World Trade Center Indoor Environment Assessment: Selecting Contaminants of Potential Concern and Setting Health-Based Benchmarks

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Prepared by the Contaminants of Potential Concern (COPC) Committee
of the World Trade Center Indoor Air Task Force Working Group

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Table of Contents

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Foreword

Following the collapse of the World Trade Center on September 11, 2001, federal, state, and municipal health and environmental agencies initiated numerous studies to assess environmental conditions in the area. A multi-agency task force was specifically formed to evaluate indoor environments for the presence of contaminants that might pose long-term health risks to local residents. As part of this evaluation, a task force committee was established to identify contaminants of primary health concern and establish health-based benchmarks for those contaminants in support of ongoing residential cleanup efforts in Lower Manhattan. In September 2002, the committee released a draft document titled "World Trade Center (WTC) Indoor Air Assessment: Selecting Contaminants of Potential Concern (COPC) and Setting Health-Based Benchmarks."

In October 2002, a panel of 11 experts conducted an independent peer review of the draft COPC document to ensure that the evaluations presented in the document were technically based and scientifically sound. A final report with peer reviewers' conclusions and recommendations was released in February 2003. The peer review report and the COPC Committee's response to peer review comments can be accessed on-line at: www.tera.org.

The responsiveness summary provides the formal responses to peer reviewer comments. EPA, through its chairmanship of the multi-agency committee that authored the response to peer review comments, assumes ownership and fully endorses that report's content. The responsiveness summary presents background on the peer review process, an overview of the peer reviewers' main conclusions and recommendations, and the document authors' responses to specific comments. The final COPC document presents the updated approaches for selecting COPC and setting health-based benchmarks, based on peer reviewer input.

Copies of the final COPC document can be obtained on-line at www.epa.gov/WTC. Inquires regarding the content of this document should be directed to:

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This document is just one product that addresses environmental and public health concerns related to the WTC. Individuals interested in other studies and research projects related to the WTC should refer to the following Web pages:

1.01 U.S. EPA: www.epa.gov/WTC
1.02 ATSDR: www.atsdr.cdc.gov/
1.03 NYCDOHMH: http://home.nyc.gov/html/doh/html/alerts/911.html

List of Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
ATSDR	Agency for Toxic Substances and Disease Registry
COPC	contaminant(s) of potential concern
CSF	cancer slope factor
EPA	U.S. Environmental Protection Agency
HEAST	Health Effects Assessment Summary Tables
IEUBK	Integrated Exposure Uptake Biokinetic
IRIS	Integrated Risk Information System
IUR	inhalation unit risk
$\mu g/m^3$	microgram per cubic meter
mg/m^3	milligram per cubic meter
MRL	ATSDR minimal risk level
NHANES	National Health and Nutrition Examination Survey
NIOSH	National Institute of Occupational Safety and Health
NJDEP	New Jersey Department of Environmental Protection
NYCDEP	New York City Department of Environmental Protection
NYCDOHMH	New York City Department of Health and Mental Hygiene
NYSDOH	New York State Department of Health
OSHA	Occupational Safety and Health Administration
PAHs	polycyclic aromatic hydrocarbons
PCM	phase contrast microscopy
PEL	OSHA permissible exposure limit
REL	NIOSH recommended exposure limit
RfD	reference dose
RfC	reference concentration
SVOC	semi-volatile organic compound
TERA	Toxicology Excellence for Risk Assessment
TLV	ACGIH threshold limit value
VOC	volatile organic compound
WTC	World Trade Center

1.0 Introduction

Background

Since September 11, 2001, the outdoor (ambient) environment around the World Trade Center (WTC) site and nearby areas has been extensively monitored by a group of federal, state, and municipal environmental and health agencies. The agencies have taken samples of air, dust, water, river sediments, and drinking water and analyzed them for the presence of contaminants that could pose a health risk to response workers at the WTC site, office workers, and local residents.

While some workers (WTC response as well as office) and local residents may have experienced acute irritant and respiratory effects from the collapse of the towers and associated fires, extended monitoring of the ambient air at and beyond the perimeter of the WTC site over the past year and a half indicates that contaminant concentrations in the ambient air pose a low risk of long-term health effects (EPA 2002). In February 2002, A multi-agency task force headed by EPA was specifically formed to evaluate indoor environments for the presence of contaminants that might pose long-term health risks to local residents. As part of this evaluation, a task force committee was established (COPC Committee) to identify contaminants of primary health concern and establish health-based benchmarks for those contaminants in support of planned residential cleanup efforts in Lower Manhattan.

Purpose

The process of selecting contaminants of potential concern (COPC) and setting health-based benchmarks—the subject of this document — is intended to determine which contaminants are likely associated with the WTC disaster for the purpose of setting health-based benchmarks for the indoor air and settled dust.

As depicted in Diagram 1, the COPC document informs the Indoor Air Residential Assistance/WTC Dust Clean-up Program, which will be referred to as the WTC Clean-up Program through the remainder of this document. In conventional hazardous waste site investigations, the COPC selection process is intended to reduce what is typically an extensive contaminant sampling list to a manageable "short list" of risk-driving chemicals. The risk from this "short list" is then calculated to determine if remedial action is warranted. Regarding the WTC, there was an a priori decision to institute a clean-up program rather than launch a formal remedial investigation to determine if remediation of residential dwellings was necessary. The primary reason for this decision was to eliminate the time-consuming process of initiating a remedial investigation (i.e., developing a sampling and analysis plan, conducting representative sampling of residential dwellings, analyzing a large number of samples, and finally interpreting results) at a time when re-habitation of residential dwellings in Lower Manhattan was nearly complete. As a result of this decision, the COPC selection process associated with the WTC Clean-up Program assumed a somewhat modified purpose. Rather than serve as a process to determine the need for clean-up, the COPC selection process served to facilitate development of health-based benchmarks for the WTC Clean-up Program. By identifying COPC, health-based clearance criteria for individual contaminants could be developed for indoor air and settled dust. To summarize, first and foremost, the intent of the COPC document is to identify risk-driving chemicals and to establish specific health-based benchmarks for the WTC Clean-up Program.

As part of this initiative, the COPC selection process informed two complimentary studies that were undertaken as part of the WTC Clean-up Program. The first was the WTC Residential Confirmation

Cleaning Study (EPA 2003a). This study was initiated to evaluate the effectiveness of various cleaning methods (e.g., high-efficiency particulate air vacuuming, wet wiping) used to clean residences. The COPC selection process provided the list of contaminants to sample for in the WTC Residential Confirmation Cleaning Study. It also enabled the development of health-based benchmarks for indoor air and settled dust so the effectiveness of cleaning methods could be assessed. The cleaning methods employed also served to guide the clean-ups of other heavily impacted unoccupied buildings. Another outcome of the WTC Residential Confirmation Cleaning Study was in streamlining the post-cleaning sampling needs of the WTC Clean-up Program. Although not a specific goal, this effort identified an indicator chemical (i.e., asbestos) that signaled the reduction of all COPC to concentrations below health-based benchmarks. With thousands of residents signed up for cleaning, the use of an indicator contaminant to establish cleaning effectiveness provided a powerful tool in facilitating the WTC Clean-up Program.

The other initiative that the COPC selection process informed was the WTC Background Study (EPA 2003b). The development of remediation goals is influenced by factors such as technical implementation, analytical detection limits, and the background concentration of contaminants in the environmental setting of interest. A literature review of contaminant background concentrations in residential dwellings was conducted to inform the WTC Clean-up Program. Limited information was obtained for asbestos in indoor air and lead and dioxin in settled dust, otherwise the search yielded very little useful data. It was therefore deemed advantageous to conduct a site-specific background study to inform risk management decisions regarding the setting of clean-up goals at health-based or background concentrations. Consequently, The COPC selection process directed the group of contaminants to be sampled for in the WTC Background Study. Conversely, the results of the WTC Background Study provides data to enhance the value of the final COPC document. That is, it provides an estimate of background for COPC in Lower Manhattan to be evaluated alongside health-based benchmarks.

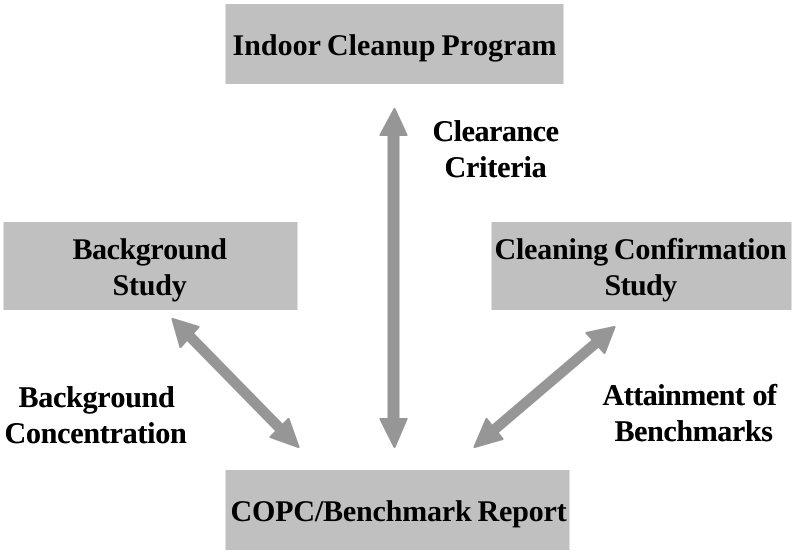

Diagram 1

2.0 Selecting the Contaminants of Potential Concern (COPC)

A systematic risk-based approach was used to select COPC. As shown in Figure 1, the selection process involved multiple steps. The process began with the review of an extremely large environmental data set, including indoor and outdoor air and dust data. This was followed by a two-level screening which considered individual contaminant toxicity, the prevalence of a contaminant within and across media, and the likelihood that a detected contaminant was related to the WTC disaster. The goal of the process was to identify those contaminants most likely to be present within indoor environments at levels of health concern.

This section details the steps and overall findings of the COPC selection process. Two appendices provide supporting documentation for the screening process. Appendix A describes how the health-based screening values used in the process were derived. Appendix B presents the findings of each step of the process.

2.1 Review of Multiple Data Sets to Identify Candidate Substances

The collapse of the WTC released a very broad range of contaminants into the air, many of which deposited with settled dust on surfaces in Lower Manhattan, both indoors and outdoors. To gain the best possible sense of the contamination levels in indoor residential environments, multiple sets of sampling data describing environmental conditions at and near the WTC site between September 11, 2001, and the present were reviewed. The primary goal of this exercise was to review data that might provide insights on the contamination levels inside Lower Manhattan residences. As a result, a large set of bulk dust and settled dust sampling results were reviewed, along with ambient and indoor air sampling data, based on the premise that contaminants entered residences through atmospheric transport.

Sampling data evaluated included those collected by the U.S. Environmental Protection Agency (EPA), Agency for Toxic Substances and Disease Registry (ATSDR), Occupational Safety and Health Administration (OSHA), New York City Department of Environmental Protection (NYCDEP), New York City Department of Health and Mental Hygiene (NYCDOHMH), the New York City Department of Education, the New Jersey Department of Environmental Protection (NJDEP), academic institutions and independent investigators. Overall, we examined results from more than 500,000 environmental samples, with sampling results available for more than 300 contaminants. The contaminants included volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), metals, asbestos, silica, other minerals, and synthetic fibers. Every contaminant identified in the sampling data was considered a candidate substance for the COPC selection process. A more complete description, including citations, of the data bases evaluated for selecting COPC can be found in Appendix B.

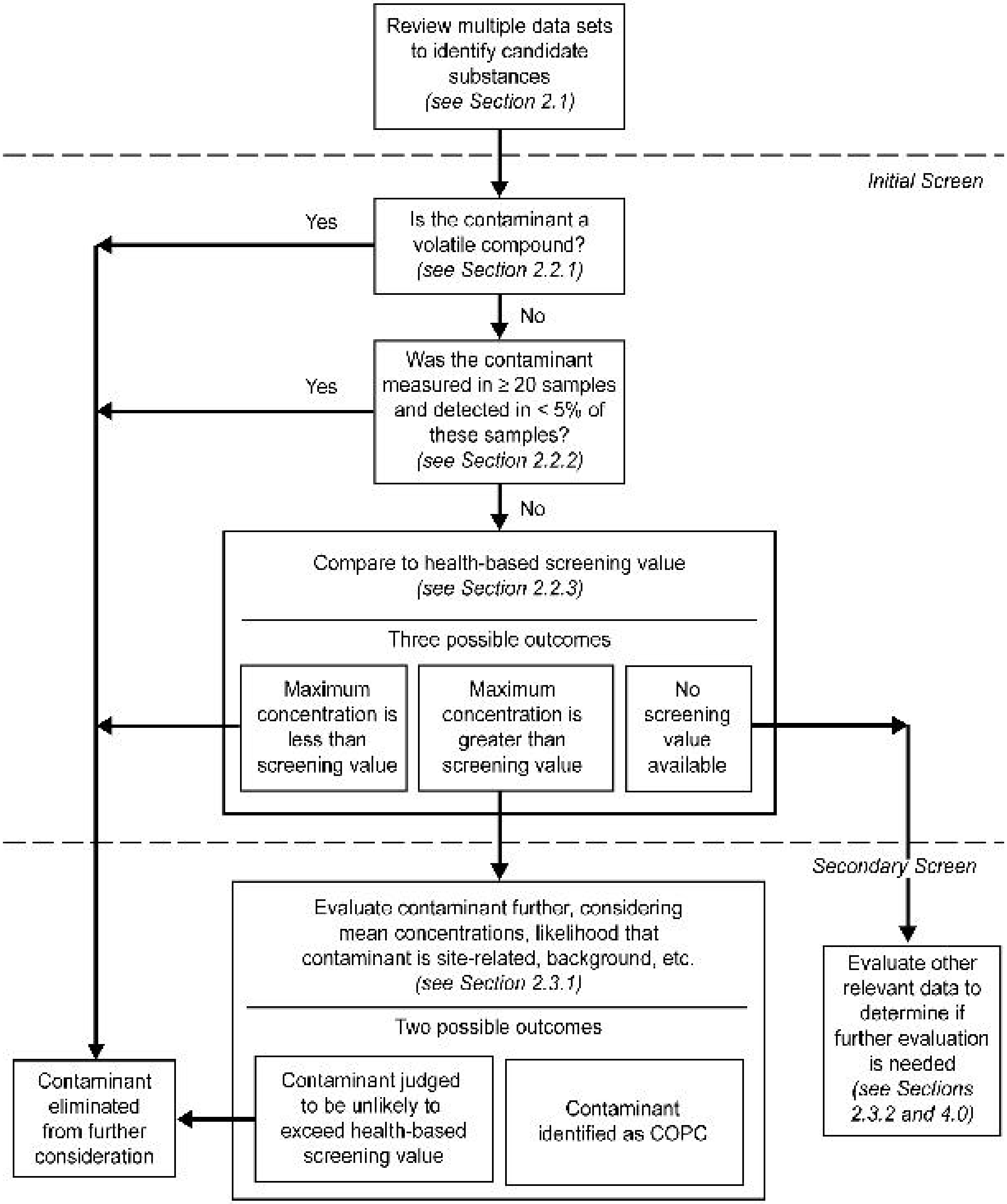

Figure 1. COPC Selection Process

2.2 Initial Screen to Identify Contaminants Requiring Further Consideration

The goal of the initial screening procedure was to sort through a large volume of data in a consistent manner to identify those substances requiring closer evaluation. In this analysis, ambient air, indoor air, bulk dust, and settled dust data were evaluated separately. The initial screening involved three main steps, as described below. The outcome of this process is detailed in Appendix B.

2.2.1 Eliminating volatile compounds

Volatile compounds were eliminated from the COPC selection process, because any volatile compound that might have been released in or adhered to dusts from the WTC site have likely evaporated or greatly dissipated since the time that air emissions from the site were controlled (i.e., since the time that the fires were extinguished - December, 2001). Any contaminant on the target compound list for Method TO-15 (ambient air) and Method 8260 (waste) was considered volatile. Further, chemical similarity to compounds on those lists and boiling point (as a surrogate for vapor pressure) were used to identify additional volatile contaminants not on these methods' target lists.

2.2.2 Eliminating contaminants detected at low frequencies

All contaminants detected in fewer than 5% of samples were removed from the list of candidate contaminants, but only if the contaminant was analyzed for in more than 20 samples. This screening approach based on frequency of detection is consistent with EPA's guidance on human health risk assessment (EPA 1989). The purpose of this step was to focus the COPC selection process on contaminants that were consistently detected, rather than on those that were infrequently detected.

The frequency of detection was calculated based on all relevant sampling data for a particular medium. WTC related environmental samples were obtained throughout Lower Manhattan from 9/11/01 through the present time. Using this approach, a contaminant could be eliminated even if it were detected at a relatively high concentration, but perhaps only in one location or at one point in time. We therefore carefully reviewed the contaminants eliminated in this step of the process to ensure that contaminants possibly linked with the WTC disaster and of potential public health importance did not get eliminated using this procedure. For example, before eliminating PCBs from further consideration, we confirmed that the PCBs detected in fewer than 3% of settled dust samples did not exceed health-based screening values.

2.2.3 Comparing detected concentrations to health-based screening values

For the contaminants that were not eliminated in the previous two steps, the maximum concentration detected in each medium was compared to corresponding health-based screening values. Health-based screening values were derived for air, bulk dust, and settled dust using methodologies, risk equations, and exposure assumptions consistent with established EPA risk assessment guidance. Appendices A and D present the specific risk equations, exposure parameters, and toxicity values used in deriving health-based screening values.

Exposure equations generally stem from EPA's Risk Assessment Guidance for Superfund (RAGS) (EPA 1989). Exposure assumptions used are those recommended in RAGS or supplemental risk assessment guidance, including EPA's Exposure Factors Handbook (EPA 1997b), Child-Specific Exposure Factors Handbook (EPA 2002a), Dermal Exposure Assessment: Principles and Applications (EPA 1992), and RAGS Part E, Supplemental Guidance for Dermal Risk Assessment (EPA 2001a).

To evaluate the settled dust pathway, EPA guidance for residential pesticide exposure assessment (EPA 2001b) was used and further supported by procedures and re-entry guidelines previously developed for scenarios evaluating fine dust particles more analogous to those associated with the WTC collapse (Kim and Hawley 1985; NJDEP 1993; Michaud et al. 1994; Radian 1999).

In calculating health-based screening values, the following criteria were applied to all exposure pathways:

- Evaluation of both cancer and non-cancer effects, with a target cancer risk of 10^{-4} and a hazard quotient of 1 for non-cancer endpoints—the more sensitive of the two being used to derive screening values.

- Evaluation of adult and child exposures, with child exposures factoring heavily into the development of dust screening values.

- Use of the most current toxicity criteria on EPA's Integrated Risk Information System (IRIS) database. In the absence of IRIS toxicity criteria, the following hierarchy of toxicity data sources was used: EPA's Health Effects Assessment Summary Tables (HEAST), ATSDR's minimal risk levels (MRLs), provisional values derived by EPA's National Center for Environmental Assessment, and, in limited cases, the use of surrogate toxicity values or cross-route extrapolations.

Three outcomes were possible from this initial screening:

1) If a contaminant's maximum concentration was lower than the corresponding screening value, that contaminant was eliminated from further consideration. Appendix B presents, by medium, the contaminants that fall into this category, listing the maximum detected concentrations and corresponding screening values.

2) If a contaminant's maximum concentration was greater than the screening value, then we evaluated the contaminant further in the secondary screening step (see Section 2.3.1 below). Fifteen contaminants fell into this category, including:

    Aluminum
    Antimony
    Arsenic
    Asbestos
    Barium
    Chromium
    Dioxins
    Lead
    Manganese
    Naphthalene
    Nickel
    PAHs (carcinogenic)
    Mercury
    4,4'-Methylene diphenyl diisocyantate (MDI)
    Thallium

3) If a contaminant did not have a toxicity value, and therefore did not have a screening value, we reviewed other relevant information (e.g., trends among sampling data, comparisons to background, the likelihood of the contaminant being related to site-specific releases) on a case-by-case basis to determine whether the contaminant should be evaluated further (see Section 2.3.2 below).

2.3 Secondary Screen to Select COPC.

As noted in the previous section, two classes of contaminants required further evaluation after the initial screen: (1) contaminants with a maximum concentrations greater than screening values and (2) contaminants for which no screening values are available. Sections 2.3.1 and 2.3.2 describe the secondary screening procedure for these two groups of contaminants. Appendix B (Section 5.0) presents detailed justifications for the contaminants included and not included as COPC.

2.3.1 Contaminants with toxicity criteria

For those substances exceeding health-based screening criteria in at least one sample, a detailed review of findings across environmental media was conducted to assess the representativeness of reported maximum concentrations, to study spatial and temporal trends, to determine the relationship of detected concentrations to available background concentrations, and to examine whether there was reason to believe a contaminant was site-related. Professional judgment entered into this part of the process. In general, contaminants with reported concentrations deemed representative of exposure conditions and detected above background (if appropriate comparison data were available) were retained as COPC.

The following list describes the final decisions reached for the 15 contaminants identified as requiring further evaluation:

- *Asbestos, dioxins, lead, and PAHs.* These contaminants were selected as COPC because they were consistently detected across environmental media at concentrations above health-based screening values.

- *Aluminum, antimony, arsenic, barium, manganese, naphthalene, nickel, MDI, and thallium.* These contaminants were not selected as COPC. In each case, closer examination presented strong evidence that these contaminants were not likely present in indoor dusts at levels of health concern (See Appendix B for additional discussion).

- *Chromium and mercury.* These two contaminants were not retained as COPC but deserve some additional discussion. Chromium in ambient air has been shown to exceed health-based screening values, though chromium levels in available bulk and settled dusts collected in Lower Manhattan are not above health-based screening values. Regarding mercury, wipe sampling data indicated that in isolated instances settled dust in Lower Manhattan residences contained mercury at levels greater than health-based screening values. In both cases, it is unclear whether detected levels were associated with the WTC. (See Appendix B for additional discussion.) Regardless, as part of the WTC Clean-up Program, EPA is performing a limited number of wipe samples for 21 non-COPC metals, including chromium and mercury.

2.3.2 Contaminants with no toxicity criteria

A subset of contaminants were detected for which no toxicity criteria or corresponding screening values were available. For these contaminants we considered any occupational or environmental standards and/or evaluated sampling trends, exposure potential, and the likelihood a contaminant was associated with the WTC collapse. The following list describes the final decisions reached for these contaminants:

- *Fibrous glass and crystalline silica*. These contaminants were retained as COPC. Both are components of building materials. Fibrous glass was consistently detected at high concentration in both bulk and settled dust samples collected at and near the WTC site. Crystalline silica, measured as alpha quartz, has been selected as a COPC for the following reasons: (1) indoor dust levels of quartz in Lower Manhattan were found to be significantly higher than those in comparison locations north of 59th Street; (2) quartz has been found in the respirable fraction of air samples, demonstrating a potential for exposure; and (3) quartz is a known component of building construction materials and was known to be released when the WTC collapsed.

- *Calcite, gypsum, and portlandite.* These contaminants were eliminated from further consideration. Detected concentrations were more than 100 times lower than occupational exposure limits for irritant effects.
- *Essential nutrients (e.g., calcium, magnesium); a limited number of specific phthalates and PAHs, and SVOCs that are not conventionally measured to support EPA risk assessment*. Due to the lack of appropriate comparison data, these substances were not carried any further in the COPC selection process. See Section 4.0 (Uncertainties and Limitations) for perspective on the impact that not evaluating these substances has on the overall COPC selection process.

3.0 Setting Benchmarks for the Contaminants of Potential Concern (COPC)

Health-based benchmarks were developed to be protective of long-term habitability of residential dwellings. The following hierarchal approach was employed for developing benchmark values: use of relevant and appropriate environmental standards/regulations; calculation of health-based benchmarks employing environmental risk assessment guidance, and adaptation of occupational standards with additional safety factors.

3.1 Use of Environmental Standards/Regulations

A review of environmental standards/regulations was conducted for each of the six COPC. The COPC Committee identified an applicable and relevant existing standard to set a health-based benchmark for lead in interior dust. The Residential Lead-Based Paint Hazard Reduction Act (Title X) Final Rule (40 CFR, Part 745, 1/5/01) established uniform national standards for lead in interior dust. Thus, both EPA and the United States Department of Housing and Urban Development (HUD) have set a dust standard for lead of 40 $\mu g/ft^2$ for floors (including carpeted floors) and 250 $\mu g/ft^2$ for interior window sills. To support the development of a dust standard EPA performed an analysis of the Rochester Lead-in-Dust Study (HUD, 1995). At 40 $\mu g/ft^2$ a multimedia analysis shows a 5.3% probability that a child's blood lead level would exceed 10 $\mu g/dl$. Thus, this standard meets the criteria established by EPA (i.e., 95% probability to be below 10 $\mu g/dl$) (EPA 1994a) for managing environmental lead hazards. However, the COPC Committee opted to set the benchmark at the more stringent HUD screening level of 25 $\mu g/ft^2$.

The clearance criteria established in the Asbestos Hazard Emergency Response Act (AHERA 1986) of 70 structures/mm^2 (0.022 f/cc) was utilized to evaluate asbestos samples from the WTC ambient (outdoor) air monitoring effort. Although not specifically risk-based, the AHERA standard was deemed an appropriate benchmark for evaluating ambient airborne asbestos data, especially since exposure to potentially elevated levels of asbestos in the ambient air was not expected to exceed the duration of time needed to clean-up Ground Zero (i.e., less than one year). However, given the potential for extended exposure in residential dwellings, a risk-based approach specifically developed to address long-term exposure was deemed more appropriate.

3.2 Developing Risk-Based Benchmarks for Indoor Air and Settled Dust

In cases where appropriate standards did not exist (e.g., asbestos), risk-based benchmarks were developed using established EPA risk assessment methods: for indoor air, methods described in EPA's "Risk Assessment Guidance for Superfund" (EPA 1989) were used; for settled dust, the most formal EPA guidance which addresses this issue is the "Standard Operating Procedures (SOPs) for Residential Exposure Assessment" originally published by the Office of Pesticides in 1997 and updated in 2001 (Appendix D - EPA 1997a and EPA 2001a). This methodology was employed with modifications. (See Appendix D for a comprehensive discussion of the methods, exposure parameters and equations used to develop risk-based benchmarks for indoor air and settled dust.) The risk-based benchmarks reflect the most current toxicity criteria (Cancer Slope Factors and RfDs/RfCs) on EPA's Integrated Risk Information System (IRIS). IRIS is a regularly updated (quarterly), online database that reports chemical toxicity reference values and information on human health effects that may result from exposure to chemicals in the environment. In the absence of IRIS toxicity criteria, the following hierarchy of toxicity data sources was used: EPA's Health Effects Assessment Summary Tables (HEAST), ATSDR's minimal risk levels (MRLs), provisional values derived by EPA's National Center for Environmental Assessment, and, in limited cases, the use of surrogate toxicity values or cross-route extrapolations. Health based benchmarks for asbestos, dioxin, and PAHs, were derived by this process.

EPA's Integrated Exposure Uptake Biokinetic (IEUBK) Lead Model (EPA, 1994) was employed to derive a health-based benchmark for lead in indoor air. EPA developed the IEUBK Lead Model to evaluate multimedia lead exposure to children in residential settings. EPA established a goal of attaining a 95% probability that blood lead levels in children be less than 10 µg g/dl (EPA 1994a). Setting the indoor air lead concentration at 0.7 µg g/m^3 and using site specific (i.e., New York City background) concentrations for lead in water, diet, soil and dust, the IEUBK Lead Model estimates that 95% of the blood lead probability distribution falls below 10 µg/dl. See Appendix E for a detailed discussion of medium-specific lead concentrations, data input spreadsheets and a graphic display of the blood lead probability distribution for children 0-7 years old.

3.3 Developing Benchmark Levels Based on Occupational Health Standards

For contaminants that lacked environmental toxicity criteria from sources listed in Section 3.2, occupational standards served as the starting point for benchmark development. Additional safety factors were added to account for higher exposure and greater sensitivity within the general population. The health-based benchmarks for fibrous glass and crystalline silica in indoor air were developed in this manner. A detailed discussion for each benchmark is provided below.

Fibrous glass. Although the TLV (1 f/cc) is based on irritant effects, the derived benchmark of 0.01 f/cc (100 fold safety factor) is believed to be protective for chronic residential exposure for glass and mineral wool. The COPC Committee did not specifically apportion this adjustment as a duration adjustment or an adjustment for application to a non-worker population. Although this total adjustment of 100 could be considered to cover the 4.2 duration adjustment, and an adjustment above that for application to non-worker population, there is considerable variation in how this second adjustment may be set. The concern is not so much can we assign a specific number for the adjustment which is accurate, but rather is the resulting benchmark protective?

Fibrous glass less than 3 microns in diameter are respirable and available to enter and deposit in the pulmonary regions of the lung (ACGIH 2001). Clearance of these fibers from the lung will be determined by fiber solubility and length (ACGIH 2001; ATSDR 2002a). Fibers cleared from the lung have less potential to create long-term health effects. Less soluble materials have a longer residence time in the lung and therefore have a greater potential to contribute to tissue damage or malignant disease. Within synthetic vitreous fiber (SVF) types, glass fibers and slag wool are considered the most soluble, and therefore least toxic. Mineral wool is less soluble than glass wool. The fibers observed in indoor and outdoor dust samples from the WTC area contained glass wool and mineral wool, both of which have lower biopersistence than other forms of synthetic vitreous fibers.

Although some animal studies have demonstrated both fibrotic and carcinogenic potential for glass and mineral wools (ACGIH 2001; ATSDR 2002a; IARC 1988), more recent studies do not fully support this finding.[1] Epidemiologic studies on workers exposed to fibrous glass do not provide consistent evidence of pulmonary effects, although some effects were noted (ATSDR 2002a; Bonn et al. 1993). Similarly, when assessing deaths due to lung cancer in workers exposed to glass wool, studies do not provide strong evidence for increased risk of cancer deaths attributable to the glass wool exposure.

The carcinogenic potential of fiberglass has been reviewed by several agencies. The IARC originally classified both glass and mineral wools as Group 2B carcinogens, possibly carcinogenic to humans, based on animal studies (IARC 1987). Similarly these materials were classified as carcinogens by the National Toxicology Program and the American Conference of Governmental Industrial Hygienists (ACGIH 2001; NTP 2001). However a review of the carcinogenic potential of these fibers by IARC in 2001, which takes into account updated human studies, animal inhalation studies, and mechanistic studies, recommends a change in this classification. The IARC has announced that the recent monograph designates both glass and mineral wool as Group 3, unclassifiable as to carcinogenicity in humans, because of inadequate evidence of carcinogenicity in humans and the relatively low biopersistence of the materials.

In contrast, the less soluble and more biopersistent refractory ceramic fibers are still considered potentially carcinogenic and are believed to more toxic than glass and mineral wools. A recent review of the toxicity of synthetic vitreous fibers by ATSDR proposes a Minimal Risk Level for chronic exposure of 0.03 f/cc for these refractory ceramic fibers (ATSDR 2002b). Although ATSDR did not set MRLs for glass and mineral wools, it notes that "insulation wools are markedly less durable and less potent than refractory ceramic fibers." Therefore the benchmark of 0.01 f/cc for glass and mineral wools, which is lower, should be considered protective.

Silica. No threshold has been established and it is possible health effects occur below the NIOSH REL of 50 :g/m3. Although duration adjustments and uncertainty factors can be applied to this REL to develop a benchmark for residential exposure, the resulting level would be below practical detection limits. Therefore the COPC Committee is recommending a benchmark of 5 :g/m^3, which is the lowest amount that can be reliably reported in a reasonable sampling time.

The level of this benchmark is technically limited by sampling constraints, including time and weight loading. It is based upon a reporting limit of 10 micrograms of crystalline silica with no more than about 3 milligrams of total dust on a single filter. (A reporting limit is the smallest amount of a substance for which a quantitative value can be determined.) More than about 3 milligrams of dust on the filter will decrease analytical sensitivity. Collection of 2 cubic meters of air over about 20 hours for a Dorr-Oliver cyclone at 1.7 L/min or about 13.3 hours using an SKC cyclone at 2.5 L/min will provide sufficient sensitivity to measure 5 μg/m^3 crystalline silica so long as the total dust weight on the filter does not

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[1] Early studies often relied upon injection and implantation studies, which may not accurately predict a pulmonary response from inhalation exposures. A review of inhalation studies indicates that glass wool did not cause pulmonary fibrosis or lung cancer in these animal studies (Bonn et al. 1993). A recent study by Hesterberg indicates no increase in pulmonary fibrosis or lung cancer even at doses of 222 f/cc, although cancer incidence in control animals was considered high.

exceed about 3 milligrams (an airborne dust concentration of 1.5 mg/m^3). Using either the nylon Dorr-Oliver or SKC Aluminum Cyclones, the following limits are possible:

Sampling Equipment (Size selection cyclones)	Duration of sampling	Volume of air (m^3)	Effective reporting limit (µg/m^3)
Dorr-Oliver (OSHA) at1.7 L/min	6 hours (360 min)	0.61	16.3
	8 hours (480 min)	0 .81	12.3
	10 hours (600 min)	1.02	9.8
	19.6 hours (1176 min)	2.0	5.0
SKC Aluminum (NIOSH) at 2.5 L/min	6 hours (360 min)	0.9	11.2
	8 hours (480 min)	1.20	8.4
	10 hours (600 min)	1.5	6.7
	13.3 hours (800min)	2.0	5.0

3.4 Health-Based Benchmarks (Summary Table)

Table 1 lists the COPC health-based benchmarks for indoor air and settled dust. Benchmarks for asbestos, fibrous glass and crystalline silica in settled dust are not provided for the following reason. These three minerals exert their toxicity primarily through the inhalation route of exposure. Therefore, a health-based benchmark for settled dust would be a function of the relationship between the mineral content in settled dust and indoor air. Limited studies (Millette and Hays, 1994) have described the empirical relationships (referred to be the authors as “ K factors”) between concentrations of asbestos fibers in settled dust and indoor air. These K factors were developed by studying matched air and settled dust samples taken from indoor environments at varying levels of activity. However, due to the numerous factors that influence the relationship between fiber concentration in settled dust and indoor air, including surface porosity, activity patterns, air exchange rates and interior volume, the COPC Committee elected against setting benchmarks for COPC in settled dust based on projected concentrations in indoor air.

COPC	**Indoor Air**	**Settled Dust**
Asbestos*	0.0009 f/cc	n/a
Lead	0.7 µg/m^3	25 µg/ft^2
MMVF	0.01 f/cc	n/a
Dioxin	0.001 ng/m3	2 ng/m^2
PAH	0.2 µg/m3	150 µg/m^2
Silica	5 µg/m3	n/a

Table 1

*Risk-based criteria were used to develop the benchmark level for asbestos in air. Conservative assumptions of continuous exposure to a constant level of airborne fibers were combined with the IRIS Slope Factor to establish a benchmark equating to a 1x10-4 excess lifetime cancer risk. This approach makes several assumptions, chief among those is the quantification of asbestos fibers in air based on the PCM equivalent (PCMe) definition of a fiber (greater than 5um in length with an aspect ratio of 3:1 or greater) and the use of the IRIS Slope Factor which was designed to apply to fibers so defined. Although there is some concern regarding shorter fibers, the approach used here represents the current consensus by the US EPA for quantifying risk of airborne asbestos fibers. It should be noted there is ongoing debate regarding the nature of health effects which may be attributed to shorter asbestos fibers. Both EPA and ATSDR are currently pursuing meetings to discuss and further refine these issues. However for the purposes of this response, addressing PCMe fibers is considered protective.

4.0 Uncertainties and Limitations

Overall, the COPC selection process used in evaluating WTC-related contamination enabled us to select appropriate indicator contaminants, leading to the development of benchmark criteria which support ongoing efforts to safely clean up residential environments in Lower Manhattan. However, some uncertainties are inherent in the COPC selection and benchmark setting processes.

The primary uncertainties associated with the COPC selection process include the nature of the environmental data sets used in the selection process and the absence of toxicity criteria for some contaminants. Other uncertainties relate to the exposure assumptions used in setting benchmark values, especially for settled dust. The impact of these factors on the outcome of the process are detailed below.

Data limitations. Outside of the WTC Clean-up Program itself, extensive, systematic sampling of indoor air and dusts in Lower Manhattan residences has not occurred. However, in selecting COPC, we drew from the much larger sampling data from other media to account for this shortcoming. We feel that these data are sufficient to identify those contaminants most likely to be present in indoor environments and to support the derivation of clean-up criteria. Ambient air monitoring data need to be interpreted with caution before being used to evaluate indoor environments. For example, samples collected months after the WTC collapse may not have characterized much of what made it into the residences as dust. Fortunately, indoor air and residual dust sampling being conducted as part of EPA's ongoing residential clean-up program offer additional insight to the nature and extent of contaminants found in indoor environments.

As discussed earlier, to promote a timely response to the WTC disaster, conventional remedial investigation approaches were not used to generate our study data. That is, an investigation of indoor environments with targeted sampling was not conducted. Instead, to expedite cleanup, we relied on existing data sets realizing that many of the data sets were generated independently, by multiple entities, for various purposes, and with varying data quality objectives. Sampling and analytical methods varied across some studies, and that limited results exist for some contaminants in some media. To the extent possible, we factored contaminant- and study-specific considerations into final decisions on COPC (e.g., sample size, detection limits, etc.). Lastly, environmental sampling data do not specifically "fingerprint" the possible unique pattern of substances that may have been released from the WTC collapse and settled in indoor dust. Nonetheless, we still screened hundreds of contaminants, many of which are known to be associated with building materials or thermal or chemical degradation products (e.g., asbestos, PAHs and other SVOCs, dioxins, and metals). Through a combined analysis of air and settled dust data, the process enabled the identification of risk-driving contaminants within indoor environments.

- *Absence of contaminant-specific toxicity criteria.* Though toxicity values are not currently available for a subset of contaminants tested for and detected in some air and dust samples in Lower Manhattan, the COPC selected are indicative of the most prevalent, most toxic contaminants associated with the WTC releases. A wide range of contaminant classes were captured, among which some of the more toxic members were identified and screened (e.g., dioxins, PAHs, metals). Basing COPC selection on the contaminants with known toxicity criteria (and arguably some of the more toxic compounds) that are measured at higher levels than the contaminants in question is believed to be appropriate and reasonably health-protective.

  The list of contaminants without toxicity criteria that were not carried through the COPC selection process include (1) essential nutrients (e.g., calcium, magnesium), which EPA generally does not carry through its risk assessments; (2) a limited number of specific phthalates and PAHs; (3) and SVOCs that are not conventionally measured to support EPA risk assessment. The lengthiest list of SVOCs for which no toxicity criteria exist comes from Lioy et al. (2002)—a study of three outdoor bulk dust samples collected in Lower Manhattan on September 16 and 17, 2001. Most of the SVOCs that do not have toxicity criteria were not consistently detected across the three samples. Further, the concentrations measured were consistently lower than other SVOCs (e.g., PAHs) that have been selected as COPC. Finally, because many of the SVOCs identified by Lioy are rarely considered in environmental sampling studies, we have no knowledge whether the measured levels are consistent with background concentrations in urban settings or if the levels are unusually high.

- *Absence of child-specific toxicity criteria.* Ideally, toxicity criteria should consider the critical exposure periods and toxicity endpoints relevant to children's health. However, the development of additional toxicity criteria for children to support the COPC selection process is beyond the scope of this effort. Our screening process did consider, however, toxicity endpoints relevant to children's health where available (e.g., lead). As stated earlier, the critical studies and endpoints used in developing IRIS and alternate toxicity values served as the basis for our screening values. Currently, most consensus toxicity values are based on the evaluation of adult exposures, not early-life exposures, though EPA does factor in relevant information on reproductive and developmental endpoints (or the lack thereof) when deriving toxicity values.

  It should be noted that research evaluating the significance of early-life exposures to toxic chemicals is ongoing by EPA and others. For example, EPA recently developed draft guidance for assessing cancer susceptibility from early-life exposure to carcinogens (EPA 2003). Because most current cancer slope factors do not account for susceptibility differences with respect to early life stages, agency scientists are exploring the possibility of applying additional uncertainty factors when evaluating childhood carcinogenic risks to some (e.g., mutagenic) carcinogens. Much of the impetus for such an approach is the growing knowledge and understanding of how a particular carcinogen exerts its effect (i.e., its mode of action) and how a particular mode of action may increase the risk of tumor response if exposure occurs during early-life stages. The COPC Committee acknowledge that the current approach of applying existing toxicity criteria to all age groups introduces some uncertainty to the evaluation biased toward an underestimation of risk.

- *Uncertainty in deriving settled dust screening and benchmark values.* As detailed in Appendix D, derivation of settled dust screening values required multiple assumptions in estimating exposure to surfaces, which add uncertainty to our analysis. For example, factors affecting surface loading and transfers to skin have not been well studied and are likely to be highly variable (e.g., characteristics of different surfaces, activities patterns related to surface contact, and surface cleaning techniques and frequency). As a result, limited data were available for many of the input parameters used to estimate dose from exposure to contaminants in settled dust. However, consistent with general human health risk assessment practice, every effort was made to select exposure input parameters that would define a reasonable maximum exposure and produce protective screening values. Upper-bound exposure estimates were used whenever available. Therefore, overall, the process represents a reasonably protective approach.

- *Evaluating multiple-contaminant exposures*. Benchmarks were developed on a contaminant-by-contaminant basis. It is clearly recognized that the residents in Lower Manhattan are not exposed to environmental contaminants singularly, but instead to combinations of chemical and physical agents. Development of benchmarks, however, was driven by a combined consideration of individual COPC-specific toxicity, background levels, and practicalities and limitations related to sampling. Mixture toxicology was not factored into the derivation process because little or no quantitative dose-response data exist regarding specific interactions across the WTC COPC (asbestos, dioxins, lead, PAHs, fibrous glass, and crystalline silica)[2].

The contaminant-specific approach is believed to be health protective, however, for the following reasons:

1) For non-carcinogens, COPC benchmarks are set at concentrations well below observed effect levels and generally at or below no-observed-adverse-effect levels (NOAELs). Presumably, exposures to one or multiple substances below or near the NOAEL will not result in adverse effects (EPA 2000b).

2) The likelihood of interactions are increased if substances behave similarly toxicologically. A review of the toxicology of individual COPC (target organ toxicity, mode of action) and any documented chemical interactions among WTC COPC revealed the following:

    < Target organs and critical effects resulting from ingestion and dermal exposures generally differ across individual COPC, though lead, dioxins, and PAHs are all considered potential human carcinogens via the ingestion route. Each of these contaminants can affect a wide range of biological systems, but each generally exerts its effects via different mechanisms.

    < At high concentrations, inhalation exposure to several of the COPC (asbestos, PAHs, fibrous glass, and crystalline silica), as well as the small particulate matter released during the WTC disaster, has been shown to result in point of contact toxicity to the lung. Specific lung effects vary across these substances, ranging from acute irritant effects produced by fibrous glass to cancers of the lung associated with asbestos. Exposures to COPC at or below benchmark concentrations—which are set at levels significantly lower than observable effect levels—would be unlikely to produce effects individually or in combination.

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[2] Note that combined effects within dioxin and PAH mixtures were accounted for in the development of benchmarks using toxic equivalency (TEQ) approaches that account for the relative potency of the components of these complex mixtures. Toxicity equivalent factors used in this approach are based on our understanding of the most toxic component of each mixture (i.e., 2,3,7,8-TCDD for dioxins and benzo(a)pyrene for PAHs).

One EPA study looking at acute airway effects in mice exposed to WTC fine particulate matter (2.5 microns) provides some insights to the magnitude of total dust exposures leading to observable effects. This study revealed that components of WTC dust promotes respiratory inflammation at “high” doses only (EPA 2002). This study does not evaluate the effects of long-term or repeated exposures to lower levels of WTC dust and is not directly useful in the development of benchmarks.

5.0 References

American Conference of Governmental Industrial Hygienists (ACGIH). 2001. TLV Documentation: Manmade Vitreous Fibers (MMVF), 2001.

ATSDR. 1995. Toxicological Profile for Asbestos. U.S. Dept. of Health and Human Services, Atlanta, GA.

ATSDR. 1998. Toxicological Profile for Chlorinated Dibenzo-p-dioxins. Atlanta: U.S. Department of Health and Human Services. December 1998.

ATSDR 2000. Toxicological Profile for Arsenic. Atlanta: U.S. Department of Health and Human Services. September 2000.

ATSDR. 2001. Guidance Manual for the Assessment of Joint Toxic Action of Chemical Mixtures. Draft for Public Comment. Atlanta: U.S. Department of Health and Human Services. February 2001.

ATSDR. 2002a. Technical Briefing Paper: Health Effects from Exposure to Fibrous Glass, Rock Wool or Slag Wool. Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, Atlanta, GA. 2002.

ATSDR 2002b. Toxicological Profile for Synthetic Vitreous Fibers. Atlanta: U.S. Department of Health and Human Services. September 2002.

Bonn WB, Bender JR, et. al. 1993. Recent Studies of Man-made Vitreous Fibers: Chronic Animal Inhalation Studies. J Occup Med. 1993;35(2):101-113.

EPA. 1986. EPA’s Guidelines for the Health Risk Assessment of Chemical Mixtures. EPA/630/R-98/002. September 1986.

EPA. 1989. Risk Assessment Guidance for Superfund. Volume 1. Human Health Evaluation Manual (Part A). Interim Final. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/1-89/002. December 1989.

EPA. 1992. Dermal Exposure Assessment: Principles and Applications. Interim Report. U.S. Environmental Protection Agency, Office of Health and Environmental Assessment. EP/600/891/001/B.

EPA 1994. Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children. Office of Emergency and Remedial Response. EPA/540/R-93/081 Washington D.C.

EPA 1994a. Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities. OSWER Directive 9355.4-12. Washington D.C.

EPA. 1997a. Health Effects Assessment Summary Tables. FY 1997 Update. Emergency Response. EPA-540-R-97-036. July 1997.

EPA 1997b. Exposure Factors Handbook. U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment. EPA/600/P-95/002Fa. August 1997.

EPA 2000a. Science Policy Council Handbook: Peer Review. U.S. Environmental Protection Agency, Office of Science Policy. EPA 100-B-00-001. December 2000.

EPA. 2000b. Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures. Risk Assessment Forum Technical Panel. EPA/630/R-00/002. August 2000.

EPA. 2000c. Draft Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds. Office of Research and Development.

EPA. 2001a. Risk Assessment Guidance for Superfund Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). Review Draft. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response EPA/540/R/99/005.

EPA 2001b. Science Advisory Council for Exposure. Policy Number 12 on Recommended Revisions to the Standard Operating Procedures (SOPs) for Residential Exposure Assessments. Revised: February 22, 2001.

EPA 2002. Exposure and Human Health Evaluation of Airborne Pollution from the World Trade Center Disaster. National Center for Environmental Assessment - Office of Research and Development. (External Review Draft) EPA/600/P-2/002A

EPA 2002a. Child-Specific Exposure Factors Handbook (Interim Report). U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment. EPA-600-P-00-002B. September 2002.

EPA. 2002b. Toxicological Effects of Fine Particulate Matter Derived from the Destruction of the World Trade Center. National Health and Environmental Effects Research Laboratory. December 2002.

EPA 2003. Supplemental Guidance for Assessing Cancer Susceptibility from Early-Life Exposure to Carcinogens. External Review Draft. EPA/630/R-03/003. February 2003.

EPA 2003a. World Trade Center Residential Confirmation Cleaning Study (Draft Report, March 2003). USEPA Region 2, New York, NY.

EPA 2003b. World Trade Center Background Study (Draft Report, March 2003) USEPA Region 2, New York, NY.

HUD 1995. The Relation of Lead-Contaminated House Dust and Blood Lead Among Urban Children. Final Report to USHUD from the University of Rochester School of Medicine (Rochester, NY) and the National Center for Lead Safe Housing (Columbia, MD).

International Agency for Research on Cancer (IARC). 1987. Monograph on Asbestos (Actinolite, Amosite, Anthophyllite, Chrysotile, Crocidolite, Tremolite), in IARC Monographs of the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer, World Health Organization, Lyon, France 1987;Supp 7:106.

International Agency for Research on Cancer (IARC). 1988. Monograph on Man-Made Mineral Fibers, in IARC Monographs of the Evaluation of Carcinogenic Risks to Humans. International Agency for Research on Cancer. World Health Organization. Lyon, France. 1988;43:39.

Kim NK, Hawley J. 1985. Re-entry guidelines: Binghamton State Office Building. New York State Dept. of Health, Bureau of Toxic Substances Assessment, Division of Health Risk Control. Albany, NY. August. Document 0549P.

Lioy P, Wiesel CP, Millette JR, Eisenreich S, Vallero D et al. 2002. Characterization of the Dust/Smoke Aerosol that Settled East of the World Trade Center (WTC) in Lower Manhattan after the Collapse of the WTC September 11, 2001. Environ. Health Perspectives. July 2002;110(7):703-14.

New Jersey Department of Environmental Protection (NJDEP). 1993. Technical Basis and Background for Cleanup Standards for Contaminated Sites. N.J.A.C. 7:26D (Draft).

Michaud JM, Huntley SL, Sherer RA, Gray MN, and Paustenbach DJ. 1994. PCB and Dioxin Re-Entry Criteria for Building Surfaces and Air. Journal of Exposure Analysis and Environmental Epidemiology; 4(2):197-227.

Milette JR, Hays SM. 1994. Settled Asbestos Dust Sampling and Analysis. Lewis Publishers. New York, NY.

National Toxicology Program (NTP). 2001. Glasswool in Report on Carcinogens, 9th Edition. U.S. Department of Health and Human Services, National Toxicology Program, Research Triangle Park, NC. 2001.

NIOSH 2002. National Institute of Occupational Safety and Health. Health Effects of Occupational Exposure to Respirable Crystalline Silica. NIOSH # 2002-129. US Department of Health and Human Services.

NYCDOHMH 2003. Personal Communication with Ken Carlino - Lead Program. New York City Department of Health and Mental Hygiene. New York, NY.

Radian International (Radian). 1999. Development of Risk-Based Wipe Sample Cleanup Levels at the Claremont Polychemical Superfund Site in Old Bethpage, New York. Prepared for the U.S. Army Corps of Engineers.

TERA 2003. World Trade Center (WTC) October 21–22, 2002, Peer Review Meeting Notes. Prepared by Toxicology Excellence for Risk Assessment. Prepared for the U.S. Environmental Protection Agency. February 7, 2003.

WHO. 1998. Environmental Health Criteria 205. Polybrominated Dibenzo-p-dioxins and Dibenzofurans.

APPENDIX A

Deriving Health-Based Screening Values for Air and Dust Exposure Pathways

1.0 Introduction

As described in Section 2.0 of the main text, the initial screening step in the COPC selection process involved the comparison of maximum detected air and dust concentrations against health-based screening values. The purpose of this appendix is to describe how screening values used in this step of the process were selected or derived.

Health-based screening values were derived for three exposure pathways as follows:

- *Air pathway*. Contaminants detected in ambient and indoor air were compared to the lower of the following EPA Integrated Risk Information System (IRIS) values: EPA reference concentrations (RfCs) (for noncarcinogens) or air concentrations associated with a 10^{-4} cancer risk (based on inhalation unit risks [IURs]). In the absence of IRIS values, a defined hierarchy was used to obtain toxicity values for this and the other pathways evaluated[3].

- *Bulk dust pathway*. Screening values were developed for bulk dust based on a soil ingestion scenario, considering both child and adult exposures. The exposure equations and age-specific assumptions are detailed below. Oral toxicity values (EPA reference doses [RfDs] for noncarcinogens and cancer slope factors [CSFs]) were used when available. Otherwise, the hierarchy described above was followed.

- *Settled dust pathway*. Screening values were developed based on exposures associated with ingestion and dermal contact with dust residues on indoor surfaces. The derivation of screening values parallels that used in developing benchmark criteria for the settled dust pathway. To evaluate this pathway, we adapted EPA guidance for residential exposure assessment, originally developed to study pesticide residues (EPA 2001). This approach was further supported by procedures and re-entry guidelines previously developed for scenarios evaluating fine dust particles more analogous to those associated with the WTC collapse (Kim and Hawley 1985; NJDEP 1993; Michaud et al. 1994; Radian 1999). Applicable parameters and the justification for selected values are detailed in Appendix D. Toxicity criteria used included EPA's RfDs and CSFs.

2.0 Air

When available, consensus inhalation toxicity values available through EPA's IRIS served as the basis for air screening values. (See above for hierarchy used to obtain toxicity values.) Screening values for cancer and non-cancer risks were derived as follows, with the lower of the two values used in the

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[3] In the absence of IRIS values, the following hierarchy was used to obtain toxicity values:

1.01 EPA Health Effects Assessment Summary Tables (HEAST) values (RfC/RfD, IUR/CSF).
1.02 ATSDR minimal risk level (MRL).
1.03 On a case-by-case basis, other sources were consulted (e.g., EPA's National Center for Environmental Assessment (NCEA) provisional values, National Ambient Air Quality Standards (NAAQS), cross-route extrapolations after consideration of critical effect/target organ).

COPC selection process. A complete list of the toxicity criteria and screening values used in the analysis of air concentrations is presented in Table A-1.

Carcinogens

$$SV = TR / IUR$$

Non-carcinogens

$$SV = THI * RfC$$

Where:

SV = screening value (mg/m^3)
TR = target cancer risk of 1×10^{-4} (Appendix C explains the rationale for this value)
IUR = inhalation unit risk (the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent per unit concentration)
THI = target hazard index of 1
RfC = reference concentration (mg/m^3) (an estimate of a continuous inhalation exposure to the human population [including sensitive subgroups] that is likely to be without an appreciable risk of deleterious effects during a lifetime)

3.0 Bulk Dust

Screening values for bulk dust were derived based on a residential soil ingestion scenario. This exposure scenario conservatively assumes that exposure to dust will be equivalent to that of incidental ingestion of substances in soil. Because children are expected to ingest more soil per body weight than adults, childhood exposure factors were included in the analysis. Screening values for carcinogens are based on combined childhood and adult exposure. Screening values for non-carcinogens are based on childhood exposure alone.

Equations and assumptions used in the derivation of bulk dust screening values follow, including sample calculations. Table A-2 presents a complete list of the toxicity criteria and screening values used in the analysis of bulk dust.

Carcinogens:

$$SV_{ca} = \left(\frac{TR \times AT \times CF}{EF \times CSFo}\right)\left(\frac{EDc \times IRc}{BWc} + \frac{EDa \times IRa}{BWa}\right)^{-1}$$

Where:

SV_{ca} = screening value for cancer effects (mg/kg)
TR = target risk of 1×10^{-4} (Appendix C explains the rationale for this value)
AT = averaging time (70 years x 365 days/year = 25,500 days)
BWc = body weight, child (15 kg)
BWa = body weight, adult (70 kg)
CF = conversion factor (10^6 mg/kg)
EF = exposure frequency (365 days/year)

EDc = exposure duration child, 6 years
EDa = exposure duration adult, 24 years
IRc = ingestion rate, child (200 mg/day)
IRa = ingestion rate, adult (100 mg/day)
CSFo = oral cancer slope factor $(\mathrm{mg/kg/day})^{-1}$

As an example, the SV_{ca} for heptachlor (CSF = 4.5 $\mathrm{mg/kg/day}^{-1}$) was derived as follows:

$$SV_{ca} = \left(\frac{10^{-4} \times 25{,}500_{days\ /\ year} \times 10^{6}}{365_{days} \times 4.5_{mg\ /\ kg\ /\ day^{-1}}} \right) \left(\frac{6_{years} \times 200_{mg\ /\ day}}{15_{kg}} + \frac{24_{years} \times 100_{mg\ /\ day}}{70_{kg}} \right)^{-1}$$

$$SV_{ca} = 14 \text{ mg/kg}$$

Non-carcinogens:

$$SV_{nc} = \frac{THI \times RfDo \times AT \times BWc \times CF}{EF \times ED \times IR}$$

Where:

SV_{nc} = screening value for non-cancer effects (mg/kg)
THI = target hazard index of 1
RfDo = oral RfD (mg/kg/day)
AT = averaging time (6 years x 365 days/year = 2,190 days)
BWc = body weight, child (15 kg)
CF = conversion factor (10^6 mg/kg)
EF = exposure frequency (365 days/year)
ED = exposure duration, child (6 years)
IR = ingestion rate (200 mg/day)

For example, the SV_{nc} for cadmium (RfD = 0.001 mg/kg/day) was derived as follows:

$$SV_{nc} = \frac{1 \times 0.001_{mg/kg/day} \times 2{,}190_{days/year} \times 15_{kg} \times 10^6}{365_{days/year} \times 6_{years} \times 200_{mg/day}}$$

SV_{nc} = 75 mg/kg

4.0 Settled Dust

Screening values for settled dust were developed based on exposures associated with ingestion and dermal contact with dust residues on indoor surfaces. Continuous age-specific exposure parameters from age 1 through 31 were factored into this approach. Dose rates were estimated based on a number of assumptions—for example, the fraction of dust residues that can be transferred to the skin, daily skin loads, mouthing behaviors for different age groups, and dissipation of surface loading over time. All of these parameters and the justification for selected values are detailed in Appendix D. Table A-3 presents the screening values derived for settled dust, including the toxicity criteria (RfDs and CSFs) used in the process.

Table A-1. Air Screening Values and Supporting Toxicity Criteria

Substance Name	**Screening Value (mg/m^3)**	**Toxicity Value**		**Toxicity Value Source**
		Cancer $(mg/m^3)^{-1}$	**Noncancer (mg/m^3)**	
SVOCs				
Benzaldehyde	0.35		0.35	IRIS oral RfD[a] (0.1 mg/kg/day)
2-Methylnaphthalene	0.07		0.07	NCEA oral RfD[a] (0.02 mg/kg/day)
4,4'-Methylene diphenyl diisocyanate (MDI)	0.0006		0.0006	IRIS RfC
Inorganics				
Aluminum	0.0035		0.0035	NCEA oral RfD[a] (0.001 mg/kg/day)
Antimony	0.0004		0.0004	NCEA RfC
Arsenic	0.00002	4.3		IRIS IUR
Asbestos	0.0004 f/cc	0.23		IRIS IUR
Barium	0.00049		0.00049	HEAST oral RfD[a] (0.00014 mg/kg/day)
Chromium	0.000008	12	0.0001	IRIS IUR[b], IRIS RfC (chromium VI)
Copper	0.14		0.14	HEAST oral RfD[a] (0.04 mg/kg/day)
Iron	1.05		1.05	NCEA oral RfD[a] (0.3 mg/kg/day)
Lead	0.0015		0.0015	NAAQS
Manganese	0.00005		0.00005	IRIS RfC
Mercury	0.0003		0.0003	IRIS RfC
Naphthalene	0.003		0.003	IRIS RfC
Nickel	0.0002		0.0002	ATSDR c-MRL
Phosphoric Acid	0.01		0.01	IRIS RfC
Vanadium	0.0002		0.0002	ATSDR a-MRL
Zinc	1.05		1.05	IRIS oral RfD[a] (0.3 mg/kg/day)
Dioxins				
2,3,7,8 TCDD TEQ	$3.5x10^{-10}$	$2.9x10^{+5}$		EPA 2000 Dioxin Reassessment CSF[c] ($1x10^6$ $mg/kg/day^{-1}$)

[a] Route-to-route extrapolation. RfD converted to RfC using the following equation:
RfC mg/m^3 = RfD mg/kg/day x 70 kg (body weight) / 20 m^3/day (inhalation rate)

[b] The screening value is based upon the IRIS IUR.

[c] Route-to-route extrapolation. CSF converted to IUR using the following equation:
IUR = CSF $mg/kg/day^{-1}$ x 20 m^3/day (inhalation rate)/ 70 kg (body weight)

Table A-2. Bulk Dust Screening Values and Supporting Toxicity Criteria

Substance Name	Screening Value (mg/kg)	Toxicity Value		Toxicity Value Source
		CSF (mg/kg/day)$^{-1}$	RfD (mg/kg/day)	
SVOCs				
Benzyl alcohol	22500		0.3	HEAST
Benzyl butyl phthalate	15000		0.2	IRIS
Biphenyl	3750		0.05	IRIS
bis(2-Chloroethyl)ether	56	1.1		IRIS
bis(2-Chloroisopropyl)ether	873	0.07	0.04	HEAST CSF[a] IRIS RfD
bis(2-Ethylhexyl)phthalate	1500	0.014	0.02	IRIS CSF IRIS RfD[a]
2-Chlorophenol	375		0.005	IRIS
Dibenzofuran	300		0.004	NCEA
Dibutyl phthalate	7500		0.1	IRIS
3,3'-Dichlorobenzidine	136	0.45		IRIS
Diethylphthalate	60000		0.8	IRIS
2,4-Dimethylphenol	1500		0.02	IRIS
2,4-Dinitrophenol	150		0.002	IRIS
4,6-Dinitro-2-methylphenol	7.5		0.0001	NCEA
2,4-Dinitrotoluene	150		0.002	IRIS
2,6-Dinitrotoluene	75		0.001	HEAST
Di-n-octylphthalate	30000		0.4	ATSDR i-MRL
Hexachlorobenzene	38	1.6	0.0008	IRIS CSF[a] IRIS RfD
Hexachloroethane	75	0.014	0.001	IRIS CSF IRIS RfD[a]
Isophorone	15000	0.00095	0.2	IRIS CSF IRIS RfD[a]
2-Methylnaphthalene	1500		0.02	NCEA
2-Methylphenol	3750		0.05	IRIS
4-Methylphenol	375		0.005	HEAST
Naphthalene	1500		0.02	IRIS
Naphthalene, 1-(methylthio)-	1500		0.02	IRIS
Naphthalene, 1,3-dimethylene	1500		0.02	IRIS
2-Nitroaniline	3750		0.05	IRIS
3-Nitroaniline	23	0.02	0.0003	NCEA CSF NCEA RfD[a]
4-Nitroaniline	225	0.02	0.003	NCEA CSF NCEA RfD[a]
Nitrobenzene	37.5		0.0005	IRIS
n-Nitroso-Di-n-propylamine	9	7		IRIS
n-Nitrosodiphenylamine	1500	0.0049	0.02	NCEA

Substance Name	Screening Value (mg/kg)	Toxicity Value		Toxicity Value Source
		CSF (mg/kg/day)$^{-1}$	RfD (mg/kg/day)	
PAHs (total)	0.3	7.3		IRIS (benzo[a]pyrene)
Pentachlorophenol	509	0.12	0.03	IRIS CSF[a] IRIS RfD
Phenol	22500		0.3	IRIS
2,4,5-Trichlorophenol	7500		0.1	IRIS
2,4,6-Trichlorophenol	5557	0.011		IRIS
Pesticides and PCBs				
Aldrin	2		0.00003	IRIS
"-BHC	10	6.3	0.008	IRIS CSF[a] IRIS RfD
$-BHC	34	1.8	0.0006	IRIS CSF[a] IRIS RfD
(-BHC	23		0.0003	ATSDR i-MRL
Carbazole	3056	0.02		HEAST
"-Chlordane	38	0.01	0.0005	IRIS CSF IRIS RfD[a] (technical chlordane)
(-Chlordane	38	0.35	0.0005	IRIS CSF IRIS RfD[a] (technical chlordane)
Chlordanes (total)	45	0.35	0.0006	IRIS CSF ATSDR c-MRL[a]
p,p'-DDD	255	0.24		IRIS
p,p'-DDE	180	0.34		IRIS
p,p'-DDT	38	0.34	0.0005	IRIS
Dieldrin	4	16	0.00005	IRIS CSF IRIS RfD[a]
Endosulfan (I)	450		0.006	IRIS
Endosulfan (II)	450		0.006	IRIS
Endosulfan Sulfate	450		0.006	IRIS
Endrin	23		0.0003	IRIS
Endrin Aldehyde	23		0.0003	IRIS
Endrin Ketone	23		0.0003	IRIS
Heptachlor	14	4.5	0.0005	IRIS CSF[a] IRIS RfD
Heptachlor Epoxide	1	9.1	0.000013	IRIS CSF IRIS RfD[a]
Methoxychlor	375		0.005	IRIS
Metribuzin	1875		0.025	IRIS
Mirex	15		0.0002	IRIS
Prometryn (caparol)	300		0.004	IRIS
Toxaphene	56	1.1		IRIS
PCBs (total)	1.5	2	0.00002	IRIS CSF IRIS RfD[a] (Aroclor 1254)

Substance Name	**Screening Value (mg/kg)**	**Toxicity Value**		**Toxicity Value Source**
		CSF (mg/kg/day)$^{-1}$	**RfD (mg/kg/day)**	
Inorganics				
Aluminum	75000		1	NCEA
Antimony	30		0.0004	IRIS
Arsenic	23	1.5	0.0003	IRIS CSF IRIS RfD[a]
Barium	5250		0.07	IRIS
Beryllium	150		0.002	IRIS
Cadmium	75		0.001	IRIS
Chromium	225		0.003	IRIS (chromium VI)
Cobalt	1500		0.02	NCEA
Copper	3000		0.04	HEAST
Fluoride	4500		0.06	ATSDR c-MRL
Iron	22500		0.3	NCEA
Lead	400			EPA Soil Screening Value
Lithium	1500		0.02	NCEA
Manganese	1500		0.02	IRIS (non-food)
Mercury	11		0.00014	IRIS (methylmercury)
Molybdenum	375		0.005	IRIS
Nickel	1500		0.02	IRIS
Nitrate	120000		1.6	IRIS
Selenium	375		0.005	IRIS
Silver	375		0.005	IRIS
Strontium	45000		0.6	IRIS
Thallium	5		0.00007	RBC
Titanium	300000		4	NCEA
Uranium	225		0.003	IRIS
Vanadium	525		0.007	HEAST
Zinc	22500		0.3	IRIS
Dioxins				
2,3,7,8 TCDD TEQ	0.00006	1000000		EPA 2000 Dioxin Reassessment

[a] Toxicity value upon which screening value is based.

Table A-3. Settled Dust Screening Values and Supporting Toxicity Criteria

Substance Name	Screening Value[a] ($\mu g/m^2$)	Toxicity Value		Toxicity Value Source
		CSF $(mg/kg/day)^{-1}$	RfD (mg/kg/day)	
Inorganics				
Aluminum	1567888		1.0	NCEA
Antimony	627		0.0004	IRIS
Arsenic	387	1.5	0.0003	IRIS CSF IRIS RfD[b]
Barium	109752		0.07	IRIS
Beryllium	3136		0.002	IRIS
Cadmium	1557		0.001	IRIS
Chromium	4704		0.003	IRIS (chromium VI)
Cobalt	31358		0.02	NCEA
Copper	62716		0.04	HEAST
Iron	940733		0.6	NCEA
Lead	270			HUD standard
Manganese	31358		0.02	IRIS (non-food)
Mercury	157		0.0001	IRIS (methylmercury)
Nickel	31358		0.02	IRIS
Selenium	7839		0.005	IRIS
Silver	7839		0.005	IRIS
Thallium	110		0.00007	RBC
Vanadium	10975		0.007	HEAST
Zinc	470366		0.3	IRIS
Other				
PAHs (total)	145	7.3		IRIS (benzo[a]pyrene)
PCBs (total)	16	2.0		IRIS
Dioxins	0.0017	1000000		EPA 2000 Dioxin Reassessment

[a] Refer to Appendix D for derivation of screening values.

[b] Toxicity value upon which screening value is based.

APPENDIX B

Results of the COPC Selection Process

This appendix presents the results of each step of the COPC selection process. As described in Section 2.0 of the main text, the approach involved a review of multiple data sets to identify candidate substances, followed by an initial and secondary screening process. Ambient air, indoor air, bulk dust, and settled dust were evaluated.

As part of the initial screen for each of these media, volatile contaminants and those detected at low frequencies were eliminated from further consideration. Remaining contaminants were screened against health-based screening values derived for air and dust (see Appendix A). Three outcomes were possible for this step. If a contaminant's maximum concentration was lower than the corresponding screening value, that contaminant was eliminated from further consideration. If a contaminant's maximum concentration was greater than the screening value, then the contaminant was evaluated further in the secondary screening step. If a contaminant did not have a toxicity value, and therefore did not have a screening value, other relevant information (e.g., trends among sampling data, comparisons to background, the likelihood of the contaminant being related to site-specific releases) were reviewed to determine whether the contaminant should be evaluated further. Where possible, occupational or environmental criteria were considered in determining whether contaminants needed further evaluation.

Any contaminant detected even once above a screening value within an individual medium was flagged as requiring further consideration. In the secondary screen, we reviewed findings across environmental media to assess representativeness of reported maximum concentrations, studied spatial and temporal trends, determined the relationship of detected concentrations to available background concentrations, and examined whether there was reason to believe a contaminant was site-related. From this, a judgment was made whether or not to select the contaminant as a COPC.

Sections 1.0 through 4.0 below detail the findings of the initial screening process for each medium. Section 5.0 presents the findings of the secondary screen; it reviews each of the contaminants identified in the initial screen as requiring further consideration and provides justification for selecting a contaminant as a COPC or eliminating it from further consideration.

1.0 Ambient Air

Ambient air sampling results were obtained from the following sources:

- *EPA Region 2's database of environmental sampling results.* The processed database contains more than 200,000 records, with more than half being asbestos sampling results. The database includes sampling conducted by multiple agencies; EPA collected most of the samples, but samples collected by the New York City Department of Environmental Protection (NYCDEP) and New Jersey Department of Environmental Protection (NJDEP) are also included. Sampling results are available for 137 contaminants.[4] The database includes samples

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[4] Tentatively identified compounds were not included in the list of contaminants. All measurements for dioxins and furans are considered as one contaminant in this tally, and were screened using a TEQ analysis. All measurements for asbestos are considered one contaminant, though measurements used different analytical methods and counted different subsets of fiber types and sizes. All measurements for PCBs are considered one contaminant, though the studies reported concentrations under several different groupings of congeners (e.g., total PCBs, Aroclors).

with various averaging times (both grab and integrated samples), sampling locations (most samples in Lower Manhattan, but some from locations outside of Manhattan), sampling dates (September 2001 through July 2002), sampling methods, and detection limits.

- *New York City Department of Health and Mental Hygiene (NYCDOHMH)/Agency for Toxic Substances and Disease Registry (ATSDR) public health investigation (2002).* This study documents sampling results from 30 residential buildings in Lower Manhattan and 4 comparison buildings north of 59th Street. Samples were collected in November and December, 2001. The study reports outdoor levels of fibers (PCM) for 32 samples collected in Lower Manhattan, including results from co-located sampling devices. None of the samples from outdoor locations was analyzed for asbestos or synthetic vitreous fibers. Additionally, the study reports concentrations of six minerals in 354 air samples from Lower Manhattan. The sampling results for minerals are applied to both the ambient air and indoor air COPC screening process, because the final study report does not specify what fraction of the 354 samples were collected indoors versus outdoors.

- *New York City Department of Education sampling in schools.* This study documents sampling results from six schools: PS-89, PS-150, PS-234, Stuyvesant High School (M-477), High School for Leadership and Public Services (M-894), and High School of Economics and Finance (M-833). Sampling occurred between September 2001 and June 2002, both indoors and outdoors. Because the database does not clearly distinguish these two types of samples, the COPC selection process considers all of the sampling results both for the indoor air and ambient air analysis. The project database includes more than 30,000 records of air sampling results. Asbestos sampling results account for more than half of these records, with the rest of the results being for more than 70 other contaminants.[1]

- *Chattfield and Kominsky's (2001) survey of indoor air quality.* This study characterizes impacts of WTC dusts in two buildings in Lower Manhattan. The study focuses on the indoor environment, but two outdoor air samples were collected and analyzed for asbestos.

COPC Selection Process for Ambient Air

Step 1: Do not consider volatile contaminants

Volatile contaminants were eliminated from the COPC selection process. Any contaminant on the target analyte list for Method TO-15 (ambient air) and Method 8260 (waste) was considered volatile. Further, chemical similarity to compounds on those lists and boiling point (as a surrogate for vapor pressure) were used to identify additional volatile contaminants not on these methods' target lists.

- 83 contaminants removed from list (see Table B-1)
- 73 contaminants remained for further consideration

Step 2: Do not consider contaminants detected in fewer than 5% of samples, only if more than 20 samples were collected

- 43 contaminants removed from list (see Table B-2)
- 30 contaminants remained for further consideration

Step 3: Compare maximum detected concentrations against health-based screening values

Using the health-based screening values described in Appendix A:

- 8 contaminants removed from list (maximum concentration < screening value, see Table B-3)
- 10 contaminant do not have health-based screening values (see Table B-4)
- 12 contaminants remained for further consideration (listed below)

Contaminants requiring further consideration (see Section 5.0):

1) Aluminum
2) Arsenic
3) Asbestos
4) Barium
5) Chromium
6) Dioxins
7) Lead
8) Manganese
9) Mercury
10) 4,4'-Methylene diphenyl diisocyanate (MDI)
11) Naphthalene
12) Nickel

Table B-1. Volatile Contaminants Removed from COPC Selection Process

1,1,1-Trichloroethane	Carbon disulfide	Methyl isobutyl ketone
1,1,2,2-Tetrachloroethane	Carbon tetrachloride	Methyl tert-butyl ether
1,1,2-Trichloroethane	Chlorobenzene	Methylcyclopentane
1,1-Dichloroethane	Chlorodifluoromethane	Methylene chloride
1,1-Dichloroethylene	Chloroethane	n-Butane
1,2,4-Trimethylbenzene	Chloroform	n-Heptane
1,2-Dibromoethane	Chloromethane	n-Hexane
1,2-Dichlorobenzene	cis-1,2-Dichloroethylene	Nitric acid
1,2-Dichloroethane	cis-1,3-Dichloropropylene	Nitric oxide
1,2-Dichloropropane	Cyclohexane	Nitrogen dioxide
1,3,5-Trimethylbenzene	Dibromochloromethane	n-Pentane
1,3-Butadiene	Dibromomethane	o-Xylene
1,3-Dichlorobenzene	Dichlorodifluoromethane	Ozone
1,3-Dichloropropane	Dichlorotetrafluoroethane	Propane
1,4-Dichlorobenzene	Ethanol	Propylene
1,4-Dioxane	Ethyl acetate	Styrene
1-Heptene	Ethylbenzene	Sulfur dioxide
2-Butanone	Formaldehyde	Tetrachloroethylene
2-Hexanone	Hexachlorobutadiene	Tetrahydrofuran
3-Chloropropylene	Hydrogen bromide	Toluene
4-Ethyltoluene	Hydrogen chloride	trans-1,2-Dichloroethylene
Acetone	Hydrogen cyanide	trans-1,3-Dichloropropylene
Acrylonitrile	Hydrogen fluoride	Trichloroethylene

a-Methylstyrene	i-Propylbenzene	Trichlorofluoromethane
Benzene	Isopentane	Trichlorotrifluoroethane
Bromodichloromethane	Isopropyl alcohol	Vinyl acetate
Bromoform	m,p-Xylene	Vinyl chloride
Bromomethane		Xylene (total)

Table B-2. Contaminants Removed from the COPC Selection Process Due to Frequency of Detection

Contaminant	Samples	Frequency of Detection	Contaminant	Samples	Frequency of Detection
1,2,4-Trichlorobenzene	1010	1.8%	Dibenzo(a,h)anthracene	573	0.0%
1-Methylnaphthalene	573	2.1%	Dibenzofuran	528	0.0%
2,4-TDI	48	0.0%	Fluoranthene	573	0.0%
2,6-Dimethylnaphthalene	528	0.0%	Fluorene	573	0.0%
2,6-TDI	48	0.0%	Halite	354	3.4%
Acenaphthene	573	0.0%	HDI	48	0.0%
Acenaphthylene	573	0.0%	Indeno(1,2,3-cd)pyrene	573	0.0%
Anthracene	570	0.0%	IPDI	48	0.0%
Benzo(a)anthracene	573	0.0%	Isopropylbenzene	430	0.0%
Benzo(a)pyrene	573	0.0%	HMDI	48	0.0%
Benzo(b)fluoranthene	576	0.0%	Mica	354	2.0%
Benzo(e)pyrene	528	0.0%	Molybdenum	471	0.0%
Benzo(g,h,i)perylene	572	0.0%	Phenanthrene	573	0.2%
Benzo(k)fluoranthene	570	0.0%	Potassium	738	3.1%
Benzyl Chloride	1010	1.4%	Pyrene	573	0.2%
Beryllium	738	0.1%	Selenium	737	1.2%
Biphenyl	528	0.0%	Silica Dust	798	4.3%
Cadmium	1216	1.1%	Silver	738	2.2%
Carbazole	528	0.0%	Thallium	738	2.6%
Chrysene	573	0.0%	Tridymite	597	0.0%
Cobalt	1209	4.4%	Total PCBs	633	4.9%
Cristobalite	597	0.0%			

Notes:

TDI	toluene diisocyanate
HDI	hexamethylene diisocyanate
HMDI	methylene bis-(4-cyclohexylisocyanate)
IPDI	isophorone diisocyanate

In addition to total PCB data, multiple Aroclors were not detected in any samples collected in six Lower Manhattan schools.

Table B-3. Contaminants with Measured Levels Lower than Health-Based Screening Values

Contaminant	Maximum Concentration (mg/m^3)	Health-based Screening Value (mg/m^3)	Basis for Screening Value
2-Methylnaphthalene	0.009	0.07	Extrapolation from oral RfD
Antimony	0.00033	0.0004	NCEA provisional RfC
Benzaldehyde	0.032	0.35	Extrapolation from oral RfD
Copper	0.063	0.14	Extrapolation from oral RfD
Iron	0.064	1.05	Extrapolation from oral RfD

Phosphoric acid	ND	0.01	IRIS RfC
Vanadium	0.0001	0.0002	ATSDR acute MRL
Zinc	0.0081	1.05	Extrapolation from oral RfD

Table B-4. Contaminants with No Health-Based Screening Values

Bromobenzene	Magnesium
Calcite	Portlandite
Calcium	Quartz
Fibers (PCM)	Sodium
Gypsum	Sulfuric Acid

2.0 Indoor Air

Indoor air sampling results were obtained from the following sources:

- *EPA Region 2's database of environmental sampling results.* The processed database contains 73 records of indoor air sampling results, all for asbestos. EPA collected these samples from three buildings in Lower Manhattan in September and October, 2001. Of the 73 records, 20 document PCM analyses and 53 document TEM analyses.

- *NYCDOHMH/ATSDR (2002) public health investigation.* This study documents sampling results from 30 residential buildings in Lower Manhattan and 4 comparison buildings north of 59th Street. Samples were collected in November and December, 2001. The study reports indoor levels of fibers (PCM) for 96 samples collected in Lower Manhattan, including results from co-located sampling devices. A small subset of these samples was analyzed further for asbestos and synthetic vitreous fibers. Additionally, the study reports concentrations of six minerals in 354 air samples from Lower Manhattan. The sampling results for minerals are applied to both the ambient air and indoor air COPC screening process, because the final study report does not specify what fraction of the 354 samples were collected indoors versus outdoors.

- *New York City Department of Education sampling in schools.* This study documents sampling results from six schools: PS-89, PS-150, PS-234, Stuyvesant High School (M-477), High School for Leadership and Public Services (M-894), and High School of Economics and Finance (M-833). Indoor and outdoor sampling occurred between September 2001 and June 2002. However, because the database does not clearly distinguish these two types of samples, the COPC selection process considers all sampling results both for the indoor air and ambient air analysis. The project database includes more than 30,000 records of air sampling results. Asbestos sampling results account for more than half of these records, with the rest of the results being for more than 70 other contaminants.[1]

- *Chattfield and Kominsky's (2001) survey of indoor air quality.* This study characterizes impacts of WTC dusts in two buildings in Lower Manhattan. The study includes 11 indoor air samples that were collected and analyzed for asbestos.

COPC Selection for Indoor Air

Step 1: Do not consider volatile contaminants

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[1] Tentatively identified compounds were not included in the list of contaminants. All measurements for asbestos are considered one contaminant, though measurements used different analytical methods and counted different subsets of fiber types and sizes. All measurements for PCBs are considered one contaminant, though the schools study reported concentrations for multiple Aroclors.

Volatile contaminants were eliminated from the COPC selection process. Any contaminant on the target analyte list for Method TO-15 (ambient air) and Method 8260 (waste) was considered volatile. Further, chemical similarity to compounds on those lists and boiling point (as a surrogate for vapor pressure) were used to identify additional volatile contaminants not on these methods' target lists.

- 35 contaminants removed from list (see Table B-5)
- 44 contaminants remained for further consideration

Step 2: Do not consider contaminants detected in fewer than 5% of samples, only if more than 20 samples were collected

- 27 contaminants removed from list (see Table B-6)
- 17 contaminants remained for further consideration

Step 3: Compare maximum detected concentrations against health-based screening values

Using the health-based screening values described in Appendix A:

- 6 contaminants removed from list (maximum concentration < screening value, see Table B-7)
- 7 contaminant do not have health-based screening values (see Table B-8)
- 4 contaminants remained for further consideration (listed below)

Contaminants requiring further consideration:

1) Aluminun
2) Asbestos
3) Chromium
4) Mercury

Table B-5. Volatile Contaminants Removed from COPC Selection Process

1,1,1-Trichloroethane	Hydrogen cyanide
1,1,2,2-Tetrachloroethane	m,p-Xylene
1,1-Dichloroethylene	Methylene chloride
1,2-Dibromoethane	n-Heptane
1,2-Dichloroethane	n-Hexane
1,2-Dichloropropane	Nitric oxide
1,3-Dichloropropane	Nitrogen dioxide
1-Heptene	n-Pentane
3-Chloropropylene	o-Xylene
Acetone	Ozone
Acrylonitrile	Styrene
Benzene	Sulfur dioxide
Bromoform	Tetrachloroethylene
Carbon tetrachloride	Toluene
Chlorobenzene	Trichloroethylene
Chloroform	Vinyl chloride
Ethylbenzene	Xylene (total)
Formaldehyde	

Table B-6. Contaminants Removed from the COPC Selection Process Due to Frequency of Detection

Contaminant	Samples	Frequency of Detection	Contaminant	Samples	Frequency of Detection
Acenaphthene	45	0.0%	Halite	354	3.4%
Acenaphthylene	45	0.0%	Indeno(1,2,3-cd)pyrene	45	0.0%
Anthracene	42	0.0%	Isopropylbenzene	430	0.0%
Benzo(a)anthracene	45	0.0%	Magnesium	471	4.2%
Benzo(a)pyrene	45	0.0%	Manganese	471	0.0%
Benzo(b)fluoranthene	48	0.0%	Mica	354	2.0%
Benzo(g,h,i)perylene	45	0.0%	Molybdenum	471	0.0%
Benzo(k)fluoranthene	42	0.0%	Nickel	471	0.6%
Cadmium	478	0.0%	PCBs	32	0.0%
Chrysene	45	0.0%	Phenanthrene	45	2.2%
Cobalt	471	0.0%	Pyrene	45	2.2%
Dibenzo(a,h)anthracene	45	0.0%	Silica Dust	798	4.3%
Fluoranthene	45	0.0%	Zinc	471	0.6%
Fluorene	45	0.0%			

Table B-7. Contaminants with Measured Levels Lower than Health-Based Screening Values

Contaminant	Maximum Concentration (mg/m^3)	Health-based Screening Value (mg/m^3)	Source of Screening Value
2-Methylnaphthalene	0.00092	0.07	Extrapolation from oral RfD

Contaminant	Maximum Concentration (mg/m^3)	Health-based Screening Value (mg/m^3)	Source of Screening Value
Copper	0.00389	0.14	Extrapolation from oral RfD
Iron	0.00577	1.05	Extrapolation from oral RfD
Lead	0.00136	0.0015	NAAQS
Naphthalene	0.00099	0.003	RfC
SVF	0.00025 f/cc	0.03 f/cc	Proposed ATSDR MRL

Table B-8. Contaminants with No Health-Based Screening Values

1-Methylnaphthalene	Gypsum
Bromobenzene	Portlandite
Calcite	Quartz
Fibers	

3.0 Bulk Dust

Bulk dust sampling results were obtained from the following sources:

- *EPA Region 2's database of environmental sampling results.* The processed database contains 1,936 records of bulk dust sampling; 1,930 of the records were from EPA sampling, and 6 were from NYCDEP sampling. Most samples were collected in September and October, 2001; the database also includes results from multiple samples collected in May, 2002. The majority of sampling occurred in Lower Manhattan, but some results are also available for Brooklyn and the Fresh Kills Landfill. The database includes dust samples from indoor and outdoor locations. Samples were analyzed for asbestos, metals, pesticides, PAHs, and other semi-volatile organic compounds.

- *NYCDOHMH/ATSDR (2002) public health investigation.* This study documents sampling results from 30 residential buildings in Lower Manhattan and 4 comparison buildings north of 59th Street. Samples were collected in November and December, 2001. This data summary considered only the dust samples (both indoor and outdoor) collected in Lower Manhattan, and not those from the comparison population. Data are available for asbestos, synthetic vitreous fibers, and six minerals.

- *New York City Department of Education sampling in schools.* This study documents sampling results from six schools: PS-89, PS-150, PS-234, Stuyvesant High School (M-477), High School for Leadership and Public Services (M-894), and High School of Economics and Finance (M-833). Sampling occurred between September 2001 and June 2002. The project database includes nearly 3,000 records of sampling results for bulk settled dust; these samples were collected at various indoor and outdoor locations. The only contaminants analyzed for in the samples were asbestos and fiberglass. All samples were analyzed using polarized light microscopy (PLM).

- *Chattfield and Kominsky's (2001) survey of indoor air quality.* This study characterized impacts of WTC dusts in two buildings in Lower Manhattan. During the study, an indoor dust sample and two outdoor dust samples (rooftop and exterior window ledge) were analyzed for dioxins, PCBs, and metals. Additionally, four exterior dust samples were analyzed for asbestos. All sampling occurred in September, 2001.

- *Lioy et al. (2002) study*. This study documents results from three outdoor bulk dust samples collected in Lower Manhattan on September 16 and 17, 2001. The samples were analyzed for a wide range of compounds, including metals, PCBs, dioxins, pesticides, asbestos, and semi-volatile organic compounds.

- *OSHA's data set*. Results from 11 bulk dust samples collected on June 5, 2002, in a Lower Manhattan building were reviewed. All samples were apparently collected indoors and analyzed for 13 metals.

COPC Selection for Bulk Dust

Step 1: Do not consider volatile contaminants

Volatile contaminants were eliminated from the COPC selection process. Any contaminant on the target analyte list for Method TO-15 (ambient air) and Method 8260 (waste) was considered volatile. Further, chemical similarity to compounds on those lists and boiling point (as a surrogate for vapor pressure) were used to identify additional volatile contaminants not on these methods' target lists.

- 12 contaminants removed from list (see Table B-9)
- 176 contaminants remained for further consideration

Step 2: Do not consider contaminants detected in fewer than 5% of samples, only if more than 20 samples were collected

- 1 contaminant (fiberglass) removed from list
- 175 contaminants remained for further consideration

Step 3: Compare maximum detected concentrations against health-based screening values

Using the health-based screening values for bulk dust described in Appendix A (based on a soil ingestion scenario):

- 84 contaminants removed from list (maximum concentration < screening value, see Table B-10)
- 83 contaminant do not have health-based screening values (see Table B-11)
- 8 contaminants remained for further consideration (listed below)

Contaminants requiring further consideration:

1) Antimony
2) Asbestos
3) Chromium
4) Dioxins
5) Lead
6) Manganese
7) PAHs
8) Thallium

Table B-9. Volatile Contaminants Removed from COPC Selection Process

1,2,4-Trichlorobenzene	2,4-Dimethylheptane
1,2-Dichlorobenzene	2,4-Dimethylhexane
1,3-Dichlorobenzene	3,3-Dimethylhexane
1,4-Dichlorobenzene	Hexachlorobutadiene
2,3,4-Trimethylhexane	Hexachlorocyclopentadiene
2,3-Dimethyl-1-pentanol	n-Octane

Table B-10. Contaminants with Measured Levels Lower than Health-Based Screening Values

Contaminant	Maximum (mg/kg)	Screening Value (mg/kg)	Contaminant	Maximum (mg/kg)	Screening Value (mg/kg)
2,4,5-Trichlorophenol	ND	7500 NC	Endrin	ND	22.5 NC
2,4,6-Trichlorophenol	ND	5557 C	Endrin Aldehyde	ND	22.5 NC
2,4-Dimethylphenol	ND	1500 NC	Endrin Ketone	ND	22.5 NC
2,4-Dinitrophenol	ND	150 NC	Fluoride	0.22	4500 NC
2,4-Dinitrotoluene	ND	150 NC	g-BHC	ND	22.5 NC
2,6-Dinitrotoluene	ND	75 NC	g-Chlordane	0.0081	37.5 NC
2-Chlorophenol	ND	375 NC	Heptachlor	ND	13.6 C
2-Methylnaphthalene	5.1	1500 NC	Heptachlor Epoxide	ND	0.975 NC
2-Methylphenol	0.57	3750 NC	Hexachlorobenzene	0.0019	38 C
2-Nitroaniline	ND	3750 NC	Hexachloroethane	ND	75 NC
3,3'-Dichlorobenzidine	10	136 C	Iron	21000	22500 NC
3-Nitroaniline	ND	22.5 NC	Isophorone	ND	15000 NC
4,6-Dinitro-2-methylphenol	ND	7.5 NC	Lithium	29.52	1500 NC
4-Methylphenol	0.93	375 NC	Mercury	0.38	10.5 NC
4-Nitroaniline	ND	225 NC	Methoxychlor	ND	375 NC
a-BHC	ND	10 C	Metribuzin	22.1	1875 NC
a-Chlordane	ND	38 NC	Mirex	0.0008	15 NC
Aldrin	ND	2 NC	Molybdenum	ND	375 NC
Aluminum	31000	75000 NC	Naphthalene	13	1500 NC
Arsenic	11	23 NC	Naphthalene, 1-(methylthio)-	7.5	1500 NC
Barium	500	5250 NC	Naphthalene, 1,3-dimethylene	5.3	1500 NC
b-BHC	ND	34 C	Nickel	47.29	1500 NC
BDE	3.3	150 NC	Nitrate	0.33	120000 NC
Benzyl alchohol	0.62	22500 NC	Nitrobenzene	ND	37.5 NC
Benzyl butyl phthalate	94.1	15000 NC	N-Nitroso-Di-n-propylamine	ND	8.7 C
Beryllium	3.754	150 NC	N-Nitrosodiphenylamine	ND	1500 NC
Biphenyl	6.5	3750 NC	p,p'-D D D	ND	255 C
bis(2-Chloroethyl)Ether	ND	56 C	p,p'-D D E	0.003	180 C
bis(2-Chloroisopropyl)ether	ND	873 C	p,p'-D D T	0.046	37.5 NC
bis(2-Ethylhexyl)phthalate	21	1500 NC	PCBs (Aroclor 1260)	1.6	30.6 C
Cadmium	8.454	75 NC	Pentachlorophenol	ND	509 C
Carbazole	35	3056 C	Phenol	5.6	22500 NC
Cobalt	14	1500 NC	Prometryn (caparol)	10.7	300 NC
Copper	1327	3000 NC	Selenium	ND	375 NC
Dibenzofuran	18	300 NC	Silver	54	375 NC
Dibutyl phthalate	19.7	7500 NC	Strontium	720.8	45000 NC
Dieldrin	0.0028	3.75 NC	Titanium	1797	300000 NC
Diethylphthalate	31.7	60000 NC	Total chlordanes	0.0056	45 NC
Di-n-octylphthalate	4.4	30000 NC	Toxaphene	ND	56 C
Endosulfan (I)	ND	450 NC	Uranium	4.213	225 NC

Contaminant	Maximum (mg/kg)	Screening Value (mg/kg)	Contaminant	Maximum (mg/kg)	Screening Value (mg/kg)
Endosulfan (II)	ND	450 NC	Vanadium	42.61	525 NC
Endosulfan Sulfate	ND	450 NC	Zinc	3000	22500 NC

Notes:

NC	Screening value based on non-cancer endpoint (HQ=1; child exposure)
C	Screening value based on cancer endpoint (10-4 risk)
BDE	Total bromodiphenyl ethers (BDE47, 99, 100, 153, 154, 209)

Table B-11. Contaminants with No Health-Based Screening Values

Lioy et al. Database	
(E)-2-(6-Nonexnoxy)-tetrahydropyran	Bismuth
1,2,3-Triphenyl-3-vinyl-cyclopropene	Cellulose (%)
12-Acetoxydaphnetoxin	Cesium
1-Azabicyclo[2.2.2]octan-3-one	Chloride
1-Dodecanol, 2-methyl-, (S)-	Chrysotile asbestos (%)
1H-1,2,4-Triazole, 1-ethyl	2-Hexyl-1-decanol
1-Hexadecanol, 2-methyl	3,4-Dihydrocyclopenta(cd)pyrene (acepyrene)
1-Hexyl-2-nitrocyclohexane	Cycloate
1H-Indene, 1-(phenylmethylene)-	Cyclohexanemethanol
1H-Pyrrole-3-propanoic acid, 2,5-dihydro-4-methyl-2,5-dioxo	Dibenzothiophene
1-Hydroxypyrene	Dicyclohexyl phthalate
1-Methylanthracene	Didodecyl phthalate
1-Methylphenanthrene	Dihydrogeraniol
1-Pentacontanol	Diisobutyl phthalate
2-(3'-Hydroxyphenylamino)-5-methyl-4-oxo-3,4-dihydrophyrimidine	Dimethylcyanamide
2,3-Dihydrofluoranthene	Droserone (2,8-dihydroxy-3-methyl-1,4-naphthoquinone)
2,4-DDT	Ether, hexyl pentyl
2-Benzylquinoline	Gallium
3-Methoxycarbonyl-2-methyl-5-(2,3,5-tri-O-acetyl-beta-d-ribofuranosyl)	Hexyl N-butyrate
4,4'-Biphenyldicarbonitrile	Methyl alpha-ketopalmitate
4-Hydroxymandelic acid-TRITMS	Monobutyl phthalate
4-Methyl-2-propyl-1-pentanol	Nefopam
4-Methylphenanthrene	Pentanoic acid, 4,4-dimethyl-3-methylene-, ethyl ester
7-Methyl-3,4,5(2H)-tetrahydroazepine	Phthalate
9,10-Anthraquinone	Phthalic acid, 2-hexyl ester
9H-Fluorene, 9-(phenylmethylene)	Rubidium
Auraptenol	Sulfate
Benzamide, N-acetyl-	Vernolate (vernam)
Benzene, 1,1'-(1,3-butadiyne-1,4-diyl)bis-	Xanthene
Benzimidazo [2,1-a] isoquinoline	
EPA Region 2 Database	
1-Methylnaphthalene	4-Nitrophenol
2,4-Dichlorophenol	bis(2-Chloroethoxy)methane
2,6-Dimethylnaphthalene	d-BHC
2-Chloronaphthalene	Dimethylphthalate
2-Nitrophenol	Calcium
4-Bromophenyl ether	Magnesium

4-Chloro-3-Methylphenol	Potassium
4-Chloroaniline	Sodium
4-Chlorophenyl-phenylether	
ATSDR-NYCDOH Database	
Calcite	Portlandite
Gypsum	Quartz
Halite	SVF (PLM)
Mica	

4.0 Settled Dust

Settled dust sampling results were obtained from the following sources:

- *EPA Region 2's database of environmental sampling results*. The processed database contains more than 500 records of settled dust sampling results. EPA collected wipe samples from three schools (Manhattan Community College, Stuyvesant High School, and PS234) in September 2001. The samples were analyzed for loadings of metals, PCBs, and dioxins.

- *EPA's wipe sampling data*. Preliminary results from EPA's ongoing wipe sampling study of Lower Manhattan residences were reviewed. Only those records labeled as "special pre monitoring" (excluding field blanks) were considered. Overall, 187 samples were analyzed for metals, and 191 samples were analyzed for dioxins. Samples were collected from various indoor locations (e.g., counter tops, floors, walls, window sills).

- *New York City Department of Education sampling in schools*. This study documents sampling results from six schools: PS-89, PS-150, PS-234, Stuyvesant High School (M-477), High School for Leadership and Public Services (M-894), and High School of Economics and Finance (M-833). Settled dust sampling occurred between October 2001 and December 2002. The project database includes more than 6,000 records of sampling results for settled dust; these samples were collected at various indoor and outdoor locations. Samples were analyzed for PAHs, PCBs, dioxins, and metals.

- *Chattfield and Kominsky's survey of indoor air quality*. This study characterized impacts of WTC dusts in two buildings in Lower Manhattan. During the study, six wipe dust samples were analyzed for dioxins, PCBs, and metals. All sampling occurred in September 2001.

- *PCB study by Butt et al. (2002)*. In October 2001, wipe samples were collected to characterize PCB contamination in organic films on building surface, mostly windows. Overall, 9 samples were collected and analyzed for total PCB concentrations.

COPC Selection for Settled Dust

Step 1: Do not consider volatile contaminants

Volatile contaminants were eliminated from the COPC selection process. Any contaminant on the target analyte list for Method TO-15 (ambient air) and Method 8260 (waste) was considered volatile. Further, chemical similarity to compounds on those lists and boiling point (as a surrogate for vapor pressure) were used to identify additional volatile contaminants not on these methods' target lists.

- No contaminants removed from list

- 44 contaminants remained for further consideration

Step 2: Do not consider contaminants detected in fewer than 5% of samples, only if more than 20 samples were collected

- 25 contaminants removed from list (see Table B-12)
- 19 contaminants remained for further consideration

Step 3: Compare maximum detected concentrations against health-based screening values

Using the health-based screening values for settled dust described in Appendix A (based on ingestion/dermal contact scenario):

- 11 contaminants removed from list (maximum concentration < screening value, see Table B-13)
- 5 contaminant do not have health-based screening values (see Table B-14)
- 3 contaminants remained for further consideration (listed below)

Contaminants requiring further consideration:

1) Dioxins
2) Lead
3) Mercury

Table B-12. Contaminants Removed from the COPC Selection Process Due to Frequency of Detection

Contaminant	Samples	Frequency of Detection	Contaminant	Samples	Frequency of Detection
Acenapthene	35	0%	Dibenzo(a)anthracene	35	0%
Acenaphthylene	35	0%	Fluoranthene	35	0%
Anthracene	35	0%	Fluorene	35	0%
Arsenic	215	4.7%	Indeno(1,2,3-cd)pyrene	35	0%
Benzo(a)anthracene	35	0%	Molybdenum	38	0%
Benzo(a)pyrene	35	0%	Naphthalene	35	0%
Benzo(b)fluoranthene	35	0%	PCBs	371	2.7%
Benzo(g,h,I)perylene	35	0%	Phenanthrene	35	0%
Benzo(k)fluoranthene	35	0%	Pyrene	35	0%
Beryllium	215	0%	Silver	215	1.4%
Chrysene	35	0%	Thallium	215	0.5%
Cobalt	250	2.8%	Vanadium	215	3.7%
Decaclhorobiphenyl	1	0%			

Notes:

The number of samples for "PCBs" is the total number of samples that were analyzed for any grouping of PCB congeners, including Aroclors or total PCBs. It should be noted that the highest total PCB concentration reported for a surface measurement (1.398 : g/m^2) is lower than the corresponding health-based screening value (15.6 : g/m^2).

Table B-13. Contaminants with Measured Levels Lower than Health-Based Screening Values

Contaminant	Maximum (: g/m^2)	Screening Value (: g/m^2)	Contaminant	Maximum (: g/m^2)	Screening Value (: g/m^2)
Aluminum	102,000	1,570,000	Iron	212,000	941,000
Antimony	377	627	Manganese	3,910	31,400
Barium	3,100	110,000	Nickel	1,160	31,400
Cadmium	429	1,560	Selenium	590	7,840
Chromium	1,900	4,700	Zinc	72,000	470,000
Copper	7,150	62,700			

Table B-14. Contaminants with No Health-Based Screening Values

Asbestos (inhalation value only)	Potassium
Calcium	Sodium
Magnesium	

5.0 Analysis of Contaminants Requiring Further Consideration

Two classes of contaminants required further evaluation after the initial screening described above: (1) contaminants with maximum concentrations greater than screening values and (2) contaminants for which no screening values are available. Sections 5.1 and 5.2 describe the results of this secondary analysis, providing justification for all contaminant-specific decisions.

5.1 Contaminants Found to Exceed Toxicity Criteria

From the initial screening results presented above, fifteen contaminants were detected in at least one sample from at least one medium at concentrations greater than corresponding health-based screening values. This section presents the findings of the secondary screen conducted to determine whether these contaminants would be selected or eliminated as a COPC. The decision process involved assessing the representativeness of reported maximum concentrations, studying spatial and temporal trends, determining the relationship of detected concentrations to available background concentrations, and examining whether there was reason to believe a contaminant was site-related.

From this evaluation, the following contaminants were selected as COPC:

- Asbestos
- Dioxins
- Lead
- PAHs

This evaluation eliminated the following contaminants from further consideration:

- Aluminum
- Antimony
- Arsenic
- Barium
- Manganese
- Naphthalene
- Nickel
- MDI
- Thallium

Two of the metals (chromium and mercury) did not fully meet all the criteria for selection as a COPC and were not designated as such, but some evidence exists that they may be present in indoor environments. Chromium and mercury are therefore highlighted separately below. EPA will continue to sample for these and other non-COPC metals as part of the WTC Clean-up Program.

Contaminants selected as COPC:

1) **Asbestos:** Ambient air sampling conducted by multiple parties has found asbestos concentrations greater than the air screening value (0.0004 fibers/cubic centimeter) based on cancer risk. Additionally, asbestos fibers have been found in indoor and outdoor dust samples collected at various Lower Manhattan locations. Based on these and other trends among the sampling data, our knowledge of the construction materials in the WTC buildings, and ongoing health concerns regarding potential exposure to asbestos, asbestos is being selected as a COPC.

2) **Dioxins:** As the peer review draft COPC document notes, ambient air concentrations of dioxin in samples collected in September and October, 2001, exceeded EPA's screening criteria for dioxin, regardless of whether toxicity screening was based on the current cancer slope factor or on EPA's proposed updated cancer slope factor. Since 2001, EPA has collected and analyzed nearly 200 settled dust samples from Lower Manhattan residences, and dioxin levels in this medium also were found to exceed health-based screening values.[1] Given these observations, and the knowledge that high-temperature combustion sources (like that which occurred at Ground Zero on and following September 11, 2001) release dioxins to the air, dioxins are being considered as a COPC.

3) **Lead:** EPA's ambient air monitoring database includes five samples with lead concentrations greater than the National Ambient Air Quality Standard for lead (0.0015 mg/m^3). This standard is based on a quarterly average air concentration, and quarterly average lead levels near the WTC site have not exceeded this standard. Lead was more commonly found at concentrations greater than 0.0001 mg/m^3, which has been reported as the upper bound of average air concentrations of lead in urban environments. These sampling results, taken alone, do not present extraordinarily high concentrations. However, when considering the lead levels reported in WTC dusts and the mass of material released from the collapse of the towers, potentially significant amounts of lead might have deposited in Lower Manhattan. As evidence of this, EPA's ongoing study of Lower Manhattan residences has found that lead levels in more than 90% of the indoor wipe samples collected to date have exceeded the reported background loading (1.78 μg/ft^2, the 95% UCL based on residential data). Therefore, lead is considered a COPC.

4) **PAHs:** Limited ambient air sampling was conducted for PAHs between September and December, 2001, when fires continued to burn at Ground Zero. However, bulk dust samples collected by EPA and an independent researcher contained PAHs at levels greater than health-based screening values. Based on this observation and the knowledge that combustion processes release soot particles containing PAHs into the air, PAHs are being considered a COPC.

Contaminants eliminated from further consideration:

1) **Aluminum:** Aluminum levels have been measured in more than 200 settled dust samples, 18 bulk dust samples, and more than 1,000 air indoor or ambient air samples. None of the bulk dust samples or settled dust samples collected to date have contained aluminum levels greater than health-based screening values. Fewer than 5% of the air samples had concentrations greater than NCEA's provisional reference concentration (0.0035 mg/m^3). However, no clear spatial or temporal trends are apparent among these samples. The ranges of aluminum concentrations documented in these studies are generally consistent with those that have been reported for other urban areas in the United States (ATSDR 1999a). Based on this review of the data, there is no evidence that aluminum concentrations are unusually high or consistently greater than health-based screening values. As a result, aluminum is not being considered a COPC. However, as part of ongoing cleanup efforts, EPA continues to analyze indoor dust samples for aluminum to evaluate surface loadings.

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[1] The frequency with which dioxin levels in settled dust exceeds health-based screening values depends on how one interprets non-detect observations. Whether one assigns non-detects a value of zero or one-half the detection limit, however, at least one measurement of surface loading exceeds a health-based screening value.

2) **Antimony:** Levels of antimony were measured in more than 200 settled dust samples, 25 bulk dust samples, and nearly 750 air samples. None of the air concentrations or settled dust loadings measured exceeded health-based screening values. Of the 25 bulk dust samples reviewed, only one sample contained antimony (42.1 mg/kg) at levels greater than the health-based screening value (30 mg/kg). That sample was collected from a rooftop in Lower Manhattan. Antimony is not being selected a COPC because the overwhelming majority of sampling results (>99%) are below health-based screening values. To be protective, EPA continues to analyze indoor dust samples for antimony to evaluate surface loadings.

3) **Arsenic:** Arsenic levels have been measured in 17 bulk dust samples and in 215 settled dust samples, but never detected at concentrations or loadings greater than corresponding health-based screening values. On the other hand, since September 11, 2001, 738 air samples collected in and near Lower Manhattan were analyzed for arsenic, and arsenic was detected in 64 (9%) of the samples. The measured concentrations ranged from 0.000007 mg/m^3 to 0.000343 mg/m^3. Thirty-two samples contained arsenic above the screening value (10^{-4} cancer risk) for arsenic (0.00002 mg/m^3). A clear majority of the highest concentrations were observed in samples collected in April and May, 2002, suggesting that sources other than WTC dust likely account for a considerable portion of the ambient levels. This is supported by the observation that the measured ambient air concentrations fall within the range of arsenic levels reported as being observed in urban settings (ATSDR 2000a). Local background data are a little more difficult to interpret. Annual average arsenic levels in Midtown Manhattan between 1992 and 1998 ranged from 0.0000017 mg/m^3 to 0.0000031 mg/m^3 (NYSDEC 2000). However, a direct comparison cannot be made between NYSDEC's Midtown sampling and EPA's Lower Manhattan sampling due to the differences in detection limits and the high frequency of non-detects. Overall, the observations suggest that arsenic in the WTC dusts is not at levels greater than health-based screening values and that airborne arsenic in Lower Manhattan is not unusually high when compared to the arsenic levels routinely observed in urban settings. Consequently, arsenic is not being considered a COPC, but EPA will continue to measure arsenic levels in indoor dust samples to ensure that ongoing exposures to arsenic from WTC dusts, if any, are not at levels of health concern.

4) **Barium:** Since September 11, 2001, barium levels have been measured in 738 ambient air samples, 17 bulk dust samples, and 215 settled dust samples. Of all these measurements, only two air samples had barium concentrations greater than an ambient air screening value (0.00049 mg/m^3) derived from a "HEAST alternate RfDi" reported in EPA Region 3's Risk-Based Concentration Table. Furthermore, EPA's ongoing indoor wipe sampling has found no barium levels greater than corresponding health-based screening values. These observations provide little evidence of barium consistently being greater than screening values, and barium is not being considered a COPC.

5) **Manganese:** Concentrations of manganese have been measured in more than 1,200 air samples, in 28 bulk dust samples, and in 218 settled dust samples. According to EPA's database of air sampling results, manganese levels in 236 air samples collected to date were greater than the RfC (0.00005 mg/m^3). However, the 95% UCL of the mean concentration is lower than the RfC. In bulk dust, the health-based screening value (1,500 mg/kg) was only slightly exceeded (1,600 mg/kg) in a single sample. EPA's ongoing indoor dust sampling events provide further insights into the significance of manganese levels for the indoor environment: to date, all 218 manganese concentrations measured in dusts from Lower Manhattan residences have been lower than corresponding health-based screening values. Based on these trends among the air and dust sampling data, manganese is not being selected a COPC. Nonetheless,

EPA will continue to analyze indoor dust samples for manganese to ensure that surface loadings are not at levels of health concern.

6) **4,4'-Methylene diphenyl diisocyanate (MDI):** The only sampling data available for MDI are 48 ambient air samples collected between December 2001 and February 2002. MDI was detected in three of these samples, all of which were collected on December 19, 2001. The levels measured in the three samples were higher than the RfC (0.0006 mg/m^3). The multiple detections on one day suggest that MDI might be released sporadically by one or more sources in Lower Manhattan. Regardless of the source of the airborne levels, MDI is a highly reactive compound and it is unlikely that MDI released during the collapse of the WTC towers, if any, would still be present in indoor environments today. MDI is not being considered as a COPC, nor will it be analyzed for during the ongoing residential dust sampling effort.

7) **Naphthalene:** The available sampling data include 573 air samples and 22 bulk dust samples. Of these measurements, only a single ambient air sample had a concentration (0.0073 mg/m^3) greater than the RfC (0.003 mg/m^3). This sample is J-qualified and was collected on April 18, 2002, well after WTC-related emissions subsided. Given the extremely limited evidence of naphthalene being found at levels greater than health-based screening values, this contaminant is not being considered as a COPC and indoor dust samples collected in Lower Manhattan residences will not be analyzed for naphthalene.

8) **Nickel:** Levels of nickel have been measured in more than 1,000 ambient air samples, in 28 bulk dust samples, and in more than 200 settled dust samples. The only samples found to have nickel levels greater than health-based screening values are six ambient air samples, which contained nickel at levels greater than ATSDR's inhalation MRL for *chronic* exposure (0.0002 mg/m^3). However, the 95% UCL nickel concentration (a better indicator of chronic exposure levels) is considerably lower than this screening value. Moreover, EPA's ongoing indoor dust sampling efforts show that all of the nickel levels measured in indoor wipe samples at Lower Manhattan residences have been lower than their corresponding health-based screening level. Therefore, nickel is not being considered as a COPC. Nonetheless, EPA will continue to analyze indoor dust samples for nickel to ensure that surface loadings are not at levels of health concern.

9) **Thallium:** Thallium levels have been measured in 738 ambient air samples, 17 bulk dust samples, and 215 settled dust samples. To date, only a single measurement—a bulk dust sample collected in September 2001—had a thallium concentration (11 mg/kg) greater than the corresponding health-based screening value (7 mg/kg). However, EPA's ongoing indoor wipe sampling results are more representative of current and future exposures, and this study has detected thallium in only 1 out of the 187 samples analyzed to date. Thus, thallium is not being considered a COPC, but the indoor wipe sampling program will continue to measure thallium levels to ensure that Lower Manhattan residents are not at risk from ongoing thallium exposures, if any measurable exposures exist.

Chromium and mercury:

1) **Chromium:** In the past 2 years, chromium levels in Lower Manhattan have been measured in air (more than 1,000 samples), bulk dust (28 samples) and settled dust (225 samples). None of the dust samples, including the 187 samples EPA recently collected from Lower Manhattan residences, have contained chromium at levels greater than health-based screening values. These samples are most representative of the current and future exposures that may be occurring in the indoor environment. The air sampling results provide somewhat conflicting results:

   - Chromium was detected in 449 of the 478 samples collected in and near Lower Manhattan schools. Every detected chromium concentration was greater than the screening value for 10^{-4} cancer risk (0.000008 mg/m^3) and the RfC (0.0001 mg/m^3), but additional observations must be noted. Most importantly, these concentrations were measured using NIOSH Method 7300M. NIOSH reports a "working range" for this method as 0.005 to 2.0 mg/m^3, based on a 500-liter sample. However, even the highest level measured in this sampling (0.00119 mg/m^3) is below the working range of the method. Moreover, chromium was consistently detected in blank samples, raising further questions about the validity of the measured concentrations.

   - The other information on ambient chromium levels is documented in EPA's sampling database, which documents the results of 738 samples. Chromium was detected in 23% of these samples; the highest concentration measured was 0.00051 mg/m^3 and the 95% UCL of the mean concentration was 0.000040 mg/m^3. Comments in the EPA database indicate that chromium was detected in several field blanks; however, none of the sampling results are B-qualified.

   Overall, the sampling data provide compelling evidence that chromium in bulk and settled dusts that remain in Lower Manhattan residences are below health-based screening values. Though some questions remain about the chromium found in the ambient air, the 95% UCL concentration of total chromium (0.000040 mg/m^3) collected with the most sensitive method falls within the range of chromium levels typically observed in urban environments (ATSDR 2000). While chromium is not being considered a COPC, EPA will continue to analyze dusts from Lower Manhattan residences for chromium to identify and clean homes found to have elevated levels, even though the available data suggest that chromium in settled dust is consistently less than screening values.

2) **Mercury:** Multiple studies have measured mercury levels in air and dust in Lower Manhattan following September 11, 2001, and these studies have not reached consistent findings:

- Three different parties have analyzed 13 bulk dust samples for concentrations of mercury. The highest concentration measured (0.38 mg/kg) is lower than the corresponding health-based screening value (22.5 mg/kg).

- An independent researcher prepared a report indicating that airborne mercury levels in Lower Manhattan after the WTC collapse were greater than EPA's RfC (0.0003 mg/m^3) and orders of magnitude greater than mercury levels found in non-industrial urban environments (Singh 2002). These conclusions were based on measurements made with a Jerome Mercury Vapor Analyzer, a hand-held field surveying tool with a reported mercury detection limit of 0.003 mg/m^3. These results could not be reproduced, however. A subsequent review questioned the findings from the study, noting that the sampling results could be biased due to low measurement selectivity and various positive interferences (Johnson 2002). Further, EPA initiated a follow-up mercury sampling project, during which mercury levels were measured in four occupied Lower Manhattan residences and at selected outdoor locations (Johnson 2002). In this study, both the maximum air concentration (0.0002 mg/m^3) and the 95% UCL of the mean concentration (0.00006 mg/m^3) were lower than EPA's RfC. Sampling in this study was performed with a Lumex Mercury Vapor Analyzer, which has a detection limit of 0.000002 mg/m^3.

- The New York City Department of Education sampled airborne mercury levels in six Lower Manhattan schools using NIOSH Method 6009. The database of sampling results indicates that some individual measurements were greater than the RfC (0.0003 mg/m^3) and that the 95% UCL of the mean concentration (0.00029 mg/m^3) was just below this screening value. However, the reliability of these measurements is questionable for two reasons. First, the accuracy of the NIOSH method has only been established for concentrations ranging from 0.002 to 0.8 mg/m^3, and the levels reported in this study are typically more than an order of magnitude lower than this range. Second, mercury was detected in about 75% of the blank samples, and the mass of mercury collected in the majority of field samples was indistinguishable from the levels observed in the blanks. Thus, the sampling methodology used in this study does not appear to be capable to measure mercury accurately and precisely at concentrations near the screening level for this evaluation.

- Finally, the sampling results available from EPA's ongoing study of settled dust in Lower Manhattan residences includes 182 measured surface loadings of mercury. Two of the samples collected to date contained mercury at levels greater than the corresponding health-based screening value (157 :g/m^2). Of the 24 contaminants for which data are currently available, mercury is one of only three contaminants (dioxin and lead being the others) that had any measured levels greater than screening values.

Overall, the air sampling study using the most sensitive methodology found that airborne mercury levels in Lower Manhattan (both indoor and outdoor) were lower than the RfC. The two other studies with conflicting conclusions were based on air sampling methodologies that are not designed to generate accurate readings at levels near the screening value. On the other hand, EPA's indoor dust sampling project has found that a very small fraction of Lower Manhattan residences contain settled dust with mercury levels greater than the screening value. The origin of the mercury in this limited number of homes is not known, and it may come from indoor or outdoor sources. Indoor sources of mercury include industrial instruments (e.g., fluorescent lights, thermometers), some paints, consumer products used for traditional or herbal remedies or religious practices, among others (ATSDR 1999b).

The available data suggest that settled dusts in some Lower Manhattan residences contain mercury at levels greater than health-based screening values; however, it is not clear whether this mercury is related to the WTC site. EPA will continue to analyze dusts from Lower Manhattan residences for mercury to identify and clean homes found to have elevated levels, regardless of the source.)

5.2 Contaminants with No Toxicity Criteria

Contaminants for which no toxicity criteria are available are listed in Tables B-4, B-8, B-11, and B-14. This section presents the findings of a more in-depth evaluation to determine whether any of these contaminants require further consideration. From this evaluation, two additional COPC were identified: fibrous glass and crystalline silica.

Contaminants selected as COPC:

1) **Fibrous glass:** Analysis of WTC bulk dust and debris has consistently identified fibrous glass to be a major constituent of the material (Lioy et al. 2002, USGS 2001). In addition, the NYCDOHMH/ATSDR (2002) study found fibrous glass in the interior settled dust. Air samples collected in areas with fibrous glass in settled dust indicate no fiber levels of immediate concern. Although fiber counts were found in four areas with slightly greater than background (0.004-0.006 fiber/cc), subsequent re-analysis indicated actual fibrous glass concentrations from these areas as 0.00004 to 0.00026 fiber/cc. Air samples from remaining areas showed a maximum 0.003 f/cc total fiber count by Phase Contrast Microscopy. These fibers may be skin, eye, and respiratory tract irritants. Although there are no standards to evaluate the settled dust content, the presence of fibrous glass in settled dust does indicate a potential for exposure. Therefore, fibrous glass is included as a COPC.

2) **Crystalline silica:** Settled dust and air samples taken in indoor and outdoor areas of residential buildings in November and December of 2001 indicate the presence of alpha-quartz. Other forms of crystalline silica were not found. This is consistent with outdoor dust and debris samples collected by the USGS (USGS, 2001) and subjected to mineral analysis. Quartz was found in approximately 49% of the settled dust samples from indoor areas of residential buildings and all of the associated outdoor areas sampled. Levels of quartz ranged as high as an estimated 31.4% of the dust by weight in a residence. Since quartz is a common material in sand, finding this mineral in a city where there is a great deal of concrete is not unusual. However, quartz in dust from a comparison area unaffected by the WTC collapse ranged from non-detect only up to an estimated 2.2% in the residence (NYCDOHMH, 2002). Seventeen residential areas and eleven common areas had quartz levels greater than the associated comparison area. Therefore, quartz was deemed to be elevated in some indoor areas of lower Manhattan relative to the comparison area. Additionally, quartz was found in 13% of the respirable fraction air samples taken in these areas, ranging from an estimated 4-19 $\mu g/m^3$, demonstrating a potential for exposure. Although below occupational standards, this estimated concentration is above the effective NAAQS standard for the silica fraction of respirable particulate matter. Therefore crystalline silica, measured as alpha-quartz, is included as a COPC.

Contaminants eliminated from further consideration:

1) **Calcite, gypsum, and portlandite:** In addition to crystalline silica, calcite, portlandite and gypsum were the most abundant minerals detected in settled dust samples from residential areas in lower Manhattan following the WTC collapse. Mica was detected with much less frequency, generally at less than 0.1% of the dust. Halite (salt) was also detected at trace levels. Calcite, portlandite, and gypsum are typical components of concrete and gypsum based wallboard products, which were present in the WTC buildings. While high concentrations of these minerals in airborne dust constitute a short-term health concern in the form of eye, nose and throat irritation, persisting adverse heath effects would not be anticipated, unless these minerals remained suspended in high concentrations. Indoor and street-level outdoor air sampling done in November and December of 2001 show that the levels of these chemicals, over a time-weighted sample, were below levels associated with irritant effects (see table below).

NIOSH and OSHA exposure limits and estimated maximum values in Lower Manhattan

Mineral	NIOSH REL (: g/m^3)	OSHA PEL (: g/m^3)	*Maximum Estimated Value (J) in Lower Manhattan (: g/m^3)
Gypsum	10,000 : g/m^3 (total) 5,000 (: g/m^3 resp)	15,000 : g/m^3 (total) 5,000 (resp)	14J (PM100) 15J (PM4)
Portlandite	5,000 : g/m^3	15,000 : g/m^3 (total) 5,000 : g/m^3 (resp)	95J (PM100) 84J (PM4)
Calcite	10,000 : g/m^3 (total) 5,000 : g/m^3 (resp)	15,000 : g/m^3 (total) 5,000 : g/m^3 (resp)	14J (PM100) 10J (PM 4)

NIOSH = National Institute of Occupational Safety and Health, Centers for Disease Control and Prevention
REL = recommended exposure level/limit
OSHA = Occupational Safety and Health Administration
PEL = permissible exposure limit.
resp = respirable
* [ATSDR/NYCDOHMH, 2002]

2) **Essential nutrients (e.g., calcium, magnesium, sodium):** EPA does not generally carry these elements through its risk assessments because of their natural occurrence, presence in our diets, and relatively low toxicity.

3) **A limited number of specific phthalates and PAHs and other SVOCs.** The lengthiest list of SVOCs for which no toxicity criteria exist comes from Lioy et al. (2002)—a study of three outdoor bulk dust samples collected in Lower Manhattan on September 16 and 17, 2001. Most of these SVOCs were not consistently detected across the three samples. Further, the concentrations measured were consistently lower than other SVOCs (e.g., PAHs) that have been selected as COPC. Finally, because many of the SVOCs identified by Lioy are rarely considered in environmental sampling studies, we have no knowledge whether the measured levels are consistent with background concentrations in urban settings or if the levels are unusually high.

References

Agency for Toxic Substances and Disease Registry (ATSDR), New York City Department of Health and Mental Hygiene (NYCDOHMH). 2002. Final Technical Report of the Public Health Investigation to Assess Potential Exposures to Airborne and Settled Surface Dust in Residential Areas of Lower Manhattan. September 2002.

ATSDR. 1999a. Toxicological profile for aluminum. Atlanta: U.S. Department of Health and Human Services. July 1999.

ATSDR. 1999b. Toxicological profile for mercury. Atlanta: U.S. Department of Health and Human Services. March 1999.

ATSDR. 2000a. Toxicological profile for arsenic. Atlanta: U.S. Department of Health and Human Services. September 2000.

ATSDR. 2000b. Toxicological profile for chromium. Atlanta: U.S. Department of Health and Human Services. September 2000.

Butt CM, Truong J, Diamond ML, Stern GA. 2002. Polychlorinated Biphenyl (PCB) Concentrations in Atmospherically Derived Organic Films From Lower Manhattan After September 11, 2001. Formation and Sources: Field Cases. Organohalogen Compounds 59:219–222.

Chattfield EJ, Kominsky JR. 2001. Summary Report: Characterization of Particulate Found in Apartments After Destruction of the World Trade Center. Report Requested by: “Ground Zero” Elected Officials Task Force.

Johnson C. 2002. Mercury vapor levels in dwellings in close proximity to the WTC site. Medgar Evers College (CUNY) Bklyn, NY

Lioy PJ, Weisel CP, Millette JR, Eisenreich S, Vallero D, Offenberg J, Buckley B, Turpin B, Zhong M, Cohen MD, Prophete C, Yang I, Stiles R, Chee G, Johnson W, Porcja R, Alimokhtari S, Hale RC, Weschler C, Chen LC. 2002. Characterization of the Dust/Smoke Aerosol that Settled East of the World Trade Center (WTC) in Lower Manhattan after the Collapse of the WTC 11 September 2001. Environmental Health Perspectives 110:703–14.

New York State Department of Environmental Conservation (NYSDEC). 2000. 1999 New York State air quality report: ambient air monitoring system. NYSDEC. Division of Air Resources. Bureau of Technical Support.

Singh U. 2002. Mercury Contamination after September 11, 2001: A Potential Public Health Risk in Lower Manhattan. I.H. Consultants Inc. Upper Monclair, NJ

U.S. Geological Survey (USGS). 2001. Environmental studies of the world trade center after the September 11, 2001 attack. Open File Report OFR-010429.

APPENDIX C

Basis for Screening Level of 1 E-04 (1 x 10^{-04})

Defensible analytical methodologies and sampling protocols have been chosen for indoor sampling and analysis activities. The methods chosen are ones that have been published by reputable agencies and are in common practice among testing laboratories. In some cases, minor modifications may be made to the sampling and analytical protocols, but these are modifications that are well established in the laboratory community.

All protocols chosen are designed to reach the lowest level of detection that is reasonable for the established methods. For dioxin, asbestos and PAHs in indoor air the sampling and analytical protocols are designed to reach detection limits that represent risk estimate levels of 1 E-04. To reach risk estimates of 1E-06, extraordinary modifications would have to be employed. These modifications would either have to be incorporated into the analytical protocols to increase the sensitivity of the required instrumentation, incorporated into the sampling protocols to achieve a larger sample, or a combination of both. For the Chemicals of Potential Concern (COPC) list, the analytical protocols chosen are already incorporating the maximum sensitivity of the instrumentation. Therefore, the only legitimate mechanism to lower the overall limits of detection is to modify the sampling protocol. The two means of achieving this goal are to either run the sampling equipment (pumps) at a higher flow rate, or for longer periods of time. For the COPC list modifying flow rates would involve operating the equipment to achieve flow rates on the order of 500 to 1000 liters per minute. The only equipment available to operate at such flow rates are large units that can not be brought inside a residence. Rates this high also present problems with creating excessive negative pressure for indoor environments, plus flow rates this high have not been tested using the sampling protocols, and there is high likelihood of having analyte breakthrough on the collection filters. Therefore, this is not practical. The other option is to run the equipment for long periods of time. Again with the COPC list, sampling periods of up to 800 hours (33 days of continuous operation) would be needed to reach the E-06 risk detection levels.

For silica, the analytical and sampling protocols chosen will give detection levels in the neighborhood of 5 μg/m^3 (see Section 3.3 for more detailed discussion). Instrumental sensitivity can not be set any higher to reach lower detection levels. Also, the sampling protocols involved for this analysis have been thoroughly validated by NIOSH. Any change in pump flow rate or sampling duration beyond what is documented in the method will produce results that have not been validated. Therefore, the sampling protocol should not be changed from that which is documented.

For fibrous glass the methodology is such that detection levels as low as 0.00001 f/cc can be achieved. This is well below required levels of detection for future indoor studies.

Another consideration in setting the target risk level involved the anticipated background level of contaminants such as asbestos, dioxin and PAHs in urban indoor environments. EPA has conducted a study (WTC Background Study - EPA 2003b) to characterize background conditions for WTC COPC in New York City residential dwellings. Preliminary results indicate that background concentrations of asbestos in indoor air and dioxin in settled dust are within the same order-of-magnitude as the analogous health-based benchmarks set at the E-04 risk level. Practical quantitation limits constrain the ability to measure PAH congeners below the E-04 risk level. As part of the WTC Background study, a literature review was conducted to provide a general estimate of background concentrations for carcinogenic COPC in urban indoor environments. It should be noted that the literature is limited in this regard. For asbestos, ATSDR reports that “measured indoor air values range widely, depending on the amount, type, and condition (friability) of asbestos-containing materials used in the building" (ATSDR, 1995). In its review ATSDR notes that the studies suffer from lack of common measurement reporting units. Study results have been reported as ng/m^3, f/cc (TEM) and f/cc (PCM). Using unit conversion factors recommended by the National Research Council in 1984, ATSDR (1995) reports that the arithmetic mean concentrations of monitoring data from a variety of indoor locations ranged from .00003 - .006 f/cc (PCM). The clearance level for WTC-impacted residential dwellings (.0009 PCM equivalents) is within this background range. Additional literature review (ATSDR 2000, EPA 2003 b) indicates that the background levels of PCM equivalent fibers in residential indoor environments ranges from non-detect (ND) - .002 f/cc.

APPENDIX D

Assessing Exposures to Indoor Air and to Residues on Indoor Surfaces

1.0 Introduction

The purpose of this Appendix is to provide further details on how procedures were selected to estimate exposure to indoor air and to residues on indoor surfaces in residences impacted by the WTC attack.

2.0 Indoor Air

Indoor air clearance criteria were derived using methods described in EPA's "Risk Assessment Guidance for Superfund" [RAGS, 1989]. These methods were developed to assess the risk from contaminants at Superfund sites. The risk based clearance criteria were calculated using the formulas below:

*Carcinogens: Clearance Criteria = (TR * AT) / (ED * EF * IUR)*

*Non-Carcinogens: Clearance Criteria = Target Hazard Index * RfC*

where:

TR = Target Risk
AT = Averaging Time (d)
ED = Exposure Duration (yr)
EF = Exposure Frequency (d/yr)
IUR = Inhalation Unit Risk (risk per µg/m^3)
RfC = Reference Concentration (µg/m^3)

Target Risk (TR) and Target Hazard Index
The target risk identified for these calculations was 1×10^{-4} and the target hazard index was 1.0. Appendix C explains the rationale for these values.

Averaging Time (AT) - Carcinogens
For carcinogens, exposure is averaged over a 70-year lifetime (the factor on which the cancer slope factors are based), and the AT is 70 years, in days (25,550).

Exposure Duration (ED)
A value of 30 years is assumed to match upper bound estimate of time in a residence (EPA, 1997b).

Exposure Frequency (EF)
A value of 365 days/year is used to represent a full time resident. Implicitly this approach also assumes exposure occurs continuously, i.e. 24 hr/d.

Inhalation Unit Risk (IUR)
The upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a unit concentration. The inhalation unit risk values used in this report are summarized in Table A-1 (Appendix A). Cancer risks for dioxin were evaluated on the basis of a range of unit risk values. An inhalation unit risk of 50,000 per mg/^{m3} can be calculated from the oral slope factor of 1.6×10^5 kg-d/mg given in EPA, 1985. The draft Dioxin Reassessment (EPA, 2000) proposes an oral slope factor of 1×10^6 kg-d/mg which can be converted to an inhalation unit risk of 290,000 per mg/^{m3}.

Reference Concentration (RfC)

The RfC represents an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfC values used in this report are summarized in Table A-1 (Appendix A).

3.0 Residues on Indoor Surfaces

The most formal EPA guidance which addresses this issue is the "Standard Operating Procedures (SOPs) for Residential Exposure Assessment" originally published by the Office of Pesticides in 1997 and updated in 2001 (EPA, 1997a and EPA, 2001a). This guidance was designed for estimating exposures to pesticides. Pesticides are typically applied to indoor surfaces as liquid or sprayed formulations which would create surface residues which are likely to be somewhat different than the fine dust particles associated with the WTC attack. So while this guidance was selected as the starting point for developing these procedures, a number of other sources were also reviewed including the Superfund guidance on dermal contact (EPA,1989), the procedures used to develop re-entry guidelines for the Binghamton State Office Building (Kim and Hawley, 1985), procedures used by NJDEP for setting interior building surface clean-up goals (NJDEP, 1993), the building clean-up procedures presented by Michaud et al (1994) and an approach developed by the EPA Region III Superfund program that has been employed by the U.S. Army Corps of Engineers to develop risk-based clean-up goals for interior surfaces at the Claremont Polychemical Superfund site in Region II (Radian, 1999). The discussion below presents the OPP procedures and how they were adopted for application to residences near WTC.

The scenario for indoor surface exposures is assumed to be 30 years which represents an upper estimate for how long individuals may live in one residence (EPA, 1997). This contact begins at about 6-12 mo age when infants become mobile. Thus, this exposure scenario is assumed to begin at age 1 and end at 31.

3.1 Dermal Contact

The OPP guidance specifies the following procedure to estimate the Potential Dose Rate (PDR, μg/kg-day) from dermal contact with indoor surfaces:

PDR = (ISR * TC * ET)/ BW

ISR = Indoor Surface Transferable Residue (μg/cm^2)
TC = Transfer Coefficient (cm^2/hr)
ET = Exposure Time (hr/d)
BW = Body Weight (kg)

ISR represents the amount of residue on a surface that can be transferred to skin. The OPP defaults calculate this initially as a fraction of the application rate. Pesticide application rates are not relevant to the WTC situation. Instead, the following approach is recommended.

ISR = CSL * FTSS

CSL = Contaminant Surface Load (μg/cm^2)
FTSS = Fraction Transferred from Surface to Skin (unitless fraction)

Making this substitution and rearranging to allow different parameter values for hard vs soft surfaces gives the following:

$$PDR = [(TC*ET_{hard}*FTSS_{hard}*CSL_{hard})+(TC*ET_{soft}*FTSS_{soft}*CSL_{soft})]/BW$$

The discussion below defines these parameters, provides the OPP default and discusses how they should be changed for the WTC assessment. The OPP procedures provide defaults for two age classes: toddlers (ages 1-6 yr) and adults. The OPP estimate of the surface residue level includes dissipation over time. Dissipation is also expected to occur in the WTC situation, but at potentially different rates and mechanisms than pesticides. This issue is discussed separately below in Section 3.3.

<u>Fraction Transferred from Surface to Skin (FTSS, unitless fraction)</u> - This is the fraction of residue on a surface that can be transferred to skin. The OPP defaults calculate this initially as 5% of application rate for carpets and 10 % for hard surfaces with a subsequent dissipation rate. FTSS will vary depending on type of surface, type of residue, hand condition, force of contact, etc. USEPA has previously assumed a transfer fraction of 0.5 for PCBs (EPA, 1987) based on an Office of Toxic Substances (OTS) assessment. Michaud et al (1994) assumed 0.5 for PCBs and dioxins, but stated that 0.1 might be more realistic. In developing re-entry guidelines for the Binghamton State Office Building after a fire, a 100% transfer was assumed (Kim and Hawley, 1985). In a study of Malathion uptake from different surfaces, USEPA-EMSL found that FTSS of Malathion from painted Sheetrock to human hands was only 0.0003. (Mean transfer from vinyl flooring to hands was 0.0018, and from carpet to hands was 0.0152.) Malathion is a pesticide assumed to have lipophilicity more similar to PCBs than to volatiles or metals. However, the representativeness of such a number for PCBs and dioxins is unknown. PCBs are more lipophilic (have higher Kows) than malathion. Rodes et al. 2001 conducted hand press experiments on particle transfer to dry skin and measured transfers with central values of about 10% from carpets and 50% from hard surfaces. These are considered most relevant to the WTC situation and were adopted in this assessment for transfers to hands leading to ingestion (see discussion below). For dermal contact, it is important to consider that much less transfer will occur to body parts with less intensive surface contact than hands such as the arms, legs, and face. Therefore these values were reduced by half to represent an area weighted transfer to the all exposed skin (i.e. 5% from soft surfaces and 25% from hard surfaces).

<u>Transfer Coefficient (TC, cm^2/hr)</u> - This represents the rate of skin contact with the surface. The OPP defaults are 6000 cm^2/hr for toddlers and 16,700 cm^2/hr for adults. These were derived from pesticide specific studies involving very high activity levels and minimal clothing protection. For chronic exposures assumed for the WTC situation, where exposure is to dust, much lower transfer coefficients would be applicable. A value more representative of this scenario was derived by selecting a TC which yielded total dust on skin loads comparable to measured values in indoor settings. Using the model presented above, the total dust load on skin can be computed and averaged over the exposed skin area (SA) as follows:

$$\text{Daily Skin Load} = [(TC*ET_{hard}*FTSS_{hard}*CSL_{hard})+(TC*ET_{soft}*FTSS_{soft}*CSL_{soft})]/SA$$

The CSL values were set at 50 $\mu g/cm^2$ of total dust which represents typical indoor horizontal surfaces based on Rodes et al., 2001 (this value is also consistent with ranges shown in Table 2). The exposed skin surface area was set to 5000 cm^2 for children (half the skin area of 7-8 yr old) and 9000 cm^2 for adults (half the skin area of an adult) (EPA, 1997). The other parameters were set at the values presented above. A TC value of 1200 cm^2/hr was judged to provide reasonably comparable skin loads to measured levels and adopted here (see Table 1).

Table 1. Skin Load Comparisons

	Calculated Skin Load (:g/cm^2)	Measured Skin Load (:g/cm^2)
Child	17	10 - area weighted average for indoor children (EPA, 2000) 40 - area weighted average for daycare children (EPA, 2000)
Adult	9	2 to 6 - range across body parts for Tai Kwon Do students (EPA, 1997b) 2 to 43 - range across body parts for greenhouse workers (EPA, 1997b)

Exposure Time (ET, hr/d) - The OPP defaults are 8 hr/d for carpets and 4 hr/d for hard surfaces. Hard surface time is based on time in kitchen and bathroom. Carpet time is based on remaining indoor time not including sleeping. This was judged to be representative of many children under age 6 who spend most of their time at home. Normally children begin school at age 6 and spend less time at home. So for ages 6-18 this was reduced to 6 hr/d for carpets and 2 hr/d for hard surfaces. After 18, many individuals will spend more time in school or at work. Others, however, may not work or attend school and spend more time at home. To be conservative, it was decided to represent this second scenario and assume that after 18 individuals would spend 8 hr/d on carpets and 4 hr/d on hard surfaces.

Body Weight (BW, kg) - The OPP defaults are 15 kg for toddlers and 71.8 kg for adults. Since this assessment spans ages 1-31, mean weights were used to represent each year based on national data in EPA, 1997.

3.2 Dust Ingestion

The OPP guidance specifies the following procedure to estimate the Potential Dose Rate (PDR, :g/kg-day) from incidental nondietary ingestion of residues on indoor surfaces from hand-to-mouth transfer.

$$PDR = (ISR * SA * FQ * SE * ET)/ BW$$

ISR = Indoor Surface Transferable Residue (:g/cm^2)
SA = Surface Area (cm^2/event)
FQ = Frequency of hand to mouth events (events/hr)
SE = Saliva Extraction factor (unitless fraction)
ET = Exposure Time (hr/d)
BW = Body Weight (kg)

As discussed above, ISR is calculated here by multiplying the Contaminant Surface Load (CSL) by the Fraction Transferred from Surface to Skin (FTSS). Making this substitution and rearranging to allow different parameter values for hard vs soft surfaces gives the following:

$$PDR = [(ET_{hard}*FTSS_{hard}*CSL_{hard})+(ET_{soft}*FTSS_{soft}*CSL_{soft})]*SA*FQ*SE/BW$$

The discussion below defines these parameters, provides the OPP default and discusses how they should be changed for the WTC assessment. The OPP guidance provides defaults for toddlers (ages 1-6 yr) only.

Fraction Transferred from Surface to Skin (FTSS, unitless) - Rodes et al. 2001 conducted hand press experiments on particle transfer to dry skin and measured transfers with central values of about ~~of~~ 10% from carpets and 50% from hard surfaces. These are considered representative of the WTC situation and were adopted in this assessment for transfers to hands leading to ingestion. Rodes et al. presented some data suggesting that transfers to wet skin (which would be associated with mouthing behavior) would be higher than dry skin, but these results were not used since they appeared less reliable.

Surface Area (SA, cm^2/event) - This is the skin area contacted during the mouthing event. The OPP default is 20 cm^2 based on the area of a child's 3 fingers. Total skin surface area increases by about 3 fold from age 2 to an adult (EPA, 1997). Average area of both hands for an adult is about 900 cm^2, so it would be about 300 cm^2 for a 2 year old. Assuming 3 fingers of one hand represents about 5% of the total area of both hands, it would increase from 15 cm^2 to 45 cm^2 from age 2 to adult. On this basis, the SA values used here are assumed to start at 15 cm^2 and increase linearly to 45 cm^2 at age 17 and remain constant after that.

Frequency of hand to mouth events (FQ, events/hr) - The OPP defaults suggest 9.5 events/hr for toddlers, based on observations at day care centers. This will decline with age, but very little data are available for other ages. Michaud et al (1994) assumed a mouthing frequency of twice per day for adults. It was decided to step down this frequency as follows: 1 to 6 yr - 9.5 times/hr, 7 to 12 - 5 times/hr, 8 to 18 yr - 2 times/hr and 19 to 31 yr - 1 time/hr.

Saliva Extraction factor (SE, unitless fraction) - The fraction transferred from skin to mouth will depend on the contaminant, mouthing time and other behavioral patterns. The OPP default is 50%, based on pesticide studies. Michaud et al (1994) assumed that all of the residues deposited on the fingertips would be transferred to the mouth, twice per day. In the Binghamton re-entry guideline derivation, a range of factors were used: 0.05, 0.1, and 0.25 representing the fraction of residue on hand that is transferred to the mouth (Kim and Hawley, 1985). For purposes of this assessment, the OPP default of 50% was selected for all ages.

Exposure Time (ET, hr/d) - Same as dermal contact, see discussion above.

Body Weight (BW, kg) - Same as dermal contact, see discussion above.

3.3 Dissipation

The surface loading of the contaminant in the dust is likely to diminish over the 30 year exposure period as a result of volatilization, chemical degradation, surface cleaning and transfers to skin/clothing. While some redeposition will also occur, the net long term effect should be a gradual decline. The discussion below provides a review of the literature related to this issue.

Several studies indicate that the main source of new dust indoors is track-in from footwear. Thatcher and Layton (1995) found a mass increase on tracked but not cleaned/vacuumed floor surfaces of 0.01 grams/day-m^2 for linoleum, 0.15 for upstairs carpet and 0.31 for downstairs carpet. They reported a value for the front doormat of 6.2 grams /day-m^2. Allot (1992) also indicated that the main mechanism for introduction of dust indoors is tracking by footwear and noted a smaller contribution from deposition dust particles suspended in air. Without regular indoor cleaning the dust inputs would accumulate. With time, they would likely become noticeable or objectionable to the inhabitants, prompting cleaning. Lioy (2002) indicates that in a survey of 36 homes, an average time since the last cleaning was 14.2 days (range 1-150 days). Roberts et al. (1999) determined that the median value of dust loading on 11 carpets before cleaning was 1.3 g/m^2. This agrees with Camann and Buckley's (1994) estimate of the median surface loading on 362 carpets of 1.4 g/m^2. Lioy et al. (2002) report ranges of dust loadings in homes from 0.05-7 g/m^2 for floors and <1 to 63 g/m^2 for rugs. See summary in Table 2.

Table 2. Dust Loads on Indoor Surfaces

	Dust Load (: g/cm^2)	Reference
Hard Surfaces	5-700 floors	Lioy et al. (2002)
Soft Surfaces	130 - median for carpets before cleaning (n=11) 10 - median for carpets after cleaning (n=10) 140 - median for carpets (n=362) <100 to 6300 - range for rugs	Roberts et al. (1999) Roberts et al. (1999) Camann and Buckley (1994) Lioy et al. (2002)

Elevated non-porous surfaces such as walls, table tops, counters, etc. receive much of their dust loads from deposition of suspended dust. The mean dustfall rate in 100 American homes in five cities was 0.02 g/day-m^2 (Schaefer et al 1972, quoted in Roberts, Budd, et al. 1992) . This indicates that the dust inputs to these surfaces are considerably smaller than track-in for carpets near entryways.

In order to maintain a fairly constant dust loading on surfaces, dust would have to be removed by cleaning at a rate equal to the rate of input from outside sources. Otherwise dust will accumulate and probably further prompt cleaning because it would be noticeable or objectionable. Assuming an input of 0.31 grams /day$_{-1}$ m$_{-2}$ for track-in to a downstairs carpet (Thatcher and Layton (1995)), dust must be removed by cleaning at this rate to maintain a constant dust load on carpet. At a track-in rate of 0.31 g/day/m^2, an initially clean carpet would require about 5 days to achieve a dust loading of 1.3 g/m^2.

If cleaning occurred on a periodic basis as it normally does, newly tracked-in dust would continually be mixed with and removed by cleaning with dust in the carpet from previous tracking events. With continued cleaning eventually the dust reservoir (from past tracking events) would be replaced with newly tracked-in dust. This means that any initial, residual load of dust containing contaminants in a carpet would be gradually removed over time with periodic cleaning and no new significant input of contaminated dust. Roberts et al. (1999) determined that the residual lead loading in carpets could be reduced by 90 to 99% in 6 months by removing shoes on entering (lead was being tracked in from the outside), use of a doormat, and use of an efficient vacuum twice a week. They determined that vigorous vacuuming was efficient in removing the contaminated dust reservoir from carpets. If a carpet is initially loaded with a contaminated dust, a half-life for its removal can be calculated assuming 90% removal in 6 months using the Roberts et al. (1999) data. This results in a 2-month half-life for dust removal from carpets using vigorous cleaning by vacuuming. It would take roughly 12 months to reduce the initial contaminant load by 99.9% using the above scenario. With no new, significant inputs of contaminated dust to a carpet an initial, residual load would be reduced over time with regular vigorous cleaning.

Roberts (1999) also determined that the dust on the surface of 11 carpets could be reduced by 90% in 1 week with the use of a Hoover Self-Propelled Vacuum with Embedded Dirt Finder (HSPF). The pre- and post-cleaning surface loadings were as follows: pre-cleaning fine dust loading: min. 0.32 g/m^2, max. 14.4 g/m^2, median 1.30 g/m^2; final fine dust loading: min. 0.019 g/m^2, max. 0.289 g/m^2, median 0.102 g/m^2. A cumulative vacuuming rate of 6 to 45 min/m^2 of vacuuming with the HSPF removed deep dust from these carpets. The median surface loadings of fine dust in these carpets were reduced by 91%, in 1 to 15 hours of cumulative vacuuming

The above analysis deals with a carpeted surface that can act as a dust reservoir and which is a difficult surface to clean. Non-porous surfaces such as floors and tables, etc. don't have the same degree of storage potential for dust and are easily cleaned. These surfaces will have a faster removal half-life than the approximately 2 months for carpets calculated above. However, they may get re-contaminated from dust re-suspension from the carpets (carpets become the source of contamination) until the carpet contaminant load is reduced.

Further data concerning the removal half-life of dioxins in indoor dust is available from the study of the Binghamton State Office Building (BSOB) (NYSDOH 2002). The building had closed in February 1981 after an intense transformer fire spread an oily soot contaminated with polychlorinated biphenyls (PCBs), polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) throughout the 18-story structure. After extensive decontamination, testing and reconstruction, the BSOB was reopened late in 1994. Pre-occupancy sampling in July 1994 found that PCB and PCDD/F levels in air and on surfaces in workspaces were considerably less than the guidelines set for reoccupancy. In fact, they were similar to levels found in buildings that have never experienced a transformer fire. Seven rounds of dust wipe sampling of tops of in-ceiling light fixtures were performed post-occupancy. PCDD/F levels on the tops of in-ceiling light fixtures averaged 1.1 nanograms per square meter at the final round of sampling, less than any previous measurements. The seven dust wipe sampling rounds indicated a gradual decline of PCDDs over-time on the light fixtures (see Figure 1). Since reoccupancy, surfaces above the ceiling were cleaned twice, once before the March 1997 sampling and again before the sixth round of sampling in August 1998. Since reoccupancy, average PCDD/F levels in dust on light fixtures have declined steadily by about one-half every 20-22 months (a half-life of 20-22 months).

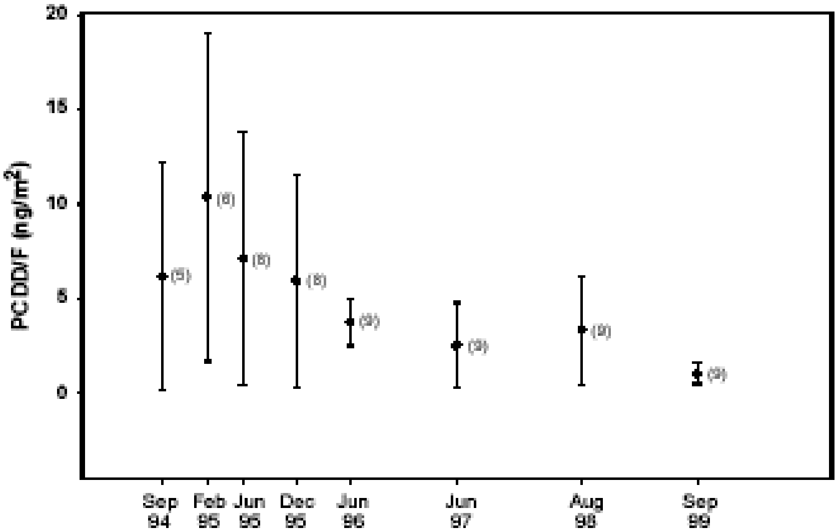


Figure 1. Average PCDD/F levels on the tops of light fixtures since September 1994. Bars are the 95% confidence interval for the means. The numbers in parentheses are the number of samples for each date.

The BSOB PCDD dust half-life value shown above was based on dust wipe sampling of the tops of light fixtures which were inaccessible to regular cleaning and only cleaned twice in 5 years. The mechanism of removal of the contaminated dust was probably a combination of cleaning, resuspension and dilution with uncontaminated dust (and possibly some volatilization). This half-life is a conservative, upper bound estimate of a removal half-life for dioxins in dust for areas that are cleaned routinely (such as would be expected were people would have daily contact). The BSOB half-life should be acceptable and conservative for use in the COPC risk assessment scenario which addresses exposure to accessible surfaces. It will capture the mechanism of dust removal from a residence due to regular cleaning that is discussed by Roberts et al. (1999) and Allot (1992) cited above and is a slower removal of dioxins in dust than would be predicted using these carpet vacuuming studies.

Further support for considering dissipation is presented below:

- The OPP guidance (EPA, 1997a and EPA, 2001a) uses a "dissipation" factor to account for degradation and other loss mechanisms after pesticide application. Similarly, Durkin et al (1995) has proposed a time-dependent transfer coefficient method for lawn treatment pesticides.
- Michaud et al (1994) proposed a mass balance model which accounts for losses from surfaces associated with building clean-ups.

Based on the above discussion, there is strong support for considering dissipation in setting criteria for building clean-ups. The recently completed study at the Binghamton State office Building described above found that dioxin has dissipated over time according to first order kinetics with a 20 to 22 month half life. As discussed above this dissipation is thought to occur from a combination of cleaning, resuspension and dilution with uncontaminated dust (and possibly some volatilization). These same physical dissipation processes would apply to other compounds addressed in this study as well. Therefore the other compounds were assumed to dissipate at the same rate as dioxin. Note that this leads to some overestimate of risk for the organic compounds with higher volatility than dioxin. In summary, a 22 month half life (decay rate constant of 0.38 yr^{-1}) was adopted here and assumed to apply to all contaminants. Exposures were calculated in a in a series of time steps where the residue level was assumed to dissipate according to first order kinetics:

$\mathrm{CSL} = \mathrm{CSL}_{\mathrm{initial}}\ e^{-kt}$
CSL = Contaminant Surface Load (:g/$\mathrm{cm}^{2)}$
$\mathrm{CSL}_{\mathrm{initial}}$ = Initial Contaminant Surface Load (:g/$\mathrm{cm}^{2)}$
k = Dissipation Rate Constant (yr^{-1})
t = Time (yr)

3.4 Calculating Clearance Criteria

The dose rates for dermal contact and ingestion were used to estimate cancer risk and noncancer hazard. The clearance criteria for surface dust loadings were derived by adjusting the levels iteratively until the risks reached the target levels. Cancer risks and noncancer hazards were calculated as follows:

Cancer Risk = LADD * CSF

Noncancer Hazard = ADD/RfD

LADD = Lifetime Average Daily Dose (µg/kg-d)
CSF = Cancer Slope Factor (kg-d/µg)
ADD = Average Daily Dose (µg/kg-d)
RfD = Reference Dose (µg/d)

For carcinogens, LADD is calculated by summing daily doses (PDR) over ages 1 to 31 and then averaging over a lifetime of 70 years. For noncarcinogens, ADD is calculated by summing daily doses over ages 1-6 and averaging over this 5 year period. Implicitly this procedure assumes that the exposure frequency is every day during the exposure period. This procedure also involves multiplying the potential dermal dose by an absorption fraction to get the absorbed dose. Absorption fraction and toxicity values are discussed below.

Oral Absorption Fraction (ABSo)

For chemicals whose dose-response parameters are based on experiments in which the absorption fraction is similar to the one expected in the exposure scenario, there is no need to adjust the RfD or CSF.

Dermal Absorption Fraction (ABSd)

This parameter is chemical-specific. Dermal absorption fractions of 0.06 for PCBs and 0.03 for dioxins from soil were first proposed in USEPA, 1992 and more recently adopted in EPA 2001b. Michaud et al (1994) used 0.02 for dioxins and 0.03 for PCBs uptake from a sooty surface, based on the ranges of estimated ABSd values for soil. The Binghamton panel used a range of values for PCBs (0.01, 0.1, and 0.5) and dioxins (0.01 and 0.1) (Kim and Hawley, 1985).

Reported ranges for dermal uptake for PCBs in solvent vehicles are reported to range from 15 to 56%, with most of the values clustering around 20% (ATSDR, 1993). Reported ranges for 2,3,7,8-TCDD in solvent vehicles are reported to range from 1 to 40% (ATSDR, 1988). Therefore, it seems that even if absorption from the wall material might be enhanced by residual solvent, the maximum possible absorption of 100% would be unrealistic even for worst-case exposure.

The values recommended here of 3% for dioxins and 13% for PAHs are based on EPA, 2001b.

Toxicity Values

Two toxicity values are used here, a Reference Dose (RfD) for non-carcinogenic compounds and a Cancer Slope Factor (CSF) for carcinogenic compounds. The RfD is defined as an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL, LOAEL, or benchmark dose, with uncertainty factors generally applied to reflect limitations of the data used. The CSF is defined as an upper bound, approximating a 95% confidence limit, on the increased cancer risk from a lifetime exposure to an agent. This estimate, usually expressed in units of proportion (of a population) affected per mg/kg/day, is generally reserved for use in the low-dose region of the dose-response relationship, that is, for exposures corresponding to risks less than 1 in 100. The RfD and Cancer Slope Factor values used in this report are summarized in Table A-1 (Appendix A).

Cancer risks for dioxin were evaluated on the basis of a range of slope factors. EPA (1985) provides an oral slope factor of 1.6×10^5 kg-d/mg and the draft Dioxin Reassessment (EPA, 2000) proposes an oral slope factor of 1×10^6 kg-d/mg.

3.5 Uncertainties

Dose Adjustments

The procedure used here, estimates the absorbed dose from dermal contact. Since dose-response relationships are typically based on an administered oral dose, ideally some adjustment is needed before calculating risks. EPA (2000) states that about 80% of dioxin in food is absorbed and therefore recommends multiplying an absorbed dose by 1.25 (100%/80%) to adjust it to a comparable administered oral dose. Since the basis for this dioxin adjustment is somewhat uncertain and similar data for other chemicals were not available, no adjustments were made for this purpose in this document. This could lead to relatively small under estimates of risk.

A similar issue applies to the ingestion pathway. Organic contaminants are likely to be more tightly bound (i.e. less bioavailable) from dust than food used in calculating dose-response relationships. About 30% of dioxins in soil are absorbed orally (EPA, 2000). On this basis, EPA recommended multiplying the ingested dose of dioxin in soil by 0.375 (80%/30%) to adjust it to a comparable basis. Given the similarity of dust and soil, this adjustment may also apply to dust. Since the basis for this dioxin adjustment is somewhat uncertain and similar data for other chemicals were not available, no adjustments were made for this purpose in this document. This could lead to over estimates of risk.

Surface to Skin Transfers

No standardized procedures have been established for estimating dust transfers to skin in indoor settings. As discussed above, the procedure used here is derived from the pesticide guidance. Pesticides are clearly different than dust. The default values for key parameters provided in the pesticide guidance (transfer fractions and transfer coefficients) were derived from experiments specific to pesticides. Although considerable judgement was used to adjust these to indoor dust, the adjusted values give total dust on skin loads that are consistent with measured values (as shown in Table 1). These uncertainties could lead to either over or under estimates of risk.

Dust Ingestion

No standardized procedures have been established for estimating indoor dust ingestion. As discussed above, the procedure used here is derived from the pesticide guidance which has uncertain application to the WTC scenarios. One way to evaluate this approach is to compute the implied dust ingestion rate:

$$\text{Ingestion Rate} = [(ET_{hard}*FTSS_{hard}*CSL_{hard})+(ET_{soft}*FTSS_{soft}*CSL_{soft})]*SA*FQ*SE$$

The CSL values were set at 50 :g/cm^2 of total dust which represents typical indoor horizontal surfaces based on Rodes et al., 2001 (this value is also consistent with ranges shown in Table 2). The other parameters were set at the values presented above. This yields an ingestion rate of 13 mg/d for children and 6 mg/d for adults. EPA (1997) recommends central estimates of total soil ingestion rates of 100 mg/d for children and 50 mg/d for adults. It is logical that lower ingestion rates would apply to dust only, however, it is uncertain how much less. This uncertainty appears to have more potential for leading to under than over estimates of risk.

Dioxin Toxicity

The toxicity of dioxin-like compounds have been intensively debated over many years. EPA currently uses an oral slope factor of 1.6 x 10^5 kg-d/mg based on EPA, 1985. The draft Dioxin Reassessment (EPA, 2000) proposes an oral slope factor of 1 x 10^6 kg-d/mg. Thus, the uncertainty in this factor spans a range of at least 6 fold.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 1988. Toxicological Profile for 2,3,7,8-Tetrachlorodibenzo-p-dioxin. United States Public Health Service, ATSDR, Atlanta, GA.

Allot RW, Kelly M, Hewitt C. 1992. Behavior of Urban Dust Contaminated by Chernobyl Fallout: Environmental Half-lives and Transfer Coefficients. Environ. Sci. Technol. 26: 2142-2147

ATSDR. 1993. Toxicological Profile Update for Polychlorinated Biphenyls. United States Public Health Service, ATSDR, Atlanta, GA.

Durkin, P.R., L. Rubin, J. Withey, and W. Meylan. 1995. Methods of assessing dermal absorption with emphasis on uptake from contaminated vegetation. Toxicology and Industrial Health 11(l):63-79.

Kim N.K. and J. Hawley. 1985. Re-Entry Guidelines: Binghamton State Office Building. New York State Dept. of Health, Bureau of Toxic Substances Assessment, Division of Health Risk Control. Albany, NY. August. Document 0549P.

EPA. 1985. Health effects assessment document for polychlorinated dibenzo-p-dioxins. Prepared by the Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH, for the Office of Emergency and Remedial Response, Washington, DC. EPA/600/8-84/014F.

EPA. 1987. Polychlorinated Biphenyls: Spill Cleanup Policy. Final Rule. Federal Register, Volume 52, Number 63. April 2.

EPA. 1989. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part A). Interim Final. Office of Emergency and Remedial Response, Washington, D.C. December.

EPA. 1992. Dermal Exposure Assessment: Principles and Applications. Interim Report. Office of Health and Environmental Assessment, Washington, D.C. January. EPA/600/891/011/B.

EPA, 1997a. Draft Standard Operating Procedures (SOPs) for Residential Exposure Assessment. Office of Pesticides Programs. December 19, 1997.

EPA, 1997b. Exposure Factors Handbook. EPA/600/P95/002

EPA, 2000. Exposure and Human health Reassessment of 2378-TCDD and Related Compounds. EPA/600/P-00/001. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=55265

EPA, 2001a. Science Advisory Council for Exposure. Policy Number 12 on Recommended Revisions to the Standard Operating Procedures (SOPs) for Residential Exposure Assessments . Revised: February 22, 2001

EPA, 2001b. Risk Assessment Guidance for Superfund Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim. EPA/540/R/99/005. Review Draft.

Lioy JL, Freeman CG, Millette JR. 2002. Dust: A Metric for Use in Residential and Building Exposure Assessment and Source Characterization. Environ. Health Persp. 110: 969-983.

Michaud, J.M., S.L. Huntley, R.A. Sherer, M.N. Gray, and D.J. Paustenbach. 1994. PCB and dioxin re-entry criteria for building surfaces and air. Journal of Exposure Analysis and Environmental Epidemiology 4(2):197-227.

New Jersey Department of Environmental Protection (NJDEP). 1993. Technical Basis and Background for Cleanup Standards for Contaminated Sites. N.J.A.C. 7:26D (Draft).

New York State Department of Health. 2002. Binghamton State Office Building: Post-occupancy Environmental Sampling, Final Round. Center for Environmental Health, Troy, NY.

Radian International. 1999. Development of risk-based wipe sample cleanup levels at the Claremont Polychemical Superfund site in Old Bethpage, New York. Prepared for: U.S. Army Corps of Engineers.

Roberts JW, Budd WT, Camann DE, Fortmann RC, Lewis RG, Ruby MG, Stamper VR, Sheldon LS. 1991. A small high volume surface dust sampler (HVS3) for lead, pesticides, and other toxics substances in house dust.[Anonymous] Proceedings Annual Meeting of Air and Waste Management Association, Vancouver, June1991. Vol.15. Pittsburgh:Air and Waste Management Assoc. p 150.2

Roberts JW, Clifford WS, Glass G, Hummer PG. 1999. Reducing Dust, Lead, Dust Mites, Bacteria, and Fungi in Carpets by Vacuuming. Arch. Environ. Contam. Toxicol. 36:477-484.
Thatcher TL, Layton DW. 1995. Deposition, Resuspension and Penetration of Particles Within A Residence. Atmos Environ 29(13):1487-97.

Rodes, C., R. Newsome, R Vanderpool, J Antley, R. Lewis. 2001. Experimental methodologies and preliminary transfer factor data for estimation of dermal exposure to particles. Journal of Exposure Analysis and Environmental Epidemiology, 11:123-139.

APPENDIX E

IEUBK Lead Model Results for Lead in Air

EPA developed the Integrated Exposure Uptake Biokinetic (IEUBK) Lead Model (EPA 1994) to evaluate multimedia lead exposure to children in residential settings. EPA established a goal of attaining a 95% probability that blood lead levels in children be less than 10 µg/dl (EPA 1994a). To meet the aforementioned goal, The IEUBK Lead Model was run using multimedia input parameters that are applicable to the residential community in Lower Manhattan. To be conservative, the IEUBK Lead Model was run under the assumption that a child would be indoors 24 hours a day. The following discussion details the basis for individual input parameters.

Lead in Drinking Water - The source of NYC's drinking water (the Catskill/Delaware and Croton systems) is remarkably low in lead. The average lead concentration is 1 µg/l in the Catskill/Delaware system and <1 µg/l in the Croton system (NYCDEP - Drinking Water Quality Test Results, 2001 - see www.nyc.gov/dep). However, the concentration of *lead* in tap water can be increased by lead containing components (pipes, solder) of a building's distribution system. Consequently, the Safe Drinking Water Act "Lead and Copper Rule" (Federal Register, June 7, 1991) requires large water systems to monitor led concentration at the tap. If more than 10% of the samples exceed the federal "Action Level" of 15 µg/l, corrective steps (e.g., source treatment, corrosion control) must be carried out. The IEUBK Lead Model is intended to run with input values that represent the average lead concentration in the environmental media of interest. As reported by NYCDEP, 2001, the median lead concentration from a total of 107 samples obtained at the tap was 3 µg/l. It should be noted that these samples represent a high bias in that they were obtained from homes where there is reason to believe that lead service lines exist. The median lead concentration in tap water city-wide is likely to be lower. However, for the purpose of this site-specific application of the IEUBK Lead Model, a value of 3 µg/l is used as a conservative central tendency estimate of lead in tap water.

Lead in Diet - No data could be located relating to the lead content in food items for residents living in Lower Manhattan. Since there is very little home gardening taking place in this community it was deemed appropriate to use data that reflects national trends for commercially available food items. EPA recently evaluated dietary lead content in children in support of revising default input parameters for the IEUBK Lead Model (EPA 2002). Lead residues in food were obtained from the Food and Drug Administration's (FDA's) Total Dietary Survey. Food consumption trends were obtained from the National Health and Nutrition Examination Survey (NHANES) . The average lead content in the diet of children 0 - 7 years old is 2.8 µg/day. Consequently, the input value of 2.8 µg/day was employed as the estimate of average daily lead intake from diet.

Lead in Soil - Numerous studies have been conducted to evaluate soil and street dust lead concentrations in New York City (NYCDOHMH, 2003). In the studies reviewed, soil/dust samples were taken by a variety of methods over a long period of time (1924 - 1993). Summary statistics were compiled by the NYCDOHMH based on whether the studies assessed known lead sources or background conditions. Ruling out studies on specific sources such as bridges, a median soil lead concentration of 200 ppm and street dust lead concentration of 895 ppm was reported. Data are lacking with regard to the relative contribution of street dust to a child's daily "soil" intake. Given this uncertainty, the median values of soil and dust were averaged to provide a composite soil/dust concentration of 548 ppm. This value was used as the soil lead concentration in the site-specific application of the IEUBK Lead Model

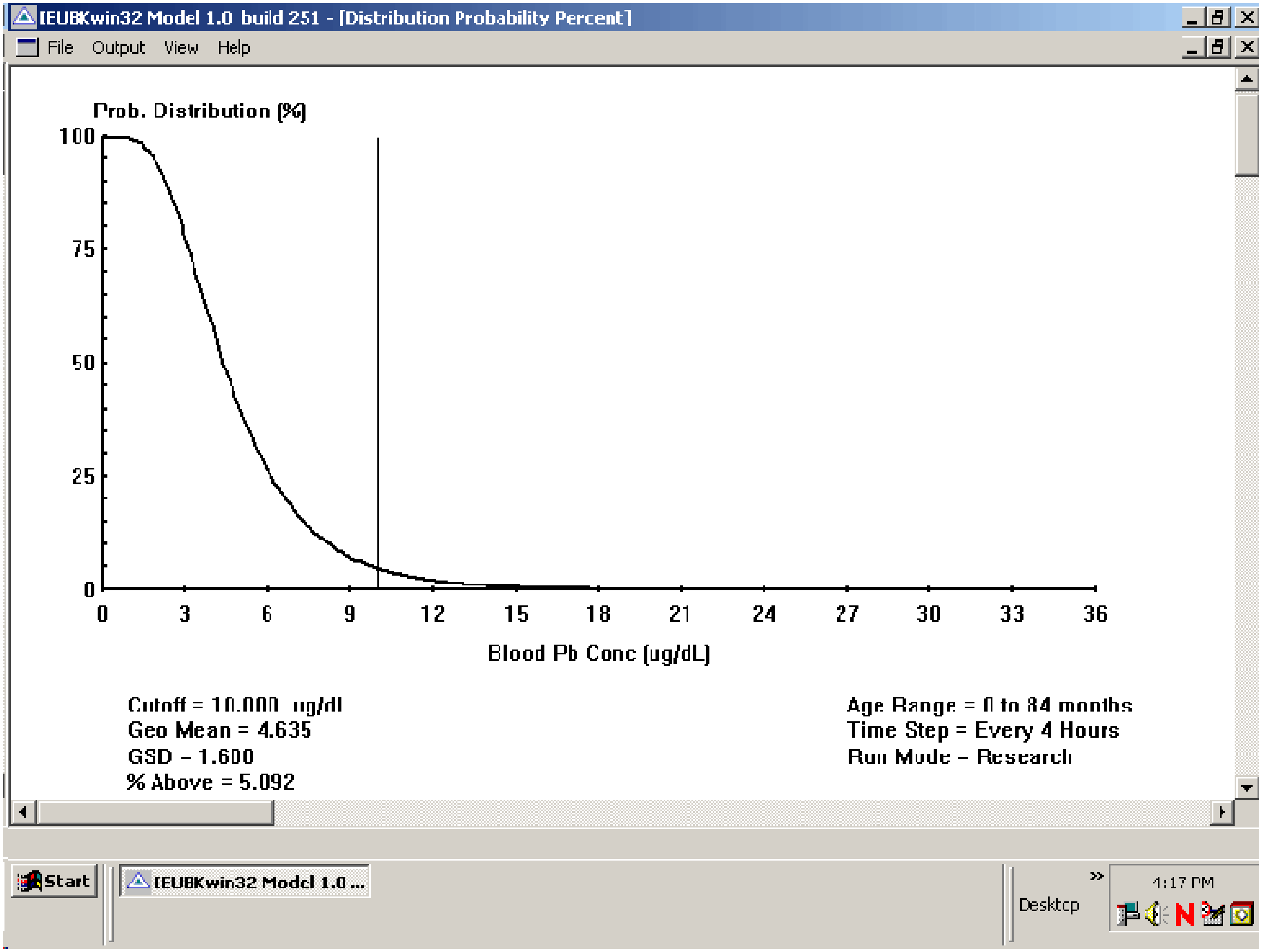
Lead in Indoor Dust - Although there exists a substantial amount of lead “load” data (i.e., mass per unit area - typically recorded in units of micrograms per square foot as per HUD reporting requirements) as a measure of lead contamination in residential dwellings, the IEUBK Lead Model requires lead concentration in settled dust to be reported in terms of concentration (i.e., mass per unit mass - typically recorded as parts per million). The WTC Background Study reported lead in house dust both in terms of lead load (µg/ft^{2}) and concentration (ppm) although more limited sampling was obtained of lead concentration (ppm) measurements. Nonetheless, because these data were specifically intended the assess background conditions in Lower Manhattan, they were used in the site-specific application of the IEUBK Model. The mean concentration of lead in settled dust in the WTC Background Study was 126 ppm (EPA 2003a). Consequently, this was the value used for lead in indoor dust for the site-specific application of the IEUBK Lead Model.

Site specific application of the IEUBK resulted in a *lead* benchmark for indoor air of 0.7 µg/m^{3}. Displayed below are data input spreadsheets and a graphic display (Page E-6) of model results.

```
LEAD MODEL FOR WINDOWS Version 1.0 Build 251


==================================================================
   Model Version: 1.0 Build 251
   User Name:
   Date:
   Site Name:
   Operable Unit:
   Run Mode: Research

==================================================================
   The time step used in this model run: 1 - Every 4 Hours (6 times a day).

   ****** Air ******

   Indoor Air Pb Concentration: 100.000 percent of outdoor.
   Other Air Parameters:

   Age      Time      Ventilation      Lung       Outdoor Air
          Outdoors       Rate        Absorption     Pb Conc
          (hours)     (m^3/day)         (%)       (ug Pb/m^3)
   -------------------------------------------------------------------
   .5-1    0.000        2.000          32.000        0.700
   1-2     0.000        3.000          32.000        0.700
   2-3     0.000        5.000          32.000        0.700
   3-4     0.000        5.000          32.000        0.700
   4-5     0.000        5.000          32.000        0.700
   5-6     0.000        7.000          32.000        0.700
   6-7     0.000        7.000          32.000        0.700

   ****** Diet ******

   Age     Diet Intake(ug/day)
   ----------------------------------
```

```
.5-1     2.800
1-2      2.800
2-3      2.800
3-4      2.800
4-5      2.800
5-6      2.800
6-7      2.800

****** Drinking Water ******

Water Consumption:
Age     Water (L/day)
-----------------------------------
.5-1     0.200
1-2      0.500
2-3      0.520
3-4      0.530
4-5      0.550
5-6      0.580
6-7      0.590

Drinking Water Concentration: 3.000 ug Pb/L

****** Soil & Dust ******

Age          Soil (ug Pb/g)      House Dust (ug Pb/g)
--------------------------------------------------------
.5-1            548.000            126.000
1-2             548.000            126.000
2-3             548.000            126.000
3-4             548.000            126.000
4-5             548.000            126.000
5-6             548.000            126.000
6-7             548.000            126.000

****** Alternate Intake ******

Age      Alternate (ug Pb/day)
-----------------------------------
.5-1    0.000
1-2     0.000
2-3     0.000
3-4     0.000
4-5     0.000
5-6     0.000
6-7     0.000

****** Maternal Contribution: Infant Model ******

Maternal Blood Concentration: 2.500 ug Pb/dL
```

```
****************************************
CALCULATED BLOOD LEAD AND LEAD UPTAKES:
****************************************

Year      Air            Diet           Alternate     Water
        (ug/dL)        (ug/day)          (ug/day)    (ug/day)
------------------------------------------------------------------------------
.5-1     0.448          1.265           0.000         0.271
1-2      0.672          1.244           0.000         0.667
2-3      1.120          1.265           0.000         0.705
3-4      1.120          1.282           0.000         0.728
4-5      1.120          1.318           0.000         0.777
5-6      1.568          1.332           0.000         0.828
6-7      1.568          1.340           0.000         0.847


Year   Soil+Dust        Total          Blood
        (ug/day)       (ug/day)        (ug/dL)
--------------------------------------------------------------
.5-1      7.280          9.264           5.0
1-2      11.373         13.956           5.7
2-3      11.558         14.647           5.4
3-4      11.718         14.848           5.2
4-5       8.920         12.135           4.3
5-6       8.113         11.841           3.7
6-7       7.708         11.462           3.3
```



Cutoff = 10.000 ug/dl
Geo Mean = 4.635
GSD = 1.600
% Above = 5.092

Age Range = 0 to 84 months
Time Step = Every 4 Hours
Run Mode = Research