Quantitative Estimates of Pollutant Release from Open Burning of Municipal Solid Waste

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Brief: *Open burning of household waste, especially in dumps, is a significant source of airborne particulate as well as hydrochloric acid, dioxins, furans, and various chlorinated benzenes, the concentrations of which can far exceed those emitted from large fossil fuel power plants*.

This document is excerpted from an Environmental Impact Assessment (EIA) prepared by the author as part of an integrated waste management plan for a jurisdiction in the Arabian Gulf. It provides information regarding the often-unrecognized environmental hazards associated with the open burning of trash* (municipal solid waste). The original EIA was prepared to determine the positive environmental effects of establishing a waste management system comprised of an engineered landfill for non-combustible solid waste and a waste to energy gasification plant for disposal of combustible solid waste. In addition to constituting a significant source of air pollution *(USEPA 2002, 2006, and Archive)*, leachate from dumpsites can be a significant source of contamination for ground waters.

A primary motivation for instituting thermal treatment of combustible waste and the disposal of non-combustible waste in an engineered landfill was the high rate of release to the environment of pollutants from the then current practice of open burning of trash. Data available from the literature provided a basis for making rough estimates as to the quantities of pollutants released by the open burning of trash in that jurisdiction. A well-regarded study published by the USEPA *(Lemieux 1998)* was selected as the basis for the estimates included in this paper.

Data on waste composition as used for the EPA study, as compared to the single load composition of MSW at three different dumpsites (in percent rounded to two significant digits), are shown in below in **Table 1.** As can be seen, the significant difference between the compositions of the two EPA waste samples is the absence of plastic from the "recycler sample". The lack of plastic in one of the samples provides a reasonable basis for estimating the effects of plastics in the fuel by comparing the emissions from the "with plastic" and "without plastic" fuels. The amount of plastic and other materials in the waste characterized at the three sites (data from two shown) was more like that of the non-recycler in composition, especially with regard to the quantity of plastics found in the waste. The measured emitted pollutants per kg of waste burned from both recycler and non-recycler samples shows that the quantities of pollutants released from the non-recycler sample is, in general, significantly higher.

*In this document, the terms 'trash' and 'municipal solid waste' are synonymous.

Lemieux (1998) reported that the combustion conditions measured were as follows: maximum bed temperature for the recycler trash was 370^{o}C, which resulted in 67 percent of the trash being burned, while the non-recycler trash reached a maximum bed temperature of 750^{o}C, resulting in burning of 49 percent of the trash.

Table 1. Composition of dumpsite MSW as compared to EPA recycler and non-recycler waste

	EPA No Recycle (%)	**EPA Recycle (%)**	**Site #1 (%)**	**Site #2 (%)**
Paper & Cardboard	62	65	1.3	13
PET	0.60	0	6.7	4.5
Other Plastic	11	0	11	2.9
Textiles	3.7	0	2.0	1.2
Wood	1.1	3.2	1.7	6.6
Glass	9.2	0	4.0	3.1
NF Metals	1.7	1.0	0.48	0
Ferrous Metals	7.3	4.1	2.4	3.1
Food Waste	5.7	0	11	2.1
Misc. Waste*	1.1	3.2	42	57
Normalized** Total (%)	100	100	100	100

*Misc. waste for sites 1 and 2 was mainly mixed paper, plastic film and food that could not be separated for weighing.

**For normalization procedure, see footnote in References.

From the literature on open burning emissions as a function of trash composition, it is clear that plastics as fuel contribute significantly to the formation of volatile organic compounds (VOCs) as well as Semi-Volatile Organic Compounds (SVOCs), as indicated by the difference in the phenanthrene, for example.

Chlorinated compounds, including polychlorinated dibenzo dioxins (PCDD)s, polychlorinated dibenzo furans (PCDFs) and HCl are more prevalent, on a “per kg of waste burned” basis, in the “recycler” material. Referring again to the literature, this would appear to be an effect of the higher paper to plastic ratio in the recycler waste composition, keeping in mind that on a per day basis, the recycler produces significantly less waste than the non-recycler. Relative amounts of paper and plastic covered cardboard in the recycler sample are higher than the non-recycler sample. The higher proportion of paper in the recycler trash represent relatively higher amounts of residual chlorine from paper bleaching and a relatively higher quantity of metal containing inks associated with the paper.

As described above, the author *Lemieux (1998,2000)* attributed this difference, in great measure, to the presence of plastics in the non-recycler sample. In order to use these data to make a rough estimate of these same pollutants released from the open burning for the EIA, this paper compares the results of two separate waste characterization evaluations to the two types of waste used in the EPA study (see **Table 1**.)

Table 2 below shows a rough estimate of the pollutant mass released as air emissions from open burning annually in the study area based on data from *Lemieux (1998).* The two right hand columns show what would be anticipated based on the EPA study cited if an average of 20 tonnes/ day of waste were burned completely with no residue. Numbers shown in the two right columns are in kg/year of emissions and assume that an average of 20 tonnes/ day of MSW were set on fire per day and that 20 percent of the material remained onsite as unburned residue comprised of ash and non-combustibles after burning.

Table 2. Annual estimated releases of pollutants from waste burning in study area

	Measured Emissions from EPA Tests		Est. Emissions from Study Area	
Compound /Pollutant	**Emissions for Waste with Paper / No Plastic (mg/kg burned)**	**Emissions for Waste with Paper and Plastic (mg/kg burned)**	**Emissions for Waste with No/Low Plastic (kg/Year)**	**Emissions for Waste with Plastic (kg/Year)**
Benzene	725	1240	4234	7242
Total VOC	4000	14400	23360	84096
Chlorinated Benzenes	1008	419	5887	2447
Aldehydes and Ketones	140	2800	818	16352
PCDDs + PCDFs	0.267	0.0441	2	0.2575
PCBs	0.97	2.86	6	16.7
HCl	2400	284	14016	1659
HCN	200	468	1168	2733
Particulate (PM10)	5800	19000	33872	110960
Particulate (PM2.5)	5.3	17.4	31	102

Numbers shown in the No/Low Plastics column reflect those anticipated from waste with low plastics content and numbers in the "Emission with Plastics" column show the anticipated mass released for these constituents of the waste burned contained approximately 10 percent or more plastic by weight.

Taking the total amount of each pollutant as determined for the non-recycler and multiplying it by the number of kg of waste burned on a daily basis on average yields an estimate

of the total emission of these pollutants per day in the study area. After accounting for the unburned residue, these numbers can be used to estimate a reasonable range for the annual emissions.

Mainly due to the proportionally high plastics content of the study area waste, benzene and VOC emission estimates are significant with more than 4 metric tonnes of benzene and up to 84 metric tonnes of total VOC released annually. The "with plastic" emission factors used for most of the pollutants considered in these estimates was the same as that used in the Yukon waste burning air dispersion study as reported in *Marson (2009).*

Given the relative paucity of printed paper materials in the waste as characterized in the study area, it is likely that the chlorinated compound release is somewhat overestimated by this method. In the EPA materials used in *Lemieux (1998),* both the recycler and non-recycler waste compositions included a high proportion of paper (over 60 percent in both). Waste characterized in the study area generally contained a substantially lower proportion of paper products as shown in **Table 1**. As described above, it is believed that the residual chlorine in paper from the bleaching process contributes to the formation of chlorinated compounds such as HCl, PCDDs, PCDFs, PCBs, and the various chlorinated benzenes.

Major improvement in air quality were expected at the sites, and the entire study area, due to complete elimination of burning of waste at the existing open dumps, restricting the landfill operations and adoption of engineered landfill practices that will also eliminate occurrence of H_2S and other odor-causing gases (mainly mercaptans) currently emanating at the existing dumpsites due to anaerobic decay of waste. It was determined that thermal conversion of combustible materials by gasification would further reduce the air emissions of these pollutants as compared to landfilling alone.

Several studies have compared the relative environmental and economic impacts of landfill, and thermal treatment and disposal of MSW. Such studies show that properly designed and operated air fed gasification systems are, by far, the most efficient and cleanest thermal technology for converting solid waste to energy. *Zaman (2009)* provided a life cycle assessment comparing landfill, incineration and gasification as primary technologies for treatment and disposal of MSW. Again, gasification ranked highest, overall, when considering the combined characteristics of conversion efficiency, cost per unit of power generated, and favorable environmental impact. The original 2012 report concluded that open burning of municipal solid waste for a total population of some 30,000 was responsible for more dioxins, furans, hydrochloric acid and chlorinated benzenes in the environment than all the oil production and refining activities carried out the entire study area jurisdiction.

References

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** Footnote to Table 1.
Column 1 of Table 1 reflects the composition of ‘as delivered’ MSW in the US. Column 1 is taken as the reference composition and its components sum to a nominal 100%. Column 2 in Table 1 adds up to less than 100% reflecting mainly the removal of recyclables, which now do not contribute to the emissions from that ‘as delivered ton’ of waste.

In order to estimate the actual emissions per ton of waste based on an 'as delivered' weight prior to sorting (as in Column 1 from US waste) the percentages in the other columns were normalized to 100% by adding back in the weight of the recyclables (in the case of column 2), and the excess moisture in the food (which does not contribute to air pollutants) and unrecoverable inorganics (such as dirt and sand in the case of Columns 3 and 4), which cannot be accurately collected and counted once the weighed load is dumped on the ground.