

Testimony to EPA WTC Expert Technical Review Panel - revised

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Thank you for the opportunity for input into the important task of measuring and remediating the contamination of the WTC environmental disaster. My relevant expertise is in understanding the processes by which burning materials are incinerated and produce pollutants, as well as pollution prevention, incinerator operations and emissions controls. I made large contributions to two chapters of the National Research Council's 2000 report, Health Effects of Waste Incineration.

Arguments Against using Asbestos as a surrogate for all other WTC pollutants

An important issue in these discussions has been whether asbestos should be considered to be a surrogate for the scores of other pollutants in the WTC dusts. First, there were two environmental disasters associated with the WTC attack: 1. the collapses, 2. the fires. The categories of pollutants generated by each were different, and the dispersion mechanisms for each were different. Asbestos came only from the collapses.

It would be wrong to assume that only the collapses produced the dust found inside buildings or HVAC systems. Data from municipal and medical waste incineration and burn barrels (see data below) demonstrate that fly ash and particulate matter are also produced by incomplete combustion of a heterogeneous waste stream containing pollutant precursors. These eventually fall out as contaminated dust. Decades of research has shown that fine carbon and metallic particles from incineration (fly ash) are typically coated with incinerator pollutants such as mercury and other heavy metals, dioxin/furan and other organics, HCl, SO₂, as the flue gases cool in incinerators. But in the case of the WTC, there was likely to have been a synergy between the two environmental events, with fine particulate matter (gypsum, fiberglass, asbestos) from the collapses adding to the carbon particles normally occurring in a fire, serving as additional condensation nuclei for mercury, dioxin, and other metals, organics, and acids, which volatilized in the heat of the fires, then condensed to solid and liquid form as they rose above the site and cooled. As the coated fly ash and particles drifted to cooler areas away from the buoyant effects of the fires, they would begin to fall out, depositing as toxic dust.

It would also be wrong to suggest that the dispersion pattern for asbestos was identical to any other pollutant (and studies by ATSDR, Liroy, and others have shown great variability in WTC dust samples). It is also wrong to assume that the quantity each of the other pollutants is in some single fixed ratio to the quantity of asbestos in all samples. This is not supported in the data. For example, table 6 (the Summary of Locations With Asbestos or Synthetic Vitreous Fibers (SVF) in Settled Surface Dust), as well as Tables 9, 10 and 12 in the "Final Technical Report of the Public Health Investigation to Assess Potential Exposures to Airborne and Settled Surface Dust in Residential Areas of Lower Manhattan" ATSDR shows that there were a number of residences where the dust contained glass fibers, but not asbestos. The ratio between these two pollutants, where both were found, is also inconsistent. Since fiberglass is a contaminant that can cause cancer and scarring of the lungs, it is important that future investigations and cleanups not be designed to miss finding it. Assuming that asbestos is a good surrogate for fiberglass is thus, a dangerously false one.

Another argument against the concept of uniform dispersion of all pollutants is that larger particles fall out closer to the source than finer particles. But the finer particles have a far greater surface area than the larger ones, and can therefore carry more toxics on their surfaces. So the toxics that volatilize in the fires and then condense on fine particles could be found further from the source than larger particles.

Formation of Dioxin from Fires / Dioxin Deposition

Dioxin has a great affinity for particulate (doesn't vaporize) Walter Shaub, 1983.

Primary Dioxin formation occurs from burning of products containing dioxin precursors – a source of lignin (basically compounds containing benzene ring), such as paper, cardboard, wood, plus PVC and other sources of chlorine in the presence of insufficient oxygen and temperature for complete combustion. Intermediate byproducts of incomplete combustion are chlorinated benzenes and chlorinated phenols which serve as direct dioxin precursors. Incomplete combustion (e.g. smoldering conditions of the WTC) favor the formation of toxic, carcinogenic compounds such as these and dioxins and furans.

In the late 1980s, German and Environment Canada research first showed how secondary dioxin formation can occur. In the presence of dioxin precursors and a temperature of about 450°F, a temperature common in smoldering ruins, with volatilized copper and other heavy metals present in flue gases, the formation of dioxin onto the surfaces of particles is catalyzed (increased). This mechanism was found to be responsible for greatly increasing the dioxin emissions of incinerators at the outlet of the air pollution control device vs. at its inlet. Dioxin catalysts were clearly in the mix of pollutants, with copper wiring, lead computers, and many other sources of heavy metals in the buildings.

I published research in the late 1980s that showed that both dioxin and mercury removal efficiency (i.e. condensation onto fine particles) increased in linear fashion towards 100% as the temperature of the flue gases dropped from 450°F towards ambient temperature. Further, my research showed that the presence of alkaline reagents, as injected particulate in dry scrubbers, increased the capture rate for dioxins and mercury onto those fine particles. The WTC disaster produced a perfect scenario for massive, uncontrolled incineration / cremation, and then in the cooling above the pile, amidst fine, alkali particles, condensation of pollutants to form dust coated with toxics.

Combustion of solid waste even in well-designed incinerators, outfitted with special equipment to regulate the availability of oxygen and to maintain a minimum temperature, absolutely require skilled and vigilant operations to minimize the conditions ripe for generation of dioxins. The dioxin emissions standard (at stack height) for municipal incinerators in Europe is 0.13 TEQ ng / dscm (corrected for temperature in the way the U.S. does it). The European standard is used for comparison since the U.S. does not have a dioxin emission standard in TEQ.) Emission standards are devised assuming that emissions disperse two or more orders of magnitude from the time they leave the stack until they reach the ground.

But it was twelve days after 9/11, that EPA took its first dioxin samples around the WTC site. Two sites measured dioxin (in Toxic Equivalents) of significantly more TEQ than this European emission standard, and at ground level perhaps a block or two from the nearest sources of smoldering. There is no indication regarding the wind conditions when these samples were gathered (i.e., was the location upwind, or downwind of the pollutant sources). Logically, shortly after the moments of impact and collapse, the formation of dioxin and adherence to particulate matter would have been far greater than that twelve days later.

Backyard Burn Barrels; Medical waste incineration; Apartment incinerators

Since burn barrels are uncontrolled incineration which has a lot in common with the WTC fires, it is instructive to review some of the literature on burn barrel emissions. Various government publications have shown that backyard burning of garbage produces smoldering conditions and promotes formation of dioxin and furan. They also show that direct inhalation impacts as well as deposition of contaminated particulate can occur in the vicinity of the source of open burning at ground level.

Emissions from medical waste incinerators and crematoria also have a lot in common with the WTC fires, in that over a thousand people were cremated there. Medical waste is typically on the order of 60% normal municipal waste plus wastes more specific to medical offices and hospitals. The following are some quotes from various publications and websites, with my comments italicized.

In 1993, 2200 apartment incinerators were phased out in New York City in a 1989 local law that my efforts inspired, because of the toxic emissions they generated due to archaic designs, inadequate operations, and frequent uncontrolled “upset” conditions which fed back into apartment corridors via the chutes on each floor. The WTC fires produced similar emissions, but on a continuous basis, with no chimney.

From EPA: <http://www.epa.gov/seahome/hazwaste/src/household.htm>

While **burning** may destroy some toxic substances, others will become concentrated in the smoke, ash, and sludge resulting from burning wastes. Repeated burning on the same location under similar weather conditions may cause the [toxic substances in smoke](#) to accumulate in a concentrated area around the burn barrel.

This supports the idea that the dusts in the WTC vicinity would not only contain toxics from the WTC collapses, but also the fires.

From NYSDEC website: <http://www.dec.state.ny.us/website/reg4/pr1.html>:

The burning of synthetic compounds like plastics causes the release of dioxins and other potential carcinogens. Burn barrels usually have fires that burn at lower temperatures than large

industrial incinerators. The lower temperature and smoldering fires often found in burn barrels result in harmful fumes released into the air and hazardous materials remaining in the ash.

According to the State Department of Health, some of the toxic chemicals released by burning household trash and their potential dangers include:

- benzene (leukemia)
- toluene diisocyanate (asthma)
- nitrogen oxides (lung damage)
- nitrile compounds (metabolic poisons and carcinogens)

Other toxic compounds released from burning trash may include:

- dioxins and formaldehyde
- hydrochloric acid and sulfuric acid
- hydrogen cyanide
- polycyclic aromatic hydrocarbons
- cadmium, lead, mercury and chromium

People should never burn the following items: plastic, foam cushions, furniture, rugs, floor coverings, appliances, rubber, tires, metals, glass, tree stumps, roots, asphalt shingles, any roofing materials, drywall, insulation, or any pressure treated wood (including deck lumber, railroad ties, and telephone poles treated with chromated copper arsenate, creosote or pentachlorophenol).

From Lake Superior Lakewide Management Plan, April, 2000, Chapter 4
<http://www.epa.gov/glnpo/lakesuperior/lamp2000/LS%20chapter%204.pdf>

The remaining largest sources of dioxin within the [*Lake Superior*] basin, appear to be burn barrels, wood treatment with pentachlorophenol (PCP) and the disposal of fly ash from the incineration of medical wastes. (pp. 13-14). Data from 1999 study in Lake Superior district showed sources of dioxin as coming primarily from medical waste incineration and burn barrels. Out of a total of 90.2 g TEQ/year, 83 g was from medical waste incinerators and about 7 g was from burn barrels – essentially the total source of dioxins. (Page 4A-11)

The burning at Ground Zero was quite similar in many respects to backyard burn barrels, which have been banned in New York State, Michigan and other places. Medical wastes (including human body parts, chlorinated plastics, fabrics, batteries containing heavy metals such as mercury, nickel, cadmium and others) are not that dissimilar from materials available at the World Trade Center. Fly ash from incineration of the WTC materials would therefore be one constituent of the dusts that were deposited in peoples' homes and businesses as well as of the plume (which would have consisted of particulate matter otherwise referred to as fly ash in incinerators).

Table A.3.3 summarizes dioxin generation emission factors for several recent studies. The table illustrates that emission rate estimates vary over several orders of magnitude. As a result, these emission factor estimates are provided to illustrate the potential significance of the source. Much additional work remains to be completed to properly estimate the dioxin emissions from household waste burning that is occurring in the basin.

Table A.3.3 Emission Factors for Household Waste Combustion in Burn Barrels

Source	Emission Factor(g TCDD/lb household waste burned)
Cohen (1999)	3.6×10^{-8} b
Lemieux (1998) (recycler) ^a	1.04×10^{-7}
Lemieux (1998) (non-recycler)	7.4×10^{-6}
Two Rivers Regional Council (1994)	6.2×10^{-10}
WLSSD (1992)	1.8×10^{-9}

^a Recyclers were assumed to reduce the proportion of newspaper, plastic, and some metals in their household waste.

^b Expressed as grams TEQ/yr.

(Page 4A-14)

Normalized for Superior district population, 4.5 million pounds (2250 tons) of waste produces about 7 g TEQ dioxins.

Adding up all the paper, cardboard, books, wood furniture, plastics, textiles, fabrics, carpets, and bodies in the seven WTC buildings, it is conceivable that the magnitude of the WTC dioxin-precursor waste burned and that of the Superior district studied might be similar.

From EPA: <http://www.epa.gov/seahome/hazwaste/src/burn.htm>

Researchers estimate that ground-level concentrations of [dioxin](#) resulting from [burning household trash](#) in a burn barrel are 7000 times the amount formed when trash is burned in a municipal incinerator. Ash and sludge resulting from on-farm burning also contain significant amounts of [toxic substances](#).

The temperatures generated at typical burning sites, burn barrels, and domestic incinerators is not adequate to eliminate the [production of toxic substances](#).

EPA Evaluation of Emissions from the open burning of household waste in Barrels:
<http://www.epa.gov/ttnatw01/burn/barlbrn1.pdf> Pp 61-66.

It may be useful to compare emissions from open burning of household waste to emissions from a full-scale municipal waste combustor (MWC) unit operating with good combustion and flue gas cleaning technology. Based on data from a field test at an MWC22, and averaging the “Normal Good” PT-08, PT-09, and PT-11 test conditions from reference 22, using the samples taken at the pollution control device outlet, the data in Table 4-1 (*below*) were generated. For the

results from this study, concentrations of all target VOCs were summed to give total VOC emissions (concentrations below detection limit were set at zero). A similar treatment was taken for PAHs, chlorobenzenes (CBs), PCDDs/PCDFs and PCBs.

When plotted as a bar graph as shown in Figure 4-1, it is readily apparent that even the significant differences between the avid recycler and non-recycler's emissions are minor in comparison to the difference between open burning of household waste and the controlled combustion of municipal waste at a dedicated municipal waste combustor facility. Note that ... emissions from open burning can be several orders of magnitude higher than controlled combustion.

Table 4-1. Comparison between open burning of household waste and controlled combustion of municipal waste in a municipal waste combustor; all emissions are in $\mu\text{g}/\text{kg}$ waste burned.

	Avid Recycler	Non-Recycler	MWC
PCDD	46.7	38.25	0.0016
PCDF	222.9	6.05	0.0019
CBs	1007.5	424.2	1.16
PAHs	23974.7	66035.65	16.58
VOCs	2052500	4277500	1.17

Emissions from backyard burning of residential solid waste are released at ground level resulting in decreased dilution by dispersion. This could potentially exacerbate the potential impacts beyond what is apparent from the magnitude of the emissions alone. The large magnitude of the emissions, coupled with the concentration of these emissions in the local neighborhoods due to poor dispersions, will lead to increased direct inhalation exposure.

The EPA 1994 Draft Dioxin Reassessment document attempted to conduct a mass balance for dioxin emissions in the United States and identified a significant gap between current deposition estimates and emission estimates. The deposition estimates were considerably higher than the emissions estimates. The EPA speculated that this indicated that there were unknown dioxin emission sources. The dioxin emissions from burn barrels may be a missing link to help account for the gap between measured deposition rates and the emissions inventories. Page 64

What goes up comes down (as deposition). As poor incineration has always been the highest category of dioxin emissions, WTC would have been an enormous concentrated source of dioxin at ground level.

Table 4-4. Summary of all test data

Parameter Average, per mass lost Average, per household

WASTE COMPOSITION	Recycler	Non-Recycler	Ratio
Total daily waste (kg)	1.5	4.9	0.31
PVC in waste (kg)	0.07	0.01	7.00
Paper waste (kg)	0.98	3.02	0.32
All plastics (kg)	0.23	0.36	0.64
Food (kg)	0	0.28	0.00
textile, leather (kg)	0	0.18	0.00
Wood (kg)	0.06	0.05	1.20
glass/ceramics (kg)	0.1	0.5	0.20
Metals (kg)	0.14	0.49	0.29

COMBUSTION RESULTS	Recycler	Non-Recycler	Ratio
max.bed temp. (°C)	370	740	0.50
Fraction burned (%)	66.7	49.1	1.36
Unburned residue (kg)	0.50	2.49	0.20

AIR CONTAMINANT EMISSIONS (mg/kg burned)	Recycler	Non-Recycler	Ratio
Benzene	725	1240	0.58
Acetone	190	940	0.20
styrene	310	740	0.42
Total TICs	4000	14400	0.28
naphthalene	40	48	0.83
phenol	85	140	0.61
dichlorobenzenes	0.320	0.160	2.00
trichlorobenzenes	0.400	0.110	3.64
tetrachlorobenzenes	0.140	0.074	1.89
pentachlorobenzene	0.100	0.053	1.89
hexachlorobenzene	0.048	0.022	2.18
acenaphthylene	3.4	11	0.31
naphthalene	5.2	18	0.29
phenanthrene	3.3	7.3	0.45
Aldehydes & ketones	140	2800	0.05
Total PCDD	0.047	0.038	1.24
Total PCDF	0.22	0.0061	36
Total PCB	2.86	0.34	0.97
PM10	5800	19000	0.31
PM2.5	5.3	17.4	0.30
HCl	2400	284	8.47
HCN	200	468	0.43

RESIDUALS IN ASH	□g (or ng) per kg ash		
PCDD, ng/kg;	14851	1556	9.54
PCDF, ng/kg;	34040	5800	5.87
PCB, □g/kg	220	122	1.80
Cr	300	92	3.26
Cu	4910	343	14
Pb	164	32	5.13
Zn	11500	721	16

The above data show the degree to which dioxins, PCBs and some heavy metals are left in bottom ash after waste is burned in a burn barrel. Under conditions on the WTC pile, these could become airborne whenever the wind picked up, and during transfer operations at the barge near Stuyvesant High School and at Fresh Kills.

Page 66

From Michigan DEQ brochure on burn barrels
<http://www.deq.state.mi.us/documents/deq-aqd-bhw.pdf>

When the amount of chemicals emitted from a barrel burn is compared to what is emitted from a municipal waste combustor (MWC) it becomes obvious how much dirtier the smoke is from a burn barrel than a MWC. Pound for pound of garbage burned:

- A burn barrel emits 10,000 times more total dioxin than a MWC.
- A burn barrel emits 1000 times more total furans than a MWC.
- A burn barrel emits 3000 times more polycyclic aromatic hydrocarbons than a MWC.

Pollutants released from burning waste in a burn barrel are transported through the air either short or long distances, and are then deposited onto land or into bodies of water. A few of these pollutants such as mercury, polychlorinated biphenyls (PCBs), dioxins and furans persist for long periods of time in the environment.

Burning household waste is unhealthy

Smoke from burning household waste is unhealthy to breathe. Small children, pregnant women, older adults and people with asthma or other respiratory ailments are especially sensitive to its effects.

- Smoke from burn barrels can contain hydrochloric acid as well as formaldehyde and other aldehydes. These chemicals are especially irritating to the eyes and lungs.
- Bleached paper products, lightweight white cardboard, and certain plastics contain chlorine which create dioxins when burned with other trash at low temperatures. Exposure to dioxins is associated with cancer, birth defects and altered immune function.
- Burning slick colored papers and cardboard printed with synthetic inks releases heavy metals into the atmosphere. The absorption of heavy metals by humans has been linked to birth defects and cancer.

- The burning of polystyrene polymers - such as foam cups, meat trays, egg containers, yogurt and deli containers - releases styrene. Styrene gas can readily be absorbed through the skin and lungs. At high levels styrene vapor can damage the eyes and mucous membranes. Long term exposure to styrene can affect the central nervous system, causing headaches, fatigue, weakness, and depression.

Mercury

As is the case for dioxins and furans, the state-of-the art method for capturing mercury in emissions from incinerators is reduction in temperature and use of a scrubber / baghouse (filter). Close to 100% capture rates can be achieved when temperatures are reduced to 100 degrees, and particularly in the presence of calcium carbonate or other alkaline reagents. Conditions were good in the vicinity of the WTC pile, whereby mercury escaping from the numerous sources in the pile (everything from dental amalgams to automobile switches to fluorescent lights, thermostats, latex paint, and batteries) would coat surfaces of particulate matter, eventually falling out as toxic dust.

Lake Superior LaMP: 2002 Progress report

Section 3: Critical Pollutants

<http://www.epa.gov/glnpo/lakesuperior/Lake%20Superior%20Part%20B.pdf>

“Consumer and commercial products have been significant sources of mercury. Mercury containing products can include thermometers, switches, dental amalgams, thermostats, button batteries, and fluorescent lamps. Industrial raw materials can also contain unwanted mercury. The elimination of mercury from latex paints and batteries was a significant pollution prevention success of the manufacturing sector in the 1990s.” (Page 3)

But the WTC was built in the early 1970s and the inside offices were painted numerous times, likely with mercury-based latex paint.

Conventional fluorescent lamps are the most commonly used light source in commercial and consumer lighting and close to 600 million fluorescent lamps are disposed of annually in North America. As each bulb contains between 9 and 40 milligrams of mercury, used bulbs contribute significant quantities of this toxic substance to the environment. Page 19.

Lake Superior Lakewide Management Plan, 2000

<http://www.epa.gov/glnpo/lakesuperior/lamp2000/LS%20chapter%204.pdf>

Mercury in products which are disposed in landfills may be eventually released to the environment through volatilization. At the 5th International Conference on Mercury as a Global Pollutant in 1999, two researchers independently estimated that an average of 15 percent of the mercury contained in products is released during the disposal process (Andrews and Swain 1999,

and Kindbom and Munthe 1999). Therefore, 15 percent of the potential release of mercury is re-emitted. (Page 4-18)

A large amount of mercury remained in the dusts in the vicinity of ground zero due to the enormity of the source and the mechanism for condensation and deposition. The mercury in these dusts do volatilize slowly, presenting a continuing source in places, such as HVAC systems and poorly cleaned indoor spaces, where it accumulated and has not been removed.

Lake Superior Lakewide Management Plan, 2000

<http://www.epa.gov/glnpo/lakesuperior/lamp2000/LS%20chapter%204.pdf>

Page 4A-4

Cremation: The 1999 estimate was determined by calculating what percentage the basin population [425,548] (Tetra Tech Inc. 1996) is of the total Michigan, Minnesota, and Wisconsin 1998 population [19,766,161] (U.S. Census 1998). This percentage (2.15 percent) was multiplied by the number of total projected cremations in Michigan, Minnesota, and Wisconsin for 2000 [46,569] (EPA 1997) to obtain the total number of cremations in the basin.

The number of cremated bodies [1,002.6] was multiplied by the emission factor of 1.50E-03 kg/body for cremation (EPA 1997).

_ $425,548/19,766,161 = 2.15$ percent

_ $.0215 * 46,569 = 1,002.6$

_ $1,002.6 \text{ bodies/yr} * 1.50\text{E-}03 \text{ kg mercury/body} = 1.50375 \text{ kg mercury/yr}$

It can be argued that roughly this number of people or more were cremated at the WTC site, as this many of the bodies of victims were never found. The cremation of these bodies would have produced 1.5 kg of mercury according to these calculations.

Lake Superior Lakewide Management Plan, 2000

<http://www.epa.gov/glnpo/lakesuperior/lamp2000/LS%20chapter%204.pdf>

Page 4A-5

The 1999 estimates are based on a population extrapolation and Minnesota mercury emission estimates from fluorescent lamp breakage for 2000 [9.07 kg/yr], which are based on the proportion of lamps not recycled and industry figures on mg/lamp (MPCA 1999).

It should be possible to estimate the number of fluorescent bulbs, batteries, switches and other sources of mercury at the WTC buildings.

Conclusions

Numerous carcinogenic substances and their precursors were present and burned under condition of low oxygen and insufficient temperature to achieve complete combustion (i.e. smoldering) in the presence of dioxin catalysts. This set up the perfect conditions for maximum generation of dioxin/furan. There was a tremendous amount of mercury in products in the WTC. The presence of tremendous numbers of particles (alkaline and otherwise) provided the perfect scenario for dioxins, mercury, and other toxics to coat and accumulate in the dusts. As these conditions (low temperature, low oxygen, presence of precursors and catalysts) vary over time and space, the generation of dioxin / furan and other related toxics also varies. Therefore, some locations are likely to have larger accumulations of these pollutants than others.

An important question to answer is whether this is purely an exercise simply to see if a previous sampling and cleaning experiment was successful in the limited area in which it took place, or whether the purpose is to identify the extent of any hazardous conditions that still exist, and to which people are still being exposed, so that a complete remediation program can be designed and executed. The purpose of the Environmental Protection Agency should be to accurately characterize the toxic burden at locations inside and outside the study area, in any areas where the plume traveled in the first 100 days after 9/11, and if toxics are found, to remediate as if it were a Superfund site (since the dusts were similar to those in some Superfund sites – e.g. Libby, Montana). Turning a blind eye to contamination that is likely to still exist in the 4/5 of apartments below Canal Street, the many businesses that did not receive proper remediation, and those outside the arbitrary boundary, is contrary to EPA's prime mission, to protect the environment and health of citizens.

It is also a mistake to be examining a only handful of contaminants, much less a single surrogate, comparing each one to a single standard, and ignoring the synergistic impacts that the dozens of pollutants were likely to have caused. If the desired result is to understand health impacts, the panel would be well advised to test for a wide spectrum of pollutants, including mercury and dioxins, as well as to research the literature on synergistic effects to evaluate the effects of the complex WTC dusts on public health.