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Indoor Air Assessment:
Choosing Contaminants of Potential Concern
And Setting Health-Based Benchmarks

DRAFT: 20 May 02

Introduction

Since September 11, 2001, the outdoor environment around the World Trade Center (WTC) site and nearby areas has been extensively monitored by a group of federal, state, and local agencies[1]. The agencies have taken samples of the air, dust, water, river sediments and drinking water and analyzed them for the presence of pollutants that might pose a health risk to response workers at the WTC site, office workers, and local residents. While some people may have experienced acute irritant and respiratory effects from the collapse of the towers and associated fires, extended monitoring of the ambient air over the past eight months indicates that contaminant concentrations pose a ~~minimal~~ low risk of long-term health effects. As the cleanup of the WTC site is coming to an end, the agencies are directing attention to monitoring the indoor environment for the presence of pollutants that might pose long-term health risks to local residents.

The investigation of indoor air began with historical information on hazardous substances that have been found in past building fires and collapses. The list was reduced to those contaminants that might be found around the WTC site, because of what was known about the towers and an analysis of ambient air monitoring data that measured the frequency, concentration, and intrinsic toxicity of an extensive list of chemicals. The resulting ~~group of~~ contaminants are called "contaminants of potential concern" or COPCs in this report.

In addition, the results of bulk samples from the site and personal air samples collected from

Selecting the Contaminants of Potential Concern (COPCs)

The list of hazardous substances that historically have been found after building fires and collapses is shown below, ~~categorized according to whether they might be found around the WTC site or not~~ [Wallace, 1990].

~~Substances Associated with WTC & Found in Significant Concentrations~~	~~Substances At Background Levels or Consistently Below .....~~
✓ Asbestos	Benzene
~~Fibrous Glass~~ Insulation Wools	PCBs
Refractory Ceramic Fibers	Chromium
Crystalline Silica	Cadmium & Manganese
Minerals	
Dioxin	Mercury
PAHs	Particulate Matter
Lead	

[1] Agencies include the U.S. Environmental Protection Agency (EPA), Agency for Toxics and Disease Registry (ATSDR), New York State Department of Health (NYSDOH), New York City Department of Health (NYCDOH), Occupational Safety and Health Administration (OSHA), New York State Department of Environmental Conservation (NYSDEC) and New York City Department of Environmental Protection (NYCDEP).

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The following substances were either not detected in the ambient air sampling around the WTC or were detected in very few cases, usually below EPA screening levels of concern. ~~A summary of the reasons why some chemicals might not be found around the WTC is provided below.~~ Full discussion of the reasons these substances were not recommended for monitoring in the indoor environment is provided in Appendix A.

Chemical	Reason
Benzene	Benzene is very volatile and dissipates into ambient air quickly. This is confirmed by results of air monitoring around the WTC.
PCBs	All measurements of ~~ambient~~ PCB in ambient air around the WTC work zone have been well below EPA's screening level of concern.
Chromium	~~Levels~~ All measurements of chromium ~~measured~~ in ambient air around the WTC work zone have ~~all~~ been below ~~the~~ EPA's screening level of concern.
Cadmium & Manganese	Cadmium was not detected in air sampling, except in one sample at a level equal to EPA's screening level. Manganese was found in only three samples that were above EPA's screening level.
Mercury	Although mercury was found once in police officers' blood tests, the cause was determined to be canned tuna fish, not ambient air. Mercury has not been detected in any air samples taken in the WTC area. A study of indoor and outdoor WTC dust samples showed that it is unlikely that harmful levels of mercury could ever be released to the air.
Particulate Matter (PM)	Ambient monitoring in the WTC area has shown that, since late October, levels of PM 10 and PM 2.5 (two commonly measured inhalable PM sizes) have been below ~~the~~ EPA's level of concern, indicating that there is no continuing source PM entering homes and offices.

The health-effects of the remaining substances were studied so that clean-up levels could be established.

Setting Benchmarks for the Contaminants of Potential Concern (COPCs)

A tiered approach was used to evaluate the health risks posed by any contaminants that might be present in the indoor environment (air and dust). For each COPC, three levels were established:

Tier I Level above which aggressive clean-up action should be taken

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Tier II Level where diligent cleaning should continue, with follow-up testing
Tier III Level below which the risk is negligible or no different from the every day

Each level (or "benchmark") was established based on existing standards, where available and applicable. For example, action levels for lead in indoor air and dust were set using EPA's National Ambient Air Quality Standard (NAAQS) and the Housing and Urban Development's (HUD's) standard for floors.

In cases where appropriate standards did not exist, risk-based criteria were developed using EPA risk assessment methods: for indoor air, methods described in EPA's "Hazard Evaluation Handbook: A Guide to Removal Actions" were used; for dust, EPA's "Wipe Sample Assessment" guidance was used. The risk-based criteria reflect the most current toxicity criteria (slope factors and RfCs) on EPA's Integrated Risk Information System (IRIS), which is a regularly updated, online database that reports chemical toxicity reference values and information.

Individual sampling results that exceed benchmark values should not be interpreted to represent the occurrence of an adverse health effect. Rather, such information indicates the need for careful monitoring and the assessment of longer-term data trends for evaluation against appropriate health criteria. That is, most of the screening levels have been developed to account for continuous one-year average exposure durations. Because these screening levels assume continuous exposure for an extended duration, the average of the measured concentrations is more appropriate for evaluating risk than an individual measurements. Consequently, miscellaneous individual values above the screening level may not necessarily be indicative of potential for concern.

Developing Risk-Based Criteria for Indoor Air

For carcinogenic compounds, the benchmarks were set so that a local resident's lifetime risk of developing cancer from exposure to WTC-related contaminants *for a certain amount of time* would be only one-in-ten-thousand greater than the resident's normal risk without this exposure (in risk assessment terms, the excess lifetime cancer risk was set at E-04). The amount of time that residents and office workers were exposed to WTC-related contaminants is unknown. To be conservative, the Tier I action level was chosen to be protective of a resident who may have been exposed to WTC-related contaminants for one year. The Tier III no-action-needed level was chosen to be protective of a resident who is exposed to WTC-related contaminants for 30 years (which is the upper-bound estimate for residency in one dwelling). The 30-year and 1-year exposure durations reflect an apportionment between child (20% of total exposure duration) and adult (80% of total exposure duration) receptors. Because children have comparatively greater (as a function of body weight) respiration rates than adults, the benchmark levels developed are marginally more stringent than values that would otherwise be derived by direct application of IRIS-verified Unit Risk values.

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For non-carcinogenic compounds, a resident's daily intake of a contaminant is compared to the Reference Dose, which is the amount of a noncarcinogenic compound that someone may take in per day without adverse health effects. That comparison is called the Hazard Quotient (chronic daily intake/Reference Dose). According to EPA guidelines, if the Hazard Quotient (HQ) is greater than one, there may be concern for potential health effects. Therefore, for Tier III, the no-action-needed level, the benchmark was chosen for an ~~Hazard Quotient (~~HQ~~)~~ of 1. For Tier I, the action level, an HQ ~~Hazard Quotient~~ of 10 is used, in accordance with the Hazard Evaluation Handbook. An HQ of 10 is used to account for the fact that chronic toxicity criteria (RfDs/RfCs) are being applied to sub-chronic exposure scenarios that are not expected to exceed six 6 months to one ~~1~~ year in duration. Accordingly, an HQ ~~Hazard Quotient~~ of 10 was used for non-carcinogens to reflect a similar (i.e., upper bound of 1 year) exposure duration. Note that contaminants (both non-carcinogens and carcinogens, alike) can exhibit acute effects from short-term, high-dose exposures. Because the benchmark levels are based on subchronic exposure (i.e., 1 year), acute effects from exposures that are below the benchmark levels would be unlikely. Additionally, a review of California EPA's (CAL-EPA) Acute Risk Levels demonstrates that the benchmark levels developed are categorically more stringent than the Cal-EPA's analogous acute levels.

Developing Risk-Based Criteria for Dust

Wipe sampling is a common technique used to estimate the amount of exposure that occurs from contact with contaminated surfaces. There is no established national guidance, and very little scientific literature, for the estimation of risks from wipe samples. The EPA approach used in this report was developed by the EPA Superfund program, and is consistent with evaluations found in literature. The approach involves analyzing the wipe sample for the concentration of the contaminant on the indoor surface, estimating the exposure to that contaminant concentration to determine dose in the body, and using this information to estimate risk.

Exposure to a contaminant on an indoor surface is estimated by calculating 1) the amount of the contaminant that is deposited on the skin touching the surface, 2) the fraction that is then transferred from the skin to the mouth, and 3) the fraction that is absorbed by the skin into the body. The three equations are as follows [Radian International 1999]:

1) $Ds = C \times SA \times CF \times FTSS \times EF \times ED$

Ds = Amount of chemical deposited on skin (mg)
C = Concentration of chemical on contaminated surface (mg/cm^2)
SA = Exposed skin surface area (cm^2)
CF = Contact frequency of skin against surface (1/day)
FTSS = Fraction transferred from surface to skin
EF = Exposure frequency (days/year)
ED = Exposure duration (years)

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2) $Do = (Ds \times FTSM \times ABSo)/(BW \times AT)$

Do = Oral dose (mg/kg/day)
FTSM = Fraction transferred from skin to mouth
ABSo = Oral absorption fraction
BW = Body weight (kilograms)
AT = Averaging time (days)

3) $Dd = (Ds \times (1\text{-}FTSM) \times ABSd)/(BW \times AT)$

Dd = Dermal dose (mg/kg/day)
FTSM = Fraction transferred from skin to mouth
ABSd = Dermal absorption fraction
BW = Body weight (kilograms)
AT = Averaging time (days)

Several assumptions are incorporated into these equations. They assume that volatilization of the chemical on the surface is negligible, and that the chemical is available on the surface for the entire exposure duration (that is, that the chemical on a surface is not carried away each time the surface is touched). It is assumed that there is a maximum amount of chemical that can be deposited on skin (a maximum Ds) in a single day, but that maximum Ds is unknown. Therefore, this method tends to be conservatively biased with respect to oral and dermal exposure. If inhalation exposure is to be considered, the volatilized amount should be subtracted before estimating the amount available for dermal transfer.

Although these equations are limited by the above assumptions, they are basically sound in theory. The difficulty is in defining the specific inputs to the equations, since some of the input parameters have very little or no experimentally determined values in literature. Assessments usually rely on professional judgment.

The daily dose (Do and Dd above) is converted to a probability of carcinogenic risk by multiplying it by a carcinogenic slope factor (CSF). The CSF is a chemical-specific value indicating the risk per intake dose of that chemical.

.....? *<Need more information & table of inputs to the equations>*

The following tables show the benchmark levels developed for each contaminant of potential concern ~~The screening values developed for each potential indicator chemical are shown in five tables. Following~~ Each table is accompanied by a summary of any contaminant-specific assumptions that were made in developing the benchmark values.

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Lead

Tier	Action	Lead (settled dust)		Lead (indoor air)	
		Level	Basis	Level	Basis
I	Aggressive cleaning. If levels persist, take additional action to reduce exposure.	>40 ug/ft^2	1) HUD standard for floors 2) Residential Lead Hazard Standard (TSCA Section 403)	>1.5 ug/m^3	NAAQS (intended to keep 99.5 % of children ~~childhood population~~ below 30 ug/dl)
II	Maintain recommended cleaning methods. Consider additional monitoring.	40 ug/ft^2 to 25 ug/ft^2 (or background)	HUD screening level for floors	1.5 ug/m^3 to 0.1 ug/m^3	0.1 ug/m3 is UBK Lead Model default value for urban background
III	No further action	<25 ug/ft^2 (or background)	~~HUD screening level or local background~~ Level could also be set at that found in background, or unaffected, areas, so that no increase in risk due to lead would be expected.	0.1 ug/m^3 (or background)	~~Determination of local background~~ Level could also be set at that found in background, or unaffected, areas, so that no increase in risk due to lead would be expected.

<need more explanation of methodology>

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Polycyclic Aromatic Hydrocarbons (PAHs)

Tier	Action	PAHs (settled dust)		PAHs (indoor air)	
		Level	Basis	Level	Basis
I	Aggressive cleaning. If levels persist, take additional action to reduce exposure.	>9 mg/m^2	~~Risk-based screening level for residential setting (E-04 x 1 yr)~~ 9 mg/m^2 represents a 1X10^{-4} risk estimate for a 1 year exposure	>6 ug/m^3	~~Risk-based screening level for residential setting (E-04 x 1 yr)~~ 6 ug/m^3 represents a 1X10^{-4} risk estimate for a 1 year exposure
II	Maintain recommended cleaning methods. Consider additional monitoring	9 mg/m^2 to 0.3 mg/m^2	~~0.3 mg/m2 is Risk-based screening level for residential setting (E-04 x 30 yr)~~ 0.3 mg/m^2 represents a 1X10^{-4} risk estimate for a 30 year exposure	6 ug/m^3 to 0.2 ug/m^3 (or background)	~~0.2 ug/m3 is Risk-based screening level for residential setting (E-04 x 30 yr)~~ 0.2 ug/m^3 represents a 1X10^{-4} risk estimate for a 30 year exposure
III	No further action	<0.3 mg/m^2 (or background)	~~Determination of local background~~ Level could also be set at that found in background, or unaffected, areas, so that no increase in risk due to PAHs would be expected.	<0.2 ug/m^3 (or background)	~~Determination of local background~~ Level could also be set at that found in background, or unaffected, areas, so that no increase in risk due to PAHs would be expected.

PAHs are a large group of compounds that are evaluated as benzo(a)pyrene-equivalents.
<need more explanation of methods>

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Dioxin

Tier	Action	Dioxin (settled dust)		Dioxin (indoor air)	
		Level	Basis	Level	Basis
I	Aggressive cleaning. If levels persist, take additional action to reduce exposure.	>70 ng/m^2	~~Risk-based screening level for residential setting (E-04 x 1 yr)~~ 70 ng/m^2 represents a 1X10^{-4} risk estimate for a 1 year exposure	>0.03 ng/m^3	~~Risk-based screening level for residential setting (E-04 x 1 yr)~~ 0.03 ng/m^3 represents a 1X10^{-4} risk estimate for a 1 year exposure
II	Maintain recommended cleaning methods. Consider additional monitoring	70 ng/m^2 to 2 ng/m^2 (or background)	~~2 ng/m2 is risk-based screening level for residential setting (E-04 x 30 yr)~~ 2 ng/m^2 represents a 1X10^{-4} risk estimate for a 30 year exposure	0.03 ng/m^3 to 0.001 ng/m^3 (or background)	~~0.001 ng/m3 is Risk-based screening level for residential setting (E-04 x 30 yr)~~ 0.001 ng/m^3 represents a 1X10^{-4} risk estimate for a 30 year exposure
III	No further action	<2 ng/m^2 (or background)	~~Determination of local background~~ Level could also be set at that found in background, or unaffected, areas, so that no increase in risk due to dioxin would be expected.	<0.001 ng/m^3 (or background)	~~Determination of local background~~ Level could also be set at that found in background, or unaffected, areas, so that no increase in risk due to dioxin would be expected.

The inputs to the dose equations were based on the exposure assumptions that NYSDOH used in assessing office buildings in Binghamton, NY, and the proposed cancer slope factor for dioxin. In addition, the Tier I and III benchmarks equate to a lifetime exposure level which is

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approximately 1/10 of that which results from current dietary intake of dioxin (65 pg/d). It is thus reasonable to assume that any lower level of exposure would result in an inconsequential reduction in the current risk levels experienced by the general U.S. population.

NYC background would also be an important consideration in determining the appropriate longer-term value. Propose selecting the longer-term value on the basis of a 10^{-4} risk level or NYC background, whichever is higher.

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Asbestos

Tier	Action	Asbestos (Settled Dust)		Asbestos (indoor air)	
		Level	**Basis**	**Level**	**Basis**
I	Aggressive cleaning. If levels persist, take additional action to reduce exposure. Evaluate conditions in the area, including representativeness of air samples, asbestos dust levels, and loading.	> 30,000 f/cm^2 ~~>100,000 f/cm2~~	Millette's K factor to estimate airborne levels for different activities (see narrative below). ~~Risk-based screening level for residential setting (E-04 x 1 yr)~~	>0.01 f/cc * ~~>0.0004 f/cc *~~	0.01 f/cc represents a 1X10^{-4} risk estimate for a 1 year exposure ~~Risk-based screening level for short term exposures (<= 1 yr) may result in exposures which contribute to long-term risk.~~
II	Maintain recommended cleaning methods. Consider additional monitoring. Evaluate conditions in the area including representativeness of air samples, fibrous glass dust levels and loading.	30,000 f/cm^2 to background ~~10,000 to 100,000 f/cm2~~	--- ~~Risk-based screening level for residential setting (E-04 x 30 yr).~~	0.01 f/cc 0.0004 f/cc (or background) ~~NYC background to 0.0004 f/cc *~~	0.0004 f/cc represents a 1X10^{-4} risk estimate for a 30 year exposure ~~*Risk-based screening level for residential setting (E-04 x 30 yr).~~
III	No further action required.	~~<or=~~ background ~~or 1000 f/cm2~~	Level is set at that found in background, or unaffected, areas. In this way, no increase in risk due to the fibers would be expected.	0.0004 f/cc (or background) ~~<or= NYC background~~	Level is set at that found in background, or unaffected, areas. In this way, no increase in risk due to the fibers would be expected.

* f/cc = fibers (greater than 5 micrometers long) per cubic centimeter of air.
Air concentrations measured by PCM, NIOSH 7402, confirmed by TEM.
~~Note that fibers and structures are used interchangeably in this report.~~

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The Tier I level for asbestos in settled dust was based on Millette's (full name & reference?) K factors, which are empirical relationships between concentrations of asbestos fibers in settled dust and indoor air. Millette developed the K factors by studying matched air and dust samples taken from various homes, at varying levels of activity in the home. The Tier I level was based on the K factor for a worst case scenario of a high level of activity. Although K factors are not rigorous enough to rely upon for a firm health decision, they are used here only to define what might constitute elevated fiber counts, that would need to be addressed as a near-term concern. This approach may overestimate potential exposures, but as such, is protective.

~~For asbestos in indoor air, the Asbestos Hazard Emergency Response Act (AHERA) standard of 70 structures per square millimeters (S/mm2), as measured by Transmission Electron Microscopy (TEM) analysis, has been used since the 1980s to confirm effective abatement of asbestos-containing material in schools. The standard represented the highest detectable level of background contamination on blank filters at the time (in the 1980s), not a risk-based analysis.~~

~~In order to develop risk-based benchmarks for this report, the AHERA standard was compared to a risk-based approach called Phase Contrast Microscopy (PCM). PCM was used for airborne asbestos analysis in most of the occupational epidemiology studies that provide robust dose-response data on asbestos-related carcinogenesis. AHERA's TEM fiber counts were converted to structures that would be visualized had the analysis been done by PCM. It should be noted that the correlation between total PCM fiber and TEM fiber counts is very uncertain and is likely to vary from one venue to another; therefore, no standard conversion factor exists for these two measurements.~~

~~The process for estimating cancer risk based on the AHERA standard includes 1) harmonizing the standard (TEM counts) with the dose-response metric (PCM counts); 2) converting units of measurement from fibers per unit area of filter paper to fibers per unit volume of air; and 3) calculating an airborne asbestos concentration that relates to an upper-bound estimate of exposure duration and acceptable risk level.~~

~~*1) Quantitative Risk Based on PCM or PCM Equivalence*~~

~~Quantitative risk assessment based on PCM assigns cancer potency to fibers greater than 5 um in length with an aspect ratio >3:1. The AHERA standard directs that all fibers greater than 0.5 um in length be counted. Therefore, the risk associated with fibers counts performed as per AHERA is a function of fiber length distribution with only those fibers > 5 um contributing to risk (i.e., PCM equivalence, or PCME).~~

~~A worst-case scenario risk analysis can be performed on the AHERA standard of 70 S/mm2 by assuming that the entire distribution of fibers is > 5 um. An additional element of conservatism is provided by including in the count extremely thin fibers (<0.25 um width). Long fibers with width <0.25 um are, generally, not visualized by PCM.~~

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2) Measurement Reporting Units: Conversion from f/mm2 to f/cc

To accommodate a quantitative risk assessment paradigm, the AHERA standard must also be converted from f/mm2 to f/cc. As per the AHERA sampling criteria (i.e., sample volume of 1,200 L, filter diameter of 25 mm), the standard of 70 f/mm2 converts to 0.022 f/cc as demonstrated below:

$$\frac{70 \text{ f} \times 385 \text{ mm2 (effective filter area of 25 mm filter)}}{1{,}200 \text{ L} \times 1{,}000 \text{ cc/L}}$$

3) WTC Screening Levels

The draft risk-based screening analysis for WTC assumes an upper bound (continuous) exposure estimate of one year duration. Based on the IRIS inhalation unit risk of 2.3 E-1 per (f/cc), excess lifetime cancer risk of 1 E-04 (one-in ten thousand) for a 70 year exposure duration equates to an asbestos concentration of .0004 f/cc. Adjusting the exposure duration to 1 year at a 1 E-04 cancer risk (target risk used for WTC screening values) yields an airborne asbestos concentration of 0.028 f/cc.

Conclusion

The above analysis indicates that continuous exposure to 70 f/mm2 (under the worst case assumption that all fibers >5 um) for a one year exposure duration would result in less than a one-in ten thousand excess lifetime cancer risk.

It is worth noting that the unit (f/mm2 to f/cc) conversion of the AHERA standard is a function of sample volume. The relationship is inverse. That is, the lower the sample volume the higher the asbestos concentration (f/cc). Thus, if a sample volume is sufficiently less than 1,200 L, the AHERA standard of 70 f/mm2 would convert to an airborne asbestos concentration that exceeds the one year, risk-based value of 0.028 f/cc. However, of greater importance to note is that to date less than 2 % of the samples have exceeded the AHERA standard of 70 f/mm2 and that the vast majority (approximately 80 - 90%) of fibers (from all sampling results) have been < 5 um in length.

In conclusion, when taken in its totality (i.e., individual sample results, length distribution of counted fibers, sample volume), The WTC airborne asbestos sampling data demonstrates that exposure to ambient air for a one year exposure duration is below WTC risk-based screening levels.

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Insulation Wools: Glass wool, rock wool and slag wool

Tier	Action	Insulation Wools (settled dust)		Insulation Wools (indoor air)	
		Level	Basis	Level	Basis
I	Aggressive cleaning. If levels persist, take additional action to reduce exposure. Evaluate conditions in the area including representativeness of air samples, fibrous glass dust levels and loading.	> 100,000 f/cm^2	Millette's K factor to estimate airborne levels for different activities (see narrative below).	> 0.1 f/cc	ACGIH TLV of 1 f/cc (see narrative below).
II	Maintain recommended cleaning methods. Consider additional montoring. Evaluate conditions in the area including representativeness of air samples, fibrous glass dust levels and loading.	100,000 f/cm^2 to background	---	0.01 to 0.1 f/cc	---
III	No further action required	background	Level is set at that found in background, or unaffected, areas. In this way, no increase in risk due to the fibers would be expected.	< 0.01 f/cc	ACGIH TLV of 1 f/cc (see narrative below)

* Fibers with length > 5μm with an aspect ratio ≥ 3:1, as defined in the ACGIH TLV. Air concentrations measured by PCM, NIOSH 7400, confirmed by SEM.

The Tier I level for insulation wools in settled dust was based on Millette's (full name & reference?) K factors, which are empirical relationships between concentrations of asbestos fibers in settled dust and indoor air. Millette developed the K factors by studying matched air and dust samples taken from various homes, at varying levels of activity in the home. The Tier I

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level was based on the K factor for a worst case scenario of a high level of activity. Although K factors are based on activity data for asbestos, they are believed to be protective for larger insulation wool fibers that are less airborne. In addition, although K factors are not rigorous enough to rely upon for a firm health decision, they are used here only to define what might constitute elevated fiber counts, that would need to be addressed as a near-term concern. This approach may overestimate potential exposures, but as such, is protective.

The Tier I level for insulation wools in indoor air was based on the American Conference of Governmental Industrial Hygienists' (ACGIH) threshold limit value (TLV) of 1 f/cc. That TLV is based on limiting irritant effects of fibrous glass. The TLV was then reduced by a factor of 10 to account for uncertainty in applying ACGIH's worker standards to a non-worker population.

The Tier III level for insulation wools in indoor air was based on the ACGIH TLV of 1 f/cc, reduced by a factor of 100 to account for 1) uncertainty in applying the worker standard to a non-worker population; and 2) weighting exposure over daily and long-term exposures.

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Refractory Ceramic Fibers (RCF)

Tier	Action	RCF (settled dust)		RCF (indoor air)	
		Level	Basis	Level	Basis
I	Aggressive cleaning. If levels persist, take additional action to reduce exposure. Evaluate conditions in the area including representativeness of air samples, fibrous glass dust levels and loading.	> 10,000 f/cm^2	Millette's K factor to estimate airborne levels for different activities (see narrative below).	> 0.01 f/cc	ACGIH TLV of 0.2 f/cc (see narrative below)
II	Maintain recommended cleaning methods. Consider additional montoring. Evaluate conditions in the area including representativeness of air samples, fibrous glass dust levels and loading.	10,000 f/cm^2 to background	---	0.01 f/cc to background	---
III	No further action required.	Background	Level is set at that found in background, or unaffected, areas. In this way, no increase in risk due to the fibers would be expected.	Background	Level is set at that found in background, or unaffected, areas. In this way, no increase in risk due to the fibers would be expected.

* Fibers with length > 5μm with an aspect ratio ≥ 3:1, as defined in the ACGIH TLV.
Air concentrations measured by PCM, NIOSH 7400, confirmed by SEM.

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The Tier I level for refractory ceramic fibers (RCF) in settled dust was based on Millette's (full name & reference?) K factors, which are empirical relationships between concentrations of asbestos fibers in settled dust and indoor air. Millette developed the K factors by studying matched air and dust samples taken from various homes, at varying levels of activity in the home. The Tier I level was based on the K factor for a worst case scenario of a high level of activity. Although K factors are based on activity data for asbestos, they are believed to be protective for larger RCFs that are less airborne. In addition, although K factors are not rigorous enough to rely upon for a firm health decision, they are used here only to define what might constitute elevated fiber counts, that would need to be addressed as a near-term concern. This approach may overestimate potential exposures, but as such, is protective.

The Tier I level for RCF in indoor air was based on the American Conference of Governmental Industrial Hygienists' (ACGIH) threshold limit value (TLV) of 0.2 f/cc. That TLV is based on plural and lung function abnormalities and a potential for carcinogenic effects after long term exposures. Although quantitative risk estimates specific to RCF are not available, RCF is expected to be intermediate in its toxic effects between other forms of fibrous glass and asbestos. Therefore, in the face of uncertainty, the conservative approach was taken to set screening values for RCF similar to those for asbestos.

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Crystalline silica - respirable fraction of alpha-quartz

Tier	Action	Crystalline Silica (settled dust)		Crystalline Silica (indoor air)	
		Level	Basis	Level	Basis
I	Aggressive cleaning. If levels persist, take additional action to reduce exposure. Evaluate conditions in the area including representativeness of air samples, asbestos dust levels and loading.			50 $\mu g/m^3$ *	Occupational exposure limit for respirable silica in air is 50 $\mu g/m^3$ as a time weighted average for an 8 hour exposure.
II	Maintain recommended cleaning methods. Consider additional montoring. Evaluate conditions in the area including representativeness of air samples, fibrous glass dust levels and loading.	above background		50 $\mu g/m^3$ to 5 $\mu g/m^3$ *	The occupational exposure limit (see above) is adjusted for a 24-hour exposure and a non-worker population by using an uncertainty factor of 10.
III	No further action required.	background	Level is set at that found in background, or unaffected, areas. In this way, no increase in risk due to the silica dust would be expected.	$\leq$ 5 $\mu g/m^3$	See above

* Silica measured in airborne respirable dust, by NIOSH 7500.

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Minerals in Settled Dust

Tier	Action	Gypsum and Calcium Sulfate Level	Calcite Level	Portlandite Level
I	Aggressive cleaning. If levels persist, take additional action to reduce exposure.	10,000 μ/m^3	2000 μ/m^3	10,000 μ/m^3
II	Maintain recommended cleaning methods. Consider additional monitoring	3300 μ/m^3	660 μ/m^3	3300 μ/m^3
III	No further action	1000 μ/m^3	200 μ/m^3	1000 μ/m^3

General approach for air screening levels:

Tier I is set at the TLV reduced by a factor of 10 to account for some of the uncertainty in predicting when the material may become irritable to sensitive populations.

Tier III which is intended to be protective over a long-term exposure is further reduced from Tier I. The additional uncertainty factor of 10 may address irritant effects after prolonged exposure, and round the clock exposure, as well as additional consideration of sensitive populations.

Tier II would be the range between Tiers I and III.

Settled dust:

Compare all minerals to loadings found in the background areas as ug/cm^2. Any increased mineral loading should be addressed as Tier II.

Dust pH should also be determined. Any dust exhibiting a pH greater than background or 8.5, which ever is higher, should be considered an irritant and addressed as Tier II.

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Mold

Mold was not generated or spread during the WTC collapse or associated fires. However, mold has become a COPC, because of actions taken in response to the collapse. Substantial quantities of water were used to extinguish the fires and to wash buildings affected by the collapse. Some of ~~T~~that water ~~infiltrated into~~ entered buildings, causing indoor mold contamination. Additionally, the loss of electric power after the collapse affected the ability of buildings' ~~air circulation~~ ventilation and plumbing systems to control indoor environments. This may have contributed to or caused indoor mold contamination in some buildings.

The most common symptoms of exposure to mold are runny nose, eye irritation, cough, congestion, and aggravation of asthma. Although there is evidence documenting severe health effects of mold in humans, most of this evidence is derived from eating ~~of~~ mold-contaminated foods, or occupational exposures in agricultural settings, where inhalation exposures were very high. There are no numeric standards to define "safe" levels of mold. In addition, it is very unlikely that the existence of mold in buildings around the WTC site can be distinguished from mold conditions existing prior to the attack. Therefore, the guidance established below is qualitative in nature and targeted towards detecting the presence of mold and removing it, rather than quantifying levels that pose health risks.

When inspecting a building, investigators should:

1. Look for evidence of visible mold or water damage throughout the apartment or office. Pay particular attention to moldy odors.

2. Ask the building management if water damage was noted as a result of the WTC attack or events thereafter. The investigator should be alert for situations where the loss of power to a building may have created a situation where either the ~~air circulation~~ ventilation or plumbing systems failed or leaked, creating water damage.

3. Ask both building management and individual tenants if they had been advised by their physician of health problems that might be related to mold exposure.

4. If mold contamination is encountered, it should be removed in accordance with New York City Department of Health mold removal guidelines:

   http://www.ci.nyc.ny.us/html/doh/html/epi/moldrpt1.html

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APPENDIX A

~~Contaminants Not Expected to be Found Around the WTC~~

Hazardous Substances Not Recommended for Sampling in Indoor Environment

Benzene

Benzene is a volatile organic chemical (VOC) that was found in emissions from the open flames and smoldering debris left after the collapse of the WTC. The benzene may have originated from the airplanes' residual jet fuel or from the continuous burning of plastics and other materials contained within the collapsed towers.

Since the fires and smoldering debris persisted long after the collapse of the WTC towers, there is a possibility that harmful levels of benzene vapor could have accumulated in nearby indoor environments. However, because benzene is very volatile and dissipates into ambient air quickly, the vapor plumes would have had to contain high concentrations of benzene, and the indoor area would have had to be relatively close to the fire source in order for indoor amounts of benzene to build up to harmful levels. In addition, unlike dioxin, benzene cannot become adsorbed by dust particles and transported indoors to settle as a long-term potential hazard. Once the source of the benzene is extinguished completely from the area, then benzene can no longer be a hazard.

Results of samples taken *within* the immediate WTC work zone from September 11 through mid-January 2002, show benzene levels of up to 180,000 parts per billion (ppb). However, tests during the same time period *outside* the work zone show levels of benzene that were below the established EPA screening level of 20 ppb, indicating how quickly benzene dissipates in the air. A specific example, for the day of October 3, is shown below:

From debris pile at	From debris pile at	From Liberty &
WTC North Tower	WTC South Tower	Greenwich Streets
28,000-39,000 ppb	4,300 ppb	less than 20 ppb

From January 26, 2002 through April 23, 2002 (the most recent test date available) levels of benzene in ambient air have remained below the 20 ppb screening level, except for one grab sample from the immediate work zone on February 9 and another sample from the same location on February 12. These tests indicate that the source of harmful ambient benzene levels has been extinguished, and therefore there is no source of benzene available to accumulate in any indoor environment. It is recommended that benzene not be monitored in any further indoor testing.

Polychlorinated Biphenyls (PCBs)

PCBs were historically used as coolants and lubricants in transformers, capacitors, and other electrical equipment. It is possible that, with the collapse of the WTC towers, PCBs could have been dispersed into the ambient air and then transported indoors. However, to date, all

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measurements of ambient air around the WTC work zone have been significantly below EPA's screening level (730 nanograms per cubic meter). This indicates that PCBs in ambient air are not considered harmful. Therefore, it is recommended that PCBs not be monitored in any indoor testing.

Chromium

Chromium is a naturally occurring element commonly used in metal alloys and plumbing coatings in high rise buildings such as the WTC. Chromium and its compounds can be found in air as very fine dust particles that eventually settle over land, and can cause cancer and other health problems if inhaled at high concentrations. To date, levels of chromium measured in ambient air around the WTC work zone have all been below EPA's screening level of 0.6 micrograms per cubic meter (ug/m^3). Because of these low values, chromium is not being considered a hazard at the WTC. Therefore, it is recommended that chromium not be monitored in any indoor testing.

Cadmium and Manganese

Cadmium and Manganese, both hazardous air pollutants, were detected in some ambient air samples taken at the WTC site. However, cadmium was detected in only one sample at a level equal to EPA's screening level of 0.2 ug/m^3. Manganese was found in only three samples that were above EPA's screening level of 0.5 ug/m^3. Because of the low ambient concentration of these two metals, it is recommended that they not be monitored in any indoor testing.

Mercury

In early January 2002, it was reported that New York City Port Authority police officers were tested with high levels of mercury in their blood. This raised concerns over the air quality at the WTC area. It was later learned that the probable cause of the high mercury levels was canned tuna fish that the officers had eaten the day before the blood tests were done, and not WTC air. In fact, mercury has not been detected in any air samples taken to date in the WTC area.

In addition, data from a U.S. Geological Survey leachability study performed on both indoor and outdoor WTC dust samples found mercury in leachate samples only at trace levels (up to 18 parts per trillion [ppt] for outdoor dust and 130 ppt in indoor dust). Because only trace levels of mercury appear to be present in indoor dust samples, the probability that harmful levels could ever be released to the air is very low. Therefore, it is recommended that mercury not be monitored in any further indoor testing.

Particulate Matter

[What follows seems rather dismissive of PM, without a full explanation. The standard referenced for PM 10 is the hourly standard. Was the annual standard or 50 ug/m^3 exceeded (or

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might it be)? This should also be discussed because while exposures to certain levels of PM 10 from the WTC may not continue for a full year, they would likely be longer than 24 hours. The same is true of PM 2.5. I don't think we should only reference exposures to the 24 hour standard. In addition, is the annual standard for PM 2.5 40 ug/m^3 or 65 ug/m^3 ?]

Particulate Matter (as fine dust and smoke) in the 10 micron and smaller size range is inhalable and may cause throat and lung irritation. Because of the energy released by the WTC disaster, dust containing particulate matter in this size range was generated. If this dust ~~was~~ had not been able to settle, or there had remained a continuous source of particulates being released into the ambient air, then there would have been a concern that hazardous dust could infiltrate nearby homes and offices. However, ambient monitoring for fine particulate matter in the WTC area has shown that, since late October, the levels of PM 10 (inhalable dust fraction 10 microns and smaller) and PM 2.5 (respirable fraction 2.5 microns and smaller) have been below the level of concern ~~(150 ug/m^3 for PM 10 and 40 ug/m^3 for PM 2.5)~~.

PM10	150 ug/m3	NAAQS 24-hour average
PM2.5	65 ug/m3	NAAQS 24-hour average
	40 ug/m3	Air Quality Index, 24-hour average (moderate impact)

This indicates that there is no continuing concern of hazardous fine particulate matter entering homes and offices in the WTC area. Therefore, it is recommended that particulate matter not be monitored in any further indoor testing.

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Dan Crane-
1980- Looked @ asbestos in carpets.

Highbridge for asbestos & Fiberglass-
Tier 1- just use background-

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