Proceedings of the 17th Biennial Waste Processing Conference
ASME 1996

COMPARISON OF AIR EMISSIONS FROM WASTE MANAGEMENT FACILITIES

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ABSTRACT

Landfilling remains the predominate disposal method for managing municipal solid waste (MSW) in the U.S. According to the U.S. EPA, in 1993 landfilling accounted for 62% of the management alternative for disposing of MSW while recycling and combustion account for 22% and 15% respectively. Recent actions such as limits on "flow control" and EPA's proposed Most Achievable Control Technology (MACT) rules for Municipal Waste Combustors (MWCs) most likely will increase the amount of MSW that will be landfilled.

The air emissions from landfill operations have in general been ignored and unregulated. This paper will make a comparison of air emissions from a landfill (Fresh Kills Landfill in NYC) and a modern MSW. The paper will present the emissions from landfill operations including "uncontrolled emissions", residual and secondary emissions from gas control systems, and emissions from diesel equipment at the landfill. The MWC emissions will include boiler pollutants and a comparison to fossil-fuel fired power plants.

INTRODUCTION

The integrated approach to the disposal and treatment of solid waste is increasing due to economic and regulatory pressure. The components of the integrated approach including recycling, composting, energy recovery, and landfilling should be combined into an overall waste management strategy that provides a balance between conservation of resources, beneficial use, community needs, and economics. Unfortunately, in the U.S. the regulatory and environmental impacts have not been fully considered in pursuing this balance.

In 1989, the U.S. Environmental Protection Agency (EPA) formally issued a national strategy for improved management of municipal solid waste (MSW). This strategy, called "integrated waste management," features a hierarchy of techniques:

- "Source Reduction" (i.e., reduce the MSW generation rate and toxicity)
- Recycling (includes composting)
- MSW Combustion (with energy recovery)
- Landfilling (Waste that cannot be practically recycled or combusted must be landfilled, likewise for the residues resulting from MSW, recycling, composting, and combustion.)

EPA placed source reduction and recycling at the top of the hierarchy. Then, for that fraction of MSW that cannot be recycled practically, EPA called for disposal by means of combustion with recovery of energy. Landfilling was designated by EPA for disposal of those waste types that cannot be recycled or combusted. EPA's ranking of waste-to-energy is consistent with the preference of other advanced, industrialized countries. For example, Switzerland has banned by law the landfilling of untreated MSW; also, such landfilling will be significantly restricted by law in Germany this decade. A comparison of U.S. solid waste disposal practices versus other developed nations is presented in Figure 1.

EPA noted that the four techniques above are complementary. No single management technique by itself is a panacea for waste management rather, an appropriate mix must be tailored to local needs.

Notwithstanding EPA's preferred waste management hierarchy, the United States continues to embrace landfilling as its principal means of MSW management. According to EPA's estimates of MSW disposal in 1993, this country landfilled 62 percent of its MSW, recycled 22 percent, and combusted only 15 percent in waste-to-energy facilities. This disparity between EPA's preferred hierarchy and actual practice is dramatically illustrated by the MSW management practices.

However, the environmental impacts of the individual components of the integrated approach have not been examined on an equal basis nor have the combination of processes that make up the overall strategy.

The air pollutant emissions from landfill operations have in general been ignored and unregulated. This paper makes a comparison of air emissions from landfills, modern municipal waste combustors (MWCs), and alternative power generation sources. Landfill emissions are more difficult to measure, evaluate, and control than the emissions from MWCs or fossil-fired power plants.

It is impossible to make an apple to apple environmental impact comparison between MWCs, power plants, landfills, and recycling plants. It is difficult to even make comparisons between MWCs and fossil-fired power plants due to the different regulations and data base. Each source has its own fingerprint of pollutants; some pollutants are emitted from one source and not from another. In addition, the source of some pollutants are regulated while other sources are not. Therefore, a pollutant from one source can not be compared to another source(s). Other problems are for example:

- Most landfill emissions are emitted at or near ground level while MWCs and fossil-fuel power plants have stacks which dilute and disperse the pollutants.

- We do not have a publicly acceptable alternative risk comparison between various pollutants. For example, is one pound of benzene, a carcinogen from a landfill as hazardous as one pound of lead, a non-carcinogen emitted from a MWC. In addition, landfill emissions include leachate and air pollutants while MWCs are limited to air emissions. How do we compare land, water, and air pollutants?

- There is a lack of data base of air emissions from landfills, composting, and recycling facilities in comparison with MWCs.

- Do we count the dioxin emissions from secondary aluminum smelters as recycling emissions or as aluminum industry emissions? If aluminum cans are not recycled and are disposed of in a MWC, the dioxin emissions would be considered as MWC emissions and would, therefore, be controlled. There is documented data showing that uncontrolled dioxin emissions from a smelter recovering aluminum cans from a recycling operation is 65 ng/Nm^3 I-TEQs, far greater than emission level of .02 ng/Nm dcsm allowed by EPA for MWCs.

- Composting products are used in gardens and lawns. The contaminants present in compost come into direct contact with people.

- The U.S. electric generation industry is currently exempt from being considered a "major source" of hazardous air pollutants (HAPs) under Title III of the CAAA of 1990 while MWC HAPs are regulated. One result of this practice is that we have a large background of data from MWC emissions but not from the electric generation industry. Electric generating plants in the U.K. have reported dioxin emissions while U.S. utilities are just starting to investigate this matter.

- In the U.K. dioxins emissions have been reported in the fugitive gas emissions from landfills as well as from treated gas and in landfill leachate.

- MWC air pollutant emissions and associated risks end when the plant is closed, however, landfill emissions can continue for over one hundred years.

This paper will be presented in two sections, the first is a summary of landfill air emissions, and the second is a comparison of MWC and fossil-fuel fired power plants. For comparison analysis the authors used as a reference a landfill and a MWC both operating at 1,500 T/D on a seven day/week basis. A 1,500 T/D MWC generates approximately 45 MWHrs of net electric power and this data base was used for comparison with fossil-fuel fired plants.

LANDFILL ENVIRONMENTAL EMISSIONS

In this section a technical overview is presented of the environmental emissions and other environmental issues associated with MSW landfills. The significant environmental issues associated with MSW landfills include the following:

* Odor emissions
* Vectors of disease (rodents, mosquitoes)
* Nuisance (blowing lifter, dust)
* Scavengers (e.g., gulls)
* Leachate migration (groundwater/surface-water impacts)
* Fires/explosions from landfill gas
* Air pollutant emissions including fugitive emissions

Most everyone knows that landfills cause odors, blowing litter, and nuisance gulls, and that landfills can attract disease carriers such as rats. Also, many people now understand the leachate threat. That is, leachate which is produced when rainwater percolates down through landfilled MSW can potentially migrate from a landfill. If the migration contaminates groundwater, this threatens the drinking water supply. If the migration contaminates surface water, this poses a risk to aquatic life. Leachate control systems act to contain leachate within the landfill using a liner under the landfill, collection drains, and cut-off walls as necessary. The collected leachate is then tested and is treated, if necessary, to meet discharge standards. Groundwater monitoring must be carried out to ensure the continued effectiveness of the leachate control systems.

A fact well-known to solid waste managers, but less so to the public, is that gaseous emissions from landfills can cause serious explosions and fires. As MSW decomposes in a landfill, "landfill gas" is produced, comprised of roughly 50% methane, 50% carbon dioxide, and less than 1% nonmethane organic compounds (NMOCs). Methane, when mixed with air, is highly explosive, and has caused fires and explosions both within and beyond landfill boundaries. Landfill gas can migrate subsurface, and accumulate in basements and other structures offsite. EPA notes that consequent explosions and fires "have caused severe injury and death." EPA compiled statistics on deaths, injuries, and property damage resulting from landfill-gas explosions and fires nationally during the 20-year period 1967 to 1987. EPA identified 20 incidents in 17 states in which gas migration resulted in explosions or fires offsite. Of those 20 incidents, EPA documented eight incidents in which a total of nine members of the public were killed and at least 20 were injured. Many of the other incidents, although not causing casualties, did result in property damage.

Very importantly, with regard to gaseous emissions from landfills, odor nuisance and explosion hazards are not the only concerns. As detailed below, gaseous emissions from landfills also contain air pollutants that pose a risk to human health and the environment. The environmental importance of air pollutant emissions from MSW landfills is a "sleeper" issue. The public knows virtually nothing about air pollutant emissions from landfills and most state-level air quality regulators are generally only marginally aware of the issue. Because of this, the issue of air pollutant emissions from landfills is the principal subject matter of this paper.

As noted previously, landfill gas is comprised roughly of 50% methane and 50% carbon dioxide, and less than 1% of nonmethane organic compounds (NMOC). NMOC is comprised mostly of VOCs i.e., volatile organic compounds. The air pollutants of concern are contained within the NMOC fraction. As summarized by EPA, the air pollutants present in landfill gas can be classified by their potential environmental effects:

- Ozone Nonattainment Precursors: Ambient ozone levels in excess of the National Ambient Air Quality Standards (NAAQS) adversely affect human health and damage vegetation. Volatile organic compounds (VOCs) are the principal precursor to ozone formation. EPA has stated that landfill "NMOCs are primarily" VOCs contributing to the ozone nonattainment problem. EPA estimated NMOC emissions from MSW landfills nationwide to be 283,000 tons per year (TPY) in 1986, accounting for one percent of all NMOC emissions nationally from stationary emitters. EPA has also projected landfill NMOC emissions nationally to be 577,000 TPY by 1997.

- Toxic Air Pollutants: EPA has expressed "a concern about cancer risk from landfill NMOC emissions." EPA has documented over 100 chemical constituents of NMOC, the most frequently detected being benzene, vinyl chloride, and trichloroethane. These are known as probable human carcinogens. Vinyl chloride is thought to be produced in ordinary landfills by bacterial decomposition of chlorinated organic solvents present in trace quantities in landfilled MSW. Besides these three carcinogens, EPA identified six others present in landfill gas (carbon tetrachloride, chloroform, ethylene dichloride, methylene dichloride, perchloroethylene, and vinyl chloride). EPA also identified constituents of landfill-gas NMOC that are associated with non-cancer toxic effects such as toluene and methylene chloride. Many of the toxic air pollutants present in landfill gas are specifically regulated by EPA as Hazardous Air Pollutants (HAPs) as will be discussed subsequently.

- Global Warming ("Greenhouse" Effect): The greenhouse theory holds that increased emissions of certain gases (principally carbon dioxide and methane) will lead to climate change. Methane is 20-30 times more potent as a greenhouse pollutant than carbon dioxide, molecule for molecule. EPA is concerned that landfill methane emissions contribute to global warming. EPA estimated methane emissions from MSW landfills nationally to be 12,000,000 TPY in 1986," and is projecting 21,000,000 TPY by 1997. EPA states that "Landfills are the single largest anthropogenic source of methane in the United States," accounting for 37 percent of such emissions nationally. EPA further indicates that on a "carbon-equivalent" basis, landfill emissions of methane account for 4 percent of all anthropogenic greenhouse gas emissions in this country which includes emissions from fossil-fuel burning, agriculture, mining, and industry.

The potential for offsite gas-migration and air pollutant emissions from landfills can be reduced by means of landfill gas control systems. Control of landfill gas begins with a gas collection system. The collection system is made up of a network of porous piping beneath the landfill to collect the gas produced. Blowers/compressors are then used to actively direct the collected gas to vents or to control devices above the landfill surface. Impervious barriers can also be installed to help prevent subsurface migration of the gas offsite. Closed portions (or "cells") of a landfill can be covered with an impervious "cap" to reduce "uncollected" emissions of the gas to the air.

Simply collecting and venting the collected gas to the atmosphere reduces the potential for gas subsurface migration, but does not abate air pollutant emissions. There are several methods available for controlling the air pollutants in collected landfill gas, the most popular being flaring and also the combustion of the gas in an internal combustion or turbine engine to generate electricity, or in a boiler to produce steam. Gas treatment (e.g., carbon filtration) is another method used to remove toxic pollutants from landfill gas. Collected gas can also be treated and sold to an energy customer.

The overall efficiency of landfill gas control depends on what fraction of all gases generated by a landfill can be collected with a landfill gas collection system, and for that portion of gas that is collected, the control efficiency provided by the control device (e.g., flare or engine). EPA stated that the efficiency of landfill gas collection systems has never been measured at any landfill, and indicated a 50-60% efficiency is achievable for a well-designed system, based on limited available information. In a more recent draft guidance, EPA has indicated a collection efficiency of 60-75% is possible. This means that roughly one-quarter to one-half the gas generated in a landfill is likely not collected, and, therefore, not controlled, but rather becomes uncontrolled, "uncollected" emissions to the ambient air.

For that fraction of the landfill gas that is collected, EPA believes that control devices (e.g., flares, engines) can achieve a 98% control efficiency for NMOC. Conversely, this means that up to two percent of the collected gas passes through the control device without being controlled, and thus, represents a residual, uncontrolled emission. These residual emissions and the "uncollected" emissions described above are additive, in characterizing total emissions of NMOC from a landfill.

In the process of controlling the collected landfill gas, devices such as flares, engines, turbines, and boilers themselves generate air pollutant emissions, referred to as "secondary emissions." Pollutants generated by these control devices include nitrogen oxides (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), hydrogen chloride (HCl), carbon dioxide (CO_2), and particulate matter (PM), as well as NMOC (VOCs). In addition, there is specific technical evidence that these combustion devices produce and emit dioxin emissions as well.

Finally, heavy diesel equipment used on site to grade, compact, and cover landfilled MSW emits these same air pollutants. On-site diesel equipment includes bulldozers and compactors, for example.

To summarize, the emission of pollutants to the air from MSW landfills has been deemed a potential risk to health and to the environment by EPA. Landfills are classified as a "stationary" emissions source of air pollutants. Contributors to these emissions at a landfill are listed in Table 1.

Basis for Emissions Estimates

In order to compare air pollutant emissions from the landfilling of MSW with emissions from MWCs, the authors used landfill emissions estimates developed previously by Alternative Resources, Inc. (ARI) for the Fresh Kills Landfill in New York City. The emission rates estimated for the Fresh Kills Landfill had been projected for each year of the 22-year period, 1994 to 2015. These projections were based on a daily fill rate of 11,500 TPD of MSW (on a seven-day-per-week basis). For the present analysis, the emissions estimates were scaled to be representative of a 1,500 TPD fill rate.

Uncontrolled emissions of landfill gas and NMOC were estimated for the Fresh Kills Landfill by applying EPA's "Landfill Air Emissions Model." Controlled emissions of landfilled gas and NMOC were assumed to be 25 percent of uncontrolled levels, as discussed further below. The emissions of NMOC are assumed here to be comprised entirely of VOCs.

Emissions of NMOC-related HAPs were estimated from the model's projections of NMOC, by using emission factors (average values) given by EPA. The EPA model is also known as the "Scholl Canyon Model," developed originally by Emcon Associates. The model is a first order decay equation that estimates the generation of landfill gas (and related air pollutants), as a function of site-specific (or default) input data. Key input data include the following, as recommended by EPA at the time the model was run in 1994:

- o Projected annual MSW filling rates for the landfill (This model application used NYCDOS data for the Fresh Kills Landfill. MSW density [in place] was assumed to be 1200 lb/yd).
- o k, the methane generation rate constant (A value of 0.0306 year-1 was assumed to apply; i.e. the average [default] value within U.S. EPA's model).
- o L_o, the methane generation potential (A value of 4953 ft^3 CH_4/Mg MSW was assumed to apply; i.e. the average [default] value within EPA's model).
- o NMOC concentration in landfill gas (A value of 1398 ppmdv, as hexane, was assumed, based on EPA proposed guidance).
- o Gas collection system efficiency (EPA has estimated 50-75 percent; 75 percent efficiency was conservatively assumed for this model application).
- o Control device efficiency (A 98% control efficiency for thermal destruction of NMOC in landfill gas was assumed for the control device; e.g., flare, engine, turbine).

Secondary emissions from the control device were estimated using emission data given by the California Air Resources Board (CARB) except for dioxin. Dioxin emissions were based on test data reported in the literature. For on-site diesel equipment, emissions were based on EPA emission factors except for dioxin. Dioxin emissions were estimated for on-site diesel equipment, based on tested dioxin emissions from diesel trucks in Norway with those test data adjusted by others to reflect a lower operating load than highway trucks. For the diesel equipment, the assumption was made that approximately 15 horse-power-hours are needed to process a ton of MSW at a landfill. Particulate matter was determined from AP-42 for road building activities.

Air Pollutant Emission Rates & Their Regulatory Significance

Air pollutant emissions associated with landfilling 1,500 TPD of MSW for a 22-year period are shown in Table 2. These are the highest annual emissions during the period. Both uncontrolled and controlled emissions are shown. Uncontrolled emissions assume no landfill gas collection and control. Controlled emissions assume 75% gas collection, with 98% control of the collected fraction of the gas. Controlled emissions are given separately for flare versus engine control devices, as the levels of secondary emissions differ between the two.

The significance of the indicated emission levels can be illustrated by comparison with regulatory thresholds defining a "major emissions source" of air pollutants.

- For new emissions sources locating where national ambient air quality standards (NAAQS) are attained, the general emissions threshold defining a major source is 250 TPY of any regulated pollutant. Uncontrolled emissions of VOCs, and controlled emissions of NO_x and CO shown in Table 2 can exceed that threshold. Thus, a 1,500 TPD landfill can have major emissions that should be subject to stringent, Federal air-permitting requirements ("BACT," air modeling).

- For new emissions sources locating where the NAAQS for ozone are not attained, there are major emissions threshold for VOCs and NO_x, and these vary from 25 TPY to 100 TPY in most cases, depending on the security of the local nonattainment condition. From Table 2, either uncontrolled or controlled emissions of VOCs could exceed the threshold; likewise for NO_x. Thus, in ozone nonattainment areas, a 1,500 TPD landfill could be a major emitter, subject to the most stringent controls achievable ("LAER") and to the requirement to secure "emissions offsets." If the landfill were an existing facility, it would be subject to retrofit control requirements ("RACT").

- For new and existing emissions sources, emissions of any regulated pollutant over 100 TPY is "major," and triggers the need to obtain a Federal Operating Permit under the Clean Air Act, Title V. Likewise, emissions of any HAP in excess of 10 TPY or any combination of HAPs in excess of 25 TPY is major, and triggers this permitting requirement. From Table 2, uncontrolled emissions of VOCs and NO_x, and controlled emissions of NO_x and CO from a 1,500 TPD landfill can be major. From Table 2, uncontrolled HAPs emissions can also be major. Thus, a 1,500 TPD landfill should be subject to Federal Operating Permit requirements.

- Emissions of methane shown in Table 2 are large. While believed important with respect to global warming concerns, methane emissions are not currently regulated by EPA.

While, as demonstrated by this analysis, air pollutant emissions from landfills can exceed EPA major-source thresholds, EPA historically has not regulated these emissions. In 1991, EPA proposed emissions standards for new and existing landfills, but these standards have not been promulgated at this writing. In 1994, EPA did announce guidance requiring air permitting for new landfills meeting certain criteria. This guidance, if enforced, would represent an important first step in regulating air pollutant emissions from new landfills. At this writing, however, air pollutant emissions from existing landfills remain unregulated by EPA.

While this is so, a Federal court has recently said for the first time that landfills are subject to the Clean Air Act (Ogden Projects vs. New Morgan Landfill, Inc., September 2, 1995 ruling). The U.S. District Court for the Eastern District of Pennsylvania ordered Morgan Landfill to pursue an air permit for its new landfill because the landfill has the "potential to emit" over 50 TPY of VOCs, and is thus a major emissions source subject to the Clean Air Act. Implications of this recent ruling will be discussed at the conference presentation.

Landfill Emissions Versus MWC Emissions

The air pollutant emission levels associated with the landfilling of 1,500 TPD of MSW (Tables 2 and 3) can be compared with the maximum emissions levels allowable for a 1,500 TPD MWC, under EPA regulations. It should be noted that actual MWC emissions typically are half the maximum allowable values. Maximum allowable emissions for a 1,500 TPD MWC are shown in Table 4. NO_x emissions from the MWC and the landfill are both substantial, but MWC emissions are greater. For all other pollutants, however, the landfill emissions are generally comparable with or greater than the MWC emissions. For example, both uncontrolled and controlled emissions of VOCs from the landfill are much greater than for the MWC emissions (MWC VOC emissions are too small to warrant regulation by EPA). Total combined emissions of HAPs from the landfill (whether uncontrolled or controlled) are greater than total emissions of regulated HAPs (Hg, Cd, Pb, dioxin) from the MWC. For dioxin emissions alone, emissions from the landfill presuming flare controls are comparable with the MWC emissions, but use of engines at the landfill to control emissions would produce dioxin emissions greater than the MWC emissions levels.

POWER GENERATION

Another area where MWC emissions are compared is in the power generation field. One of the prime benefits of the use of waste-to-energy is the ability to recover energy from the waste that would normally go to landfills. In 1992, 17.3 million MWHrs of our national power generation came from MWCs which meant that we did not need to imported the equivalent of 31 million barrels of oil. Electric Generating Facilities are exempt from the Hazardous Air Pollutant (HAPs) regulations while MWC are regulated. There is a significant data base on both HAPs emissions and control technologies for MWCs while we are just starting to develop this data for fossil-fuel fired plants. As noted previously, Table 4 presents annual emissions of regulated air pollutants from a new 1,500 T/D MWC. In addition, Table 4 compares the actual annual emissions from a typical MWC and proposed EPA standards. In actual operation, a MWC on an annual basis emits about one half of the proposed standards.

There are several ways of comparing emissions from MWC with power generation using fossil fuels. One way would be to compare the regulations for fossil-fuel power plants and MWCs. Table 5 presents a comparison of emissions based on EPA standards for facilities generating 45 MWs of power using fossil fuels versus new MWCs regulated under the rules approved on October 31, 1995. It is impossible to make a exact comparison since fossil-fired power plant technology varies throughout the U.S. For example in New York City, Consolidated Edison (Con Ed) only burns low sulfur oil or gas, some of the Ohio Valley coal burning plants are equipped with FGD systems that will reduce metal emissions, however, coal fired plants burning low sulfur fuels have in general higher metal emissions. The impacts of local operations and conditions must be considered when conducting impact studies. The data presented in Tables 5, 6 and 7 is a compilation of data from various sources and applications of control technologies,

When comparing the impacts that MWCs have in a community consideration should be given to the offsets that will occur due to the reduction in fossil fuels that will not have to be burned due to the use of MSW. Utilities reduce generation loads from their most expensive plants first when they have excess capacity. These generally are their oil, gas, and then coal-fired units. The use of MWC power will not impact the generation from nuclear or hydro power plants. In 1992 the U.S. generated the following percentage of its power from fossil fuels:

Fuel	Percent
Coal	81.7
Gas	13.6
Oil	4.7

Determining the overall impact in a community of the air quality improvements made by using MWCs to generate power (rather than fossil fuels), will be site specific depending upon the generation capacity of each local utility.

Tables 6 and 7 present a comparison of air emissions on an equivalent electric generation basis for fuel oil, coal, and MWC. Table 6 shows the combustion pollutant emissions while Table 7 has the emission rates of trace metals.

CONCLUSION

MWC environmental impacts remain among the most studied. MWC is one of the most regulated industries in the U.S. Both landfilling of MSW and power generation using fossil fuels have emissions that for most pollutants are comparable or higher than from MWC. This is because air emissions from landfills and fossil-fuel power plants are less rigorously regulated than are emissions from MWCs. In addition, EPA has not yet promulgated air emission standards for landfills and has not decided to regulate HAPs emissions from power generating facilities.

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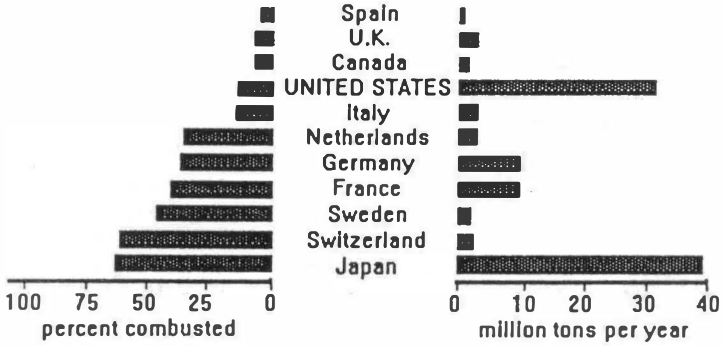
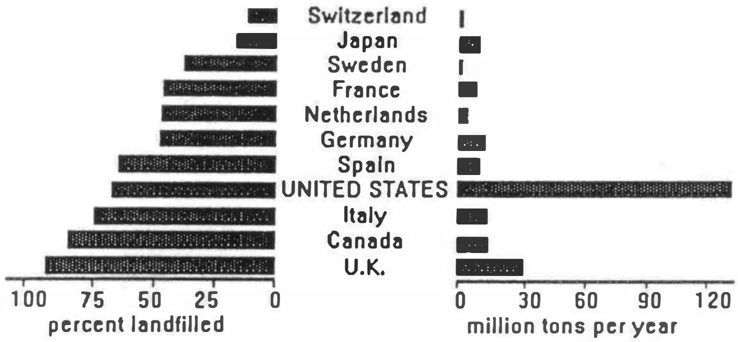
FIGURE 1

COMBUSTION OF MUNICIPAL WASTE BY MAJOR COUNTRIES



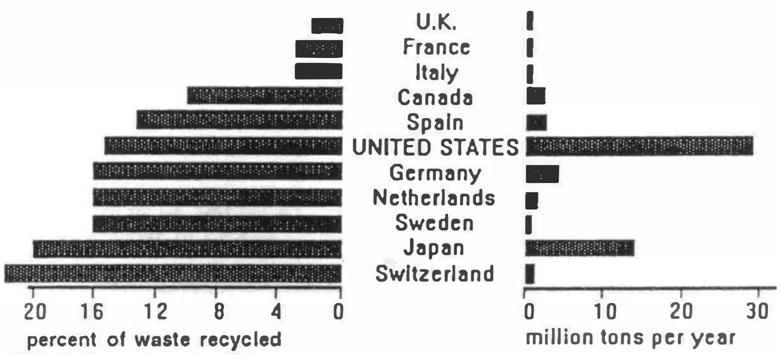
SOURCE: Warmer Bulletin, 2/95

LAND DISPOSAL OF MUNICIPAL WASTE BY MAJOR COUNTRIES



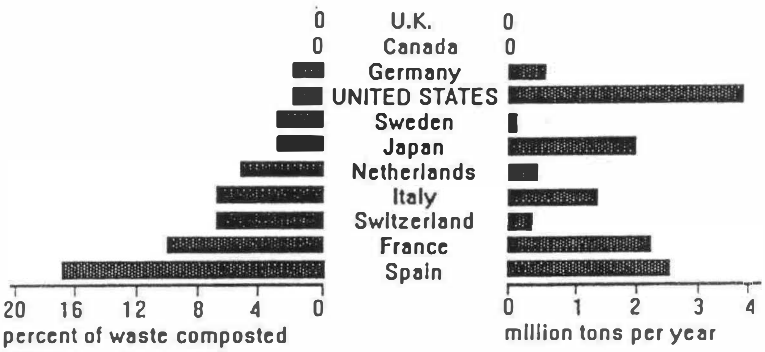
SOURCE: Warmer Bulletin, 2/95

RECYCLING OF MUNICIPAL WASTE BY MAJOR COUNTRIES



SOURCE: Warmer Bulletin, 2/95

COMPOSTING OF MUNICIPAL WASTE BY MAJOR COUNTRIES



SOURCE: Warmer Bulletin, 2/95

TABLE 1

LANDFILL EMISSION CONTRIBUTORS

EMISSIONS SOURCE	PRINCIPAL AIR POLLUTANTS
"Uncollected" emissions (i.e. gas that eludes the collection system)	◆ Volatile organic compounds (VOCs) ◆ Hazardous Air Pollutants (HAPs); e.g. benzene, vinyl chloride ◆ Methane (Greenhouse gas) ◆ Fugitive emissions dust and odors
Residual emission from the flare, engine, or turbine (i.e. the fraction of gas not controlled by the device)	◆ Volatile organic compounds (VOCs) ◆ Hazardous Air Pollutants (HAPs); e.g. benzene, vinyl chloride ◆ Methane ("Greenhouse" gas)
"Secondary" emissions from the flare, engine, or turbine.	◆ NO_x, CO, $S0_2$, PM ◆ HAPS; e.g., dioxin ◆ $C0_2$ ("Greenhouse" gas)
Emissions from on-site diesel equipment used to grade, compact, and cover landfilled MSW	◆ NO_x CO, $S0_2$, PM ◆ HAPS; e.g., dioxin ◆ $C0_2$ ("Greenhouse" gas)

TABLE 2

EMISSIONS OF AIR POLLUTANTS FROM A 1500 TPD MSW LANDFILL

POLLUTANT	EMISSION LEVELS (TPY)		
	Without Gas Collection or Control	With 75% Gas Collection and 98% Control of Collected Gas	
		Flares	Engines
VOCs			
• Collected Fraction of LF Gas (75%)	-	4	4
• "Uncollected" Fraction of LF Gas (25%)	-	70	70
• Total	281	74	74
NO_x			
• Control System	-	33	357
• On-site Diesel Equipment	-	122	122
• Total	122	155	479
CO			
• Control System	-	75	425
• On-site Diesel Equipment	-	28	28
• Total	28	113	453
HAPs			
• Collected Fraction of LF Gas (75%)	-	1	1
• "Uncollected" Fraction of LF Gas (25%)	-	10	10
• Total	41	11	11
Dioxins/Furans (I-TEQs)			
• Collected Fraction of LF Gas (75%)	-	10.3×10^{-6}	1.72×10^{-7}
• "Uncollected" Fraction of LF Gas (25%)	-	8.2×10^{-9}	8.2×10^{-9}
• Total	3.28×10^{-8}	1.0×10^{-5}	1.8×10^{-7}
Particulate Matter			
• Fugitive/ Uncollected	25	25	25
Methane			
• Collected Fraction of LF Gas (75%)	17,962	359	359
• "Uncollected" Fraction of LF Gas (25%)	5,988	5,988	5,988
• Total	23,950	6,347	6,347

TABLE 3

HAPs EMISSIONS TONS PER YEAR 1500 T/D MSW LANDFILL

POLLUTANT	UNCONTROLLED LANDFILL T/Y	CONTROLLED LANDFILL T/Y
Vinyl Chloride	1.71	0.46
Benzene	1.54	0.41
Ethyl Benzene	1.71	0.46
Xylene	5.55	1.49
Toluene	15.69	4.21
Dichlorethene	14.79	3.97
Total	41.00	11.00

TABLE 4

MWC REGULATED AIR EMISSIONS 1500 T/D MWC (OPERATING CAPACITY)

POLLUTANT	BASED ON EPA NSPS (10/95)[4]		BASED ON TYPICAL OPERATIONS	
	Emission Rate[1]	T/Y[2]	Emission Rate[1]	T/Y[2]
Particulates	0.10 grs/dscf	60	0.05 grs/dscf	30
SO_2	30 ppmv	195	15 ppmv	98
HCl	25 ppmv	93	10 ppmv	47
Cd	0.01 mg/dscm	0.09	0.005 mg/dscm	0.045
Pb	0.10 mg/dscm	0.90	0.05 mg/dscm	0.45
Hg	0.08 mg/dscm	0.72	0.04 mg/dscm	0.36
NO_x	150 ppmv	799	100 ppmv	467
CO	100 ppmv	285	25 ppmv	71
Dioxins (mass)	13 ng/dscm	4.5×10^{-7}	5 ng/dscm	1.8×10^{-7}
Dioxins (I-TEQs)[3]	0.2 ng/dscm	4.5×10^{-7}	0.08 ng/dscm	1.8×10^{-7}

1. All emission data corrected to 7% O2
2. Based on annual average emissions for 1500 T/D for 365 days
3. Dioxin not regulated by TEQs and are presented for reference only
4. Based on new, large size, mass burn technology.

TABLE 5

COMPARISON OF EMISSIONS FROM COMBUSTION OF MSW TO REPLACE 45 MW ELECTRICAL OUTPUT AT STEAM GENERATING FACILITIES FIRING COAL OR OIL

REGULATIONS BY FUEL				CONTROLLED EMISSIONS (LB/HR)						
FUEL TYPE	HHV (BTU/LB)	% S	% Cl	PM	NO_x	CO	HC	SO_2	HCl	Total Emissions
CLEAN AIR ACT - EXISTING SOURCES										
Coal - Phase I	12,000	3.0	0.12	14	236	38	19	1181	4	1492
Coal - Phase II	12,000	3.0	0.12	14	236	38	19	567	4	878
NSPS SUBPART DA - NEW SOURCES										
Pulverized Coal	12,000	3.0	0.12	14	284	38	19	284	4	643
No. 6 Residual Oil	19,000	1.0	trace	14	135	14	3	90	trace	256
No. 2 Distillate Oil	19,000	0.2	trace	6	128	17	3	90	trace	244
NSPS SUBPART EA - NEW SOURCES 10/95										
MSW, Mass Burn	5,000	0.2	0.5	12	154	62	4	43	20	323

TABLE 6

COMPARISON OF AIR EMISSIONS

WITH EQUIVALENT ELECTRICAL GENERATION CAPACITY

FUEL OIL Vs. COAL Vs. MWC

Tons per Year

Pollutant	Fuel Oil	Coal	MWC
Particulates	48	223	34
SO_2	7249	859	66
CO	100	73	43
NO_x	1345	1224	568
HC	15	9	16
PCDD/PCDF (E -07)	-	2.83	2.31

TABLE 7

COMPARISON OF METAL EMISSIONS

BASED ON EQUIVALENT ELECTRICAL GENERATION CAPACITY

FUEL OIL Vs. COAL Vs. MWC

Pounds per Hour

Metal	Fuel Oil	Coal Fired	MWC
As	0.01	0.02	0.002
Be	0.003	0.002	0.00008
Cd	0.01	0.01	0.003
Cr	0.01	0.23	0.003
Cu	0.16	0.12	0.008
Ni	0.73	0.17	0.007
Se	NR	0.01	0.0003
V	0.17	0.2	0.003
Zn	0.02	0.26	0.05
Hg	.002	0.01	0.03
Pb	0.02	0.03	0.016