ASSESSMENT OF DIOXIN INHALATION EXPOSURES AND POTENTIAL HEALTH IMPACTS FOLLOWING THE COLLAPSE OF THE WORLD TRADE CENTER TOWERS

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Introduction

In the days following the September 11, 2001, terrorist attack on New York City's World Trade Center (WTC) towers, EPA, other federal agencies, and New York City and New York State public health and environmental authorities initiated numerous air monitoring activities to better understand the ongoing impact of emissions from that disaster. Using these data, EPA conducted an inhalation exposure and human health risk assessment (http://www.epa.gov/ncea/wtc.htm). That assessment is currently being publicly reviewed. The overall evaluation focused on particulate matter, metals (lead, chromium and nickel compounds), polychlorinated biphenyls, dioxin-like compounds, asbestos, and volatile organic compounds. This abstract focuses on the analysis of the dioxin-like compounds only.

Procedure

The dioxin monitoring program entailed 14 monitors and 724 samples (see http://www.epa.gov/wtc for details on EPA's monitoring programs relating to the World Trade Center disaster). Sampling began on Sep 23, 2001, and continued until May 28, 2002. Table 1 provides the data from three monitors: a monitor at the Ground Zero site, identified as WTC-Bldg 5, a monitor at a location immediately off-site of Ground Zero in the predominant easterly wind direction, Church & Dey, and a monitor located about 5 blocks away (~500 m) also in the predominantly easterly wind direction, Park Row. TEQ concentrations in this table were calculated based on concentration of the 17 dioxin and furan congeners (coplanar PCBs were not measured at this site) assuming non-detects of individual congeners were equal to one-half the detection limit. TEQs were calculated using the International TEF scheme; use of the more recent World Health Organization TEFs would have increased concentrations by about 10%.

In order to conduct an inhalation risk assessment based on this data, three "scenarios" were developed: a WTC site worker scenario, an office worker scenario, and a resident scenario. Key exposure assumptions for the site worker include: 10 hours per day (h/d), 5 days per week (d/w), 1.3 m^3/hr inhalation rate, in the time period between Sep 12 and Nov 30, 2001. This time frame roughly corresponds to the time when it seemed clear that dioxin air levels were elevated according to the monitoring data; workers may have worked through 2002. Measurement data taken from the "WTC - Bldg 5" on-site monitor were used to derive a time-weighted concentration of 60.7 pg TEQ/m^3 during this time period. A key assumption was that air concentrations from Sep 12 to Sep 23 (the date of the first sample taken) were equal to the measurement on Sep 23, which was 161 pg TEQ/m^3. A final and very important assumption for the on-site worker scenario is that the dose is not assumed to be reduced due to the use of gas masks. For the office worker,

key assumptions include: 10 h/d, 1.0 m^3/hr, 5 d/w, and the exposure began on Sep 19, 2001 (corresponding to the time when individuals were allowed back into office buildings outside of the Ground Zero site itself but in areas initially "restricted" near Ground Zero), also continuing until Nov 30, 2001. The office worker was assumed to be exposed to air concentrations measured by the "Park Row" monitor in Table 1. Using an outdoor monitor simplistically assumes that the air concentrations within office buildings were similar to air concentrations outside of the office buildings this close to Ground Zero. This neighborhood monitor began sampling on Oct 12. The TEQ air concentration from Sep 19 to Oct 12 was assumed to be 8.4 pg/m^3, which was the measurement from this monitor on Oct 12. The time-weighted average for the period of exposure was 4.8 pg TEQ/m^3. The resident was assumed to be exposed 24 h/d, 7 d/w, the inhalation rate was 0.55 m^3/hr, the period of exposure was Sep 19 to Nov 30, and the same neighborhood monitor as was used for the office worker was used for the resident, so that the average TEQ concentration during this time was 4.8 pg/m^3.

Cancer assessments entail the development of a "dose" term, which in this case is the dose received via inhalation. Daily inhalation dose is given by, ADD = [IN * (h/d) * C * ABS] / [BW], where ADD is average daily dose (pg TEQ/kg-day); IN is the inhalation rate (m^3/hr), h/d is hours/day, C is the concentration (pg TEQ/m^3), ABS is the fraction of contaminant inhaled which is absorbed (0.80 assumed), and BW is the body weight (70 kg assumed). The "lifetime" ADD, or LADD, was estimated simply as this ADD averaged over a lifetime. Estimation of potential cancer risk uses LADD in this equation: Risk = LADD * SF, where Risk is the upper bound incremental excess lifetime cancer risk that results from the exposure described by LADD, and SF is the upper bound cancer slope factor, expressed in inverse units to LADD, or [pg TEQ/kg-day]$^{-1}$. The SF of 0.000156 [pg/kg-day]$^{-1}$ was developed by EPA in 1984 for 2,3,7,8-TCDD exposures[1] and it is applied here.

The best indicator of exposure and potential health impact for persistent, bioaccumulative, toxic substances such as dioxin is the concentration of the chemical in the organ or tissue of concern[1]. A common metric for dioxin exposure is the "body burden", which is defined as the concentration of dioxins in the body, expressed on a lipid basis in this assessment. Dioxins build up and decline over prolonged periods of time, since the overall biological half-life of dioxin-like compounds in the human body ranges from 7 to 14 years[1]. The use of the body burden as the measure of dose has implications for short-term exposures, such as those near the WTC site, where elevated exposure rates limited to a period of days or months contributed to a pool of dioxin already accumulated in the human body over a lifetime. The current estimated body burden of dioxin and furan TEQ in United States adults is approximately 18 pg/g (ppt) body lipid[1].

A simple one-compartment, first-order pharmacokinetic (PK) model was used to estimate the body burden of the "on-site worker", the "office worker", and the "resident". For an exposure of a finite time, the nonsteady-state form of this model to predict an increment in body burden (IBB, pg/g lipid) from a constant intake dose is given by: IBB = [ADD/(k * LW)] * [1 - e^{-kt}], where ADD is the average daily dose (pg TEQ/day), k is the first-order dissipation rate constant (1/day; equal to 0.000267 which is equivalent to a 7.1 year half-life), LW is the weight of body lipids (g; equal to 0.25 * 70 kg, or 17,500 g), and t is the time of exposure (days). This model is applied on a daily time step using Excel® spreadsheet procedures. This allowed for the consideration of workdays

versus weekends for the on-site and office workers.

Results and Discussion

1) Monitoring: TEQ levels in air near the WTC were up to 1000 times higher than is typical for urban areas in the United States. Typical levels for urban areas are 0.1 to 0.2 pg TEQ/m^3 [(1)], while levels found in Ground Zero and near Ground Zero, starting Sep. 23, 2001 (the date of the first sample taken) and continuing through late Nov 2001, ranged from 10 to 170 pg TEQ/m^3. Concentrations measured several blocks from Ground Zero were still elevated above typical urban background, but considerably lower than sites in or near Ground Zero, ranging from 1 to 10 pg TEQ/m^3 from Sep through Nov. As seen in Table 1, concentrations were highest at Ground Zero, to decrease slightly off-site in the predominant wind direction as indicated by the Church & Dey monitor, and to decrease further in the downwind direction, as seen in the Park Row monitor. By Dec 2001, levels decreased to typical urban background levels in the Park Row monitor. It is uncertain whether levels dropped to background levels near Ground Zero. While standard procedures were used to sample and measure the dioxin-like compounds (hi-vol sampler with a GFF and a PUF cartridge, with analysis using EPA method SW8290), 11 of 14 samplers only sampled for 8 hours and collected 5-7 m^3 of air. Three samplers, however, including the Park Row sampler, collected about 1000 m^3 over a 72-hr period. Because of such a low volume of air in the samplers collecting only 5-7 m^3, detection limits were high and most of the samplers could not quantify congener concentrations unless the TEQ concentration was near to or greater than 1.0 pg TEQ/m^3. While this was not that much an issue when the concentrations were high until about the end of Nov 2001, nearly all congener measurements were non-detects at high detection limits after November, leading to reported TEQ concentrations (calculated assuming ND = ½ DL) at about 1.0 pg TEQ/m^3 or higher. In short, concentrations could have been close to 1.0 pg TEQ/m^3 near Ground Zero after Nov 2001, or they could have been less than 0.1 pg TEQ/m^3, as they were at the Park Row monitor.

2) Cancer Risk: The TEQ ADD during the period of exposure is 9 pg/kg-day for the WTC worker, 0.6 pg/kg-day for the office worker, and 0.7 pg/kg-day for the nearby resident. This compares to the average ADD for the US population of 0.6 pg TEQ/kg-day (dioxins and furans only), although this 0.6 estimate is a lifetime ADD (LADD)[1]. Only about 0.02 pg TEQ/kg-day of this background 0.6 total is due to inhalation[1]. When averaged over a lifetime, the WTC worker dose calculates to an incremental cancer risk that is $3*10^{-6}$, which is about 100 times lower than the United States background cancer risk from dioxin-like compounds, which is about $1.4*10^{-4}$ (1 pg TEQ/kg-day * 0.000156 [pg TEQ/kg-day]$^{-1}$). The office worker and resident experience incremental lifetime cancer risk at about $3*10^{-7}$, about 1000 times lower than background.

3) Body Burden Impacts: The exposure of the WTC worker suggests that his or her body burden could rise up to 10% above current average background - the WTC worker exposure might add 1.8 ppt lipid to the current average background of 18 ppt TEQ lipid. The nearby office worker and the residents have a rise of only 1% or less.

Disclaimer

The views expressed in this article are those of the author and do not necessarily reflect the views or policies of the United States Environmental Protection Agency.

References

1. US EPA. 2000. Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds. United States Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment. Review Draft. September, 2000. EPA/600/P-00/001B(a-f). Available at, http://www.epa.gov/ncea.

Table 1. Measured dioxin TEQ air concentrations at the WTC Building 5 monitor, the Church & Dey monitor, and the Park Row monitor (all units = pg TEQ/m^3; NS = not sampled; all TEQ calculated at ND = ½ DL; values in parenthesis calculated at ND = 0 when congener data available).

Date	WTC - Bldg 5	Date	Church & Dey	Date	Park Row
9/23/01	161.0 (161.0)	9/23/01	139.0 (139.0)	10/12/01	8.35
9/27	NS	9/27	50.0	10/14	0.34
10/2	175.0 (170.0)	10/2	59.3 (57.2)	10/15	4.78
10/4	176.0 (140.0)	10/4	51.9 (50.6)	10/16	7.55
10/8	32.0 (28.7)	10/8	17.7 (15.5)	10/26	6.51
10/11	52.4 (9.6)	10/11	15.6 (11.8)	10/29	6.34
10/18	NS	10/18	9.6 (8.8)	11/1	3.05
10/26	28.1 (24.9)	10/26	11.4 (10.2)	11/5	1.54
11/2	26.8 (25.4)	11/2	16.1 (15.1)	11/8	0.27
11/6	0.3 (0)	11/6	0.1 (0)	11/12	1.33
11/8	5.6 (4.9)	11/8	7.6 (7.1)	11/15	1.33
11/12	NS	11/12	1.3 (0.6)	11/19	2.50
11/15	5.4 (1.6)	11/15	3.4 (1.6)	11/22	1.30
11/21	4.1 (3.1)	11/21	10.0 (8.3)	11/26	0.80
No samples taken from 11/21/01 to 1/15/02 1/15 - 5/28/02; n = 46 reported range: 0.4-5.5 average: 1.4 at ND = ½ DL and 0.0 at ND = 0.		11/27	5.6 (5.5)	11/29	0.16
		12/1/2001 - 5/17/2002 n = 46 reported range: 0.2 - 4.1 average: 1.1 at ND = ½ DL and 0.0 at ND = 0.		12/3/2001 - 3/14/2002: n = 29 all samples reported < = 0.16	