equal to its trace concentration in the MSW. All Hg emissions are assumed to exit the incinerator in gaseous form, and are therefore not affected by the particulate control device as the other trace metals are. This assumption has been validated by tests of incinerator bottom ash and fly ash which have not detected Hg. It seems that Hg will not condense onto fly ash after being volatilized in the incinerator due to its low vapor pressure. The estimated emission factor for mercury of 8.89×10^{-3} lb/ton MSW is based on test data from several facilities, shown in Table 4, using the average plus one standard deviation to derive a not-to-exceed emission factor. This is believed to be an adequate not-to-exceed value even with the seemingly low confidence of one standard deviation, since all of the test data are within this range, and the standard deviation is of equal magnitude to the mean. In addition, it is logical to assume that a facility with a dry scrubber will have lower emissions than those facilities in Table 4 with electrostatic precipitators due to the lower operating temperatures of dry scrubbers. It is critical not to overestimate emissions of mercury because of its potentially adverse environmental impacts.

Other Trace Metals

Another method is used to derive controlled emission factors for the other six trace metals; arsenic, beryllium, cadmium, chromium, lead, and nickel. The estimates are based on trace metal concentrations on particulate matter from several MSW incinerators, as shown in Table 5. The equivalent controlled emission factors are based on the controlled particulate emission rate in the section on particulates and the trace metal concentrations on particulate matter from Table 5.

Emission factors for five of the trace metals are based on the average of the test data from Table 5 plus two standard deviations, with the exception of lead. The lead emission factor is based on an apparently lower level of confidence using the average plus one standard deviation. However, this is believed to be an adequate not-to-exceed emission factor because, similar to the test data for mercury, test data for lead are all within this range, the standard deviation is equal in magnitude to the mean, and most of the data in the set are from facilities with electrostatic precipitators. Due to the potentially adverse environmental impacts of lead, it

TABLE 4 MERCURY EMISSION FACTORS

FACILITY LOCATION	LB/TON MSW[1]
GALLATIN, TENNESSEE	1.71E-03
GHENT BELGIUM	3.87E-03
BRAINTREE, MASSACHUSETTS	1.47E-02
PRINCE EDWARD ISLAND, CANADA	8.87E-03
ALBANY, NEW YORK	4.59E-03
NIAGARA, NEW YORK	1.58E-03
TSUSHIMA, JAPAN	1.20E-03
TULSA, OKLAHOMA	3.52E-03
MARION COUNTY, OREGON	2.62E-03
AVERAGE	4.74E-03
STANDARD DEVIATION	4.15E-03
AVERAGE PLUS STD	8.89E-03
AVERAGE PLUS TWO STD	1.30E-02

Notes: (1) To convert to SI units of g/kg MSW, multiply lb/ton MSW by 2.0.

(2) Exponents expressed in scientific notation.

TABLE 5 TRACE METAL CONCENTRATIONS ON PARTICULATE MATTER (ppm)

METALS	BRAINTREE MA	ALEX. VA	WASH. DC	NICOSIA IL	HAMILTON ONTARIO	WURZBURG W. GER.	MUNICH W. GER	TSUSHIMA JAPAN	TULSA OK	MARION CO OR	AVERAGE	STD
ARSENIC	74	210	310	200	10	3	19				118	113
BERYLLIUM						0.021			0.063	0.098	0.061	0.031
CADMIUM	765	1100	1900	1500	1400	2500	360				1,361	658
CHROMIUM		490	870	105	600	230	(1)				459	271
LEAD	24870	97000	78000	69000	5700	5100	3700	662	8800	1333	29,416	35,173
NICKEL		200	170	79	670	100	(1)				244	218

NOTES: (1) Test data for chromium and nickel from the Munich facility were inexplicably high and therefore were not used.

is particularly critical not to overestimate emissions of this pollutant

It should be noted that Table 5 includes trace metal emissions test data from several older facilities with outdated air pollution control equipment. Test data from these facilities are used due to a general lack of test data from newer facilities, particularly for arsenic, cadmium, chromium, and nickel. However, use of the data in the form of concentrations of metal on controlled particulate matter should correct for differences between particulate control efficiencies of the older facilities compared to new facilities.

Dioxins and Furans (PCDD and PCDF)

Dioxins and furans are generic terms for a family of compounds which each consist of two carbon rings linked by one or two oxygen atoms. This family of compounds includes the two groups of compounds: (a) polychlorinated dibenzodioxins (PCDD), in which the carbon rings are linked by two oxygen atoms; and (b) polychlorinated dibenzofurans (PCDF), in which the carbon rings are joined by one oxygen atom. There are over 210 different isomers of dioxin/furan, each having a unique number and arrangement of chlorine atoms. Toxicity varies by factors of 1000 to 10,000, even among closely related isomers, and the same isomer may have a wide range of effects in different species. Dioxins are also suspected of being cancer promoters if not actual carcinogens.

The formation mechanism(s) for dioxin in incinerators are unknown. At least four dioxin formation theories exist: (a) emitted dioxin enters the system as dioxin; (b) emitted dioxin is formed from precursors such as PVC, PCB's, and chlorophenols; (c) emitted dioxin is formed from unrelated materials which become chlorinated, such as lignin; or (d) dioxin is formed as a result of incomplete combustion. Recent test data from several facilities in the State of New York seem to indicate that important formation mechanisms include oxygenation and chlorination reactions which occur in electrostatic precipitators. Test data also seem to indicate that proper combustion residence times, temperatures, and turbulence are important in controlling dioxin emissions. These theories have importance with respect to effective control of dioxin emissions.

Estimated emissions of dioxins and furans are based on test data from several MSW incinerators, shown on Table 6. As shown in Table 6, there is a wide variation between the tested facilities in the quantities of dioxins and furans emitted with the standard deviations of the samples nearly equal to the averages.

It also appears that the data from the newer facilities, Commerce, Marion County, Tulsa, and Westchester, have much lower emissions than the older facilities. Marion County and Commerce have remarkably low emissions, which may be related to the more sophisticated dry scrubber/baghouse pollution control equipment instead of the electrostatic precipitators used by the other facilities. Therefore, emissions factors are based on the average plus two standard deviations for 2, 3, 7, 8 TCDD, total PCDD, and total PCDF. It should be noted that the State of New Jersey sets emission limitations for 2, 3, 7, 8 TCDD as a surrogate for total dioxins and furans. However, Table 6 summarizes emissions test data in a format that will allow for use in states that regulate dioxins differently, for example, by setting emission limitations for 2, 3, 7, 8 TCDD equivalents.

Other Pollutants

Hydrogen Fluoride (HF)

Gaseous HF emissions are a function of the amount of chemical bonding of fluorine in the waste. One-third of the fluorine in the MSW typically exists as HF and the remainder is retained in the ash. Due to a lack of test data regarding fluoride emissions, the uncontrolled emission factor is based on an estimated 0.015% fluorine content in waste along with the one-third conversion rate to HF. The dry scrubber is expected to reduce HF emissions by 90%, resulting in the following:

$$\begin{matrix} \text{HF} \\ \text{Emission} \\ \text{Factor} \end{matrix} = \frac{0.10 \text{ lb F}}{\text{ton MSW}} \times \frac{20 \text{ lb HF}}{19 \text{ lb F}} \times 0.10$$

$$= 1.05 \times 10^{-2} \text{ lb/ton MSW}$$

Sulfuric Acid (H₂SO₄)

Emissions of H_2SO_4 are a function of SO_3 formation, which is in turn a function of the quantity of free sulfur in the MSW and combustion conditions.

Uncontrolled H_2SO_4 emissions are estimated to be 0.095 lb/ton MSW based on the assumption that 1.6% of the free sulfur in the waste is converted to H_2SO_4. A controlled emission factor of 0.0095 lb/ton MSW is based on the assumption that the dry scrubber will reduce H_2SO_4 emissions by 90%.

CONCLUSIONS

State of New Jersey emission limitations and reported test data have been used to derive emission

TABLE 6   AVERAGES OF PCDD AND PCDF CONCENTRATIONS IN COMBUSTION FLUE GASES (ng/dscm @ 12% CO_2)

COMPOUND	COMMERCE (1)	TULSA	MARION CTY	WESTCHESTER (1)	SAUGUS	N. ANDOVER	AVE.	STD
2378 TCDD	0.003	0.101	0.081	0.41	1.7	1.0	0.55	0.61
OTHER TCDD	0.109	1.512	0.114	3.72	30.2	12.8	8.08	10.81
2378 PeCDD	0.003	0.189	0.009	1.07	3.4	2.0	1.11	1.25
OTHER PeCDD	0.048	2.799	0.044	3.05	32.0	18.4	9.39	11.91
2378 HxCDD	0.025	0.524	0.023	0.82	5.1	3.0	1.58	1.87
OTHER HxCDD	0.077	4.571	0.087	4.83	29.5	14.0	8.84	10.34
2378 HpCDD	0.081	2.198	0.138	8.07	30.0	36.3	12.80	14.75
OTHER HpCDD	0.044	2.229	0.046	(3)	(3)	(3)	0.39	0.82
OCDD	0.225	4.810	0.589	12.95	37.3	26.6	13.75	13.88
TOTAL PCDD	0.615	18.93	1.131	34.93	169.2	114.1	56.48	63.36
2378 TCDF	0.028	2.905	0.168	3.14	23.3	20.1	8.27	9.61
OTHER TCDF	0.740	4.403	0.154	40.35	158.3	59.3	43.87	55.79
2378 PeCDF	0.033	.382	0.025	9.15	16.3	15.4	7.05	6.96
OTHER PeCDF	0.096	1.953	0.019	16.27	89.6	33.8	23.62	31.86
2378 HxCDF	0.106	1.437	0.019	2.89	20.8	8.9	5.69	7.39
OTHER HxCDF	0.029	0.384	0.000	23.34	48.7	6.01	3.08	17.92
2378 HpCDF	0.057	1.631	0.017	15.22	36.2	49.2	17.05	19.24
OTHER HpCDF	0.070	0.719	0.000	(4)	(4)	(4)	0.13	0.26
OCDF	0.048	0.706	0.036	0.56	17.7	41.6	10.11	15.45
TOTAL PCDF	1.207	15.52	0.437	110.9	410.9	234.3	128.88	150.90

NOTES: (1)   Commerce Concentrations based on detection limits for samples without detecton.

(2)   Westchester data corrected from 7% O_2 to 12% CO_2 based on assumed flue gas characteristics.

(3)   Only total HpCDD reported, and therefore all was assumed to be of the 2,3,7,8 forms.

(4)   Only total HpCDF reported, and therefore all was assumed to be of the 2,3,7,8 forms.

(5)   Only TETRA through OCTA PCDD and PCDF are considered here.

TABLE 7 SUMMARY OF EMISSION FACTORS

POLLUTANT	EMISSION FACTORS (lb/ton MSW)[1][2]
Particulate	0.371
Sulfur Dioxide	2.88
Hydrogen Chloride	0.820
Carbon Monoxide	1.259
Nitrogen Oxides	7.24
Non-Methane Hydrocarbons	0.472
Mercury	8.89E-03
Lead	2.40E-02
Arsenic	1.28E-04
Beryllium	4.56E-08
Cadmium	9.93E-04
Chromium	3.71E-04
Nickel	2.52E-04
2,3,7,8 TCDD	1.406-08
Total PCDD	1.46E-06
Total PCDF	3.42E-06
Hydrogen Fluoride	1.05E-02
Sulfuric Acid	9.50E-03

Note: (1) Exponents expressed in scientific notation.

(2) To convert to SI units of g/kg MSW, multiply lb/ton MSW by factor of 2.0.

factors for a resource recovery facility equipped with a dry scrubber and baghouse pollution control system. The emission factors summarized in Table 7, are derived on a not-to-exceed basis, and are therefore suitable for use in establishing emission limitations for preliminary environmental assessments. However, care must be taken not to underestimate or overestimate emission factors to avoid problems with environmental acceptability of a project. Full-service vendors may, therefore, wish to guarantee lower emission factors. Full service vendors can reduce risks of not meeting emission limitations by obtaining emission guarantees from combustion and air pollution control system vendors.

ACKNOWLEDGEMENTS

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