Open burning of domestic wastes: The single largest source of dioxin to air?

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Introduction

The US Environmental Protection Agency (EPA) currently considers open burning of domestic waste to be the single largest source of dioxins (PCDD/Fs) to the atmosphere in the United States[1]. This practice of burning household trash in a burn barrel, open pile, primitive incinerator, or wood stove does not allow for the control of dioxin emissions. Surveys show open burning is widespread across rural areas of the US and around the world. The EPA's estimate of total US emissions from this source is 600 g TEQ/y. This places it first in rank ahead of municipal and medical waste incinerators whose emissions, according to the EPA, have been recently reduced through extensive technological upgrading[2]. In contrast, reduction of open burning emissions through technology is not considered feasible.

Open burning occurs mostly in rural areas, often close to agriculture. Therefore, it may disproportionately contribute to dioxin exposure in food. In contrast, sources like municipal incinerators are usually situated in urban areas. Quantifying open burning dioxin emissions and their proximity to agriculture should be important to reducing human exposure.

Yet little information exists on the emission rates from actual open burning or even from experimental simulations. Few surveys have been conducted to determine how much domestic waste is being open-burned in the US or the rest of the world. Virtually no information exists on whether those who practice open burning preferentially burn materials like polyvinyl chloride (PVC) plastics or exclude them from burning. Experimental studies show that under open burning conditions, PVC content positively correlates with dioxin emissions[3,4,5]. Other factors affect dioxin emissions but have not been studied as extensively as PVC content. These include combustion conditions, waste density, copper and moisture contents of the wastes[8].

Based on examination of recent studies and a range of plausible assumptions, the annual dioxin emissions from open burning in the US may range from 140 to 20,000 gTEQ/y. Studies also point to much higher rates of open burning in developing countries than in the US[6].

Methods and Materials

To estimate the total emissions of dioxins from open burning, the EPA uses the formula: $E_{TEQ} = EF_{TEQ} \times P \times F \times W$ where: E_{TEQ} = annual TEQ emissions (g/y); EF_{TEQ} = emission factor in gTEQ/kg of waste consumed by combustion; P = rural population; F = fraction of rural population burning household waste; W = mass burned per year per person. Together, P, F, and W make up the activity level (AL), which is the total mass of waste consumed annually by open burning.

Only a small number of studies explicitly examine dioxin emission factors (EFs) from open burning of domestic waste[7,8,9] To supplement this limited data, information was analyzed from other studies that examined dioxin emissions from poorly controlled burning of waste components like paper, cardboard, construction debris, yard wastes, PVC and other plastics[4,5]. This data was also analyzed to determine correlations between PVC content of wastes and emission factors.

The EPA used just one study to determine the US activity level for open burning[17]. This was a telephone survey in a mostly rural region of Illinois in 1993. Results from more recent surveys in other regions, using a variety of methods, are compiled and compared to this EPA study.

After collecting and analyzing the studies on emissions factors and activity levels a plausible range of total dioxin TEQ emissions from open burning is calculated.

Results and Discussion

Table 1 shows the range of emission factors (EF) calculated from published experimental data based on a variety of waste compositions, combustion conditions, and analytical methods.

Table 1. Dioxin emission factors for open burning based on recent studies.

Emission Factor ngTEQ/kg burned	Waste materials; type of burning	Percent PVC basis	Date	Source
5	yard waste; home incin.	0.0	1999	Ikeguchi[4] (CN)
40	agricultural wastes; home incin.	0.0	1999	Ikeguchi[4] (CN)
35	MSW; burn barrel	unspecified	2003	Wevers[9]
75	MSW, no yard waste; burn barrel	0.2	2000	US EPA[1,7,8]
75	MSW + solid fuel; indoor stove	unspecified	2000	EU Germany[11]
180	MSW, no yard waste; burn barrel	0.8	2000	US EPA[7,8] (CN)
300	MSW; open burning	unspecified	2001	UNEP[10]
450	MSW; open burning	unspecified	2000	EU Belgium[11]
1000	MSW; open burning	unspecified	2000	EU Swiss[11]
2,500	corrugated cardbd. + PVC; home incin.	0.8	2000	Ikeguchi[5] (CN)
3,230	MSW + solid fuel, indoor stove	unspecified	2000	EU Swiss[11]
3,500	MSW; muni. low tech incinerator	unspecified	2001	UNEP[10]

The US EPA chose an emission factor of 75 ngTEQ/kg based on their own series of experiments and an assumption of 0.2% PVC in waste. The United Nations Environment Programme (UNEP) chose 300 ngTEQ/kg, based on the same EPA data[10]. UNEP assigns 3,500 ngTEQ/kg as the default EF for small "low tech" municipal incinerators lacking pollution control devices based on studies of such plants. The European Union's dioxin inventory lists four emissions factors used in Germany, Switzerland, and Belgium[11]. The German and Swiss EFs are based on studies in those countries and differ widely from 75 to 3,230 ngTEQ/kg respectively. Two additional EFs listed in Table 2 are derived from the EPA and Ikeguchi data by correcting for a more realistic value of

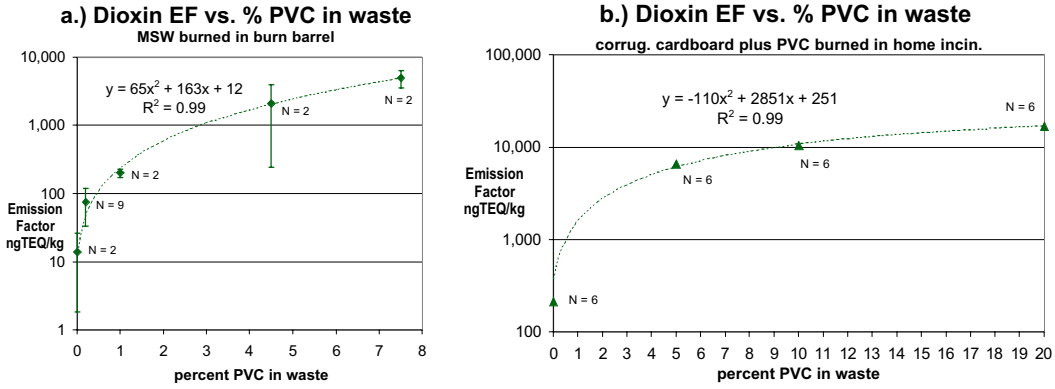

Figure 1. Dioxin emission factors as a function of percent PVC in combusted wastes. a.) MSW with various amounts PVC burned in barrel. Graph includes combined data from two similar EPA studies[7,8]. Error bars show standard deviation. b.) Corrugated cardboard plus various amounts of PVC burned in backyard incinerators[5].

0.8% PVC concentration for US burnable waste[19]. The percentage for total US municipal solid waste (MSW) is 0.6%. When materials commonly not disposed of in burn barrels are excluded, such as glass, metal, and yard waste, the PVC fraction rises to 0.8%.
All experiments that burned wastes with varying levels of PVC (or other forms of chlorine) found a positive correlation between the fraction of PVC (or chlorine) and the dioxin EF[4,5,7,8]. Results of the EPA[7,8] and Ikeguchi[5] experiments are graphed in Figure 1 to reveal the close connection between PVC content of open-burned waste and dioxin emission factor. Second order polynomial regressions were fit to both data series, and these equations were used to determine the expected EFs at 0.8% PVC reported in Table 1.

PVC's role in dioxin formation suggests that an effective method to lower emissions may be reduction in PVC burning. Burn tests of wastes with no added PVC had low emissions of dioxin, even though the wastes presumably contained small levels of chlorine from other sources.

Activity levels for open burning have been assessed in local regions by telephone or in-person interviews, by counting visible burn barrels from public roadways, and by consultation with fire prevention or environmental officials who have first-hand knowledge of their regions. From the surveys summarized in Table 2, the range of reported open-burning households in rural areas is 16 to 54%. Surveys used differing classifications of "rural," were conducted in different ways, and were done in different regions of North America. The wide range of results may reflect these varied survey methods, or it may reflect genuinely differing rates of burning in different areas.

Table 2. Surveys of open burning activity levels in North America.

Percent Burning	Type Of Location	Sample Size	Survey Type	Year	Notes (co. = county)	Source
0.2	urban & rural	536	fire officials	1997	all Maine	ME DEP[12]
8	urban & rural	-	extrapolation	2003	all US	EPA[1] (CN)
16	rural	-	fire & env. officials	2001	California cos.	CARB[13]
24	rural	1,516	telephone	2001	Ontario, Canada	Env.Can.[14]
28	rural	760	telephone	1999	Minn., Wisc. cos.	EPA[15]
29	rural	241	in person at co. fair	2001	New York co.	Otsego C[16]
40	rural	187	telephone	1993	Illinois cos.	EPA[17]
48	rural	427	visual driving	1992	New York co.	SLC Plan[18]
48	rural	509	visual driving	2002	New York co.	SLC Plan[18]
54	urban & rural	397	in person at home	1999	Morelos, Mexico	CBNS[6]
-	rural	52	examined barrels	2000	illegal items in 90%	CARB[13]

The EPA uses the US Census definition of rural that places 20% of the US population into this category. The EPA activity level was based on the Illinois study that showed 40% of rural residents open-burning, which implies an activity level for the entire US of 8%. The Maine statewide survey gave a much lower value, but it was acknowledged to be an underestimation. The CBNS study, based on the Morelos, Mexico survey and other information, estimated that 50% of all MSW in Mexico is open-burned, either at home or at informal local dumps. If this is true for other less developed parts of the world, open burning may well dominate dioxin emissions inventories for these areas.

The telephone and personal interviews all asked about quantities and types of materials burned. But in many areas, burning or burning certain materials may be illegal, therefore self-reporting should not be considered reliable. One study in California was conducted to address this issue[13]. Environmental officials randomly inspected burn barrel contents and determined that 90%

contained illegal materials such as plastics, batteries, and electronics. This was a jurisdiction where paper and yard wastes were legal to burn but other wastes were not. This brings into question responses in self-reporting surveys where less than 10% of people usually admit to burning items other than paper. Better survey methods will have to be developed to determine the amounts of wastes burned and the fraction of PVC burned. The EPA survey in Illinois had 13 volunteer families save the trash they would burn for weighing by researchers. The portion for burning was 63%, and this was used in the EPA activity level calculation.

Using EPA assumptions that 63% of burner-generated waste is burned and 20% of the US is rural and likely to have open-burner households yields a low emission estimate of 140 gTEQ/y and a high estimate of 20,000 gTEQ/y. The low is based on an EF of 35 ngTEQ/kg and 20% rural area AL. The high uses an EF of 2,500 ngTEQ/kg and 40% rural area AL. Even the low estimate places open burning as one of the largest air sources of dioxin in the US.

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