

**Signature Assessment
130 Liberty Street Property**

**Technical Memorandum
*S3: Resuspension Characteristics of WTC
Dust Under Controlled Conditions***

Report Date: May 2004

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Technical Memorandum

S3: Resuspension Characteristics of WTC Dust Under Controlled Conditions

Summary

This study was undertaken to use a reliable and repeatable test to evaluate the potential for particles of WTC Dust on surfaces in the Building to be resuspended into the air. Previous contamination reports¹ demonstrated that the Building was contaminated with WTC Dust and WTC Hazardous Substances above Appropriate Levels.² This test was designed to measure the concentrations of respirable particles released in the air from WTC Dust surface contamination by airflow that would typically be encountered in the Building if it were returned to use as an office building. In other office buildings with asbestos-containing surfacing materials, asbestos is typically contained within large, nonrespirable particles and debris released from surfacing materials.³ Because of the unique morphology of WTC Dust,⁴ the literature provided no guidance by which to assess the potential correlation⁵ between WTC Dust surface contamination and the level of WTC Dust that might become resuspended from surface areas. This technical memorandum reports the findings of the experts' studies of this relationship.

Key Findings

- WTC Dust is easily aerosolized⁶ when compared to ordinary surface dust.¹⁹
- Aerosolized WTC Dust contains significant amounts of respirable (breathable) asbestos and lead.

¹ RJ Lee Group, "Contamination Report Pursuant to Testing Protocol-01 *Interior Spaces* Summary Report," December, 2003.

² Center for Toxicology and Environmental Health, "Determination of Appropriate Levels for Surfaces in the Building," December, 2003.

³ Ewing, William M., et al., "Observations of Settled Asbestos Dust in Buildings," Environmental Information Association Technical Journal, Vol. 4, No. 1, pp 13-17, Summer 1996.

⁴ RJ Lee Group, "WTC Dust Signature Reports," December, 2003.

⁵ Lee, R.J., et al., "Dust and Airborne Concentrations - Is There A Correlation?" Advances in Environmental Measurement Methods For Asbestos, ASTM STP 1342, M.E. Beard and H.L. Rook, Eds., American Society for Testing and Materials, West Conshohocken, PA. 1999.

⁶ The term aerosolized refers to particles dispersed or suspended in air. The term is synonymous with the term resuspended.

- While measurements in this study were not intended to simulate human exposures, it is worth noting that a respirable asbestos concentration (0.87 f/cm³) near the OSHA 30-minute excursion limit⁷ of 1.0 fiber/cm³ resulted when surface dust in the Building was disturbed using low-velocity air pulses.
- Respirable lead and asbestos concentrations exceeded the U.S. EPA clearance levels for indoor air⁸ in 63% and 45% of the sample locations in this study, respectively.
- Average airborne asbestos, lead and total dust concentrations correlated extremely well with average surface concentrations in the three Building sectors tested.
- The aerosolized dust was confirmed to be WTC Dust which is comprised of a complex mixture of contaminants.⁴ Given the homogeneity of the WTC Dust, asbestos and other WTC Hazardous Substances will be distributed in the aerosolized dust, potentially resulting in exposures of building occupants to WTC Hazardous Substances.

Conclusion

This study demonstrates the unique hazard that WTC Dust represents because of the ease and consistency with which WTC Dust, including the lead and asbestos components of WTC Dust, become airborne. Average respirable lead and asbestos concentrations from resuspended surface WTC Dust correlated directly with average surface wipe lead and asbestos concentrations in the three Building sectors tested. This is in contrast to other buildings⁵ with asbestos-containing dust and debris where the presence of asbestos in dust is not necessarily an indicator of potential airborne exposure. Based on this study, unremediated WTC Dust and WTC Hazardous Substances in the Building will be resuspended as a result of activities in the Building if it were returned to use as an office building. Re-occupation of the Building would put occupants at risk of inhalation exposure to elevated airborne levels of asbestos, lead and other WTC Hazardous Substances. In addition, the airborne WTC Hazardous Substances would become redeposited on the surfaces in the Building, which would lead to dermal contact and ingestion exposure to Building occupants.

⁷ U.S. Occupational Safety and Health Administration (OSHA), "OSHA Regulations (Preambles to Final Rules) Section 5 - V. Feasibility of Measuring Excursion Limit," from the Preamble to the 1988 ruling, 29CFR1910, September, 1988.

⁸ U.S. Environmental Protection Agency (EPA), "World Trade Center Indoor Air Assessment: Selecting Contaminants of Potential Concern and Setting Health-Based Benchmarks," http://www.epa.gov/wtc/copc_benchmark.pdf. May, 2003.

1.0 Purpose

The tests conducted were designed to evaluate the potential for respirable particles to be resuspended from surface dust in the Building.

2.0 Procedure

A portable vertical elutriator, Figure 1, used low-velocity air pulses to resuspend dust from a variety of contaminated surfaces. Tests were conducted on concrete floor, ceiling tiles, fireproofing, floors and carpets, induction unit covers and office equipment. Building test sites were selected from the *below gash*, *opposite gash* and *above gash* Building sectors.¹ Nine samples were taken from locations *below gash*. Eight samples were taken from locations *opposite gash*. Three samples were taken from locations *above gash*. The locations were visually selected to represent light (above gash), moderate (opposite gash) and heavy (below gash) dust loadings.

The elutriator was sealed to the test surface with Mortite™ weather stripping, and used to resuspend, separate and collect the respirable dust particles that were resuspended from the surface. The portable elutriator was fabricated entirely from antistatic acrylic. A standardized pulse of air with a velocity of 8 mph was used to resuspend surface dust. This velocity is about 1/20 of that used in the aggressive air leaf blower clearance testing⁹ and within the range of that which would be encountered during normal Building activities if it were returned to use as an office building. The dust particles were collected on pre-weighed polycarbonate filters and analyzed by standard laboratory methods.¹ Where feasible, surface wipes were taken adjacent to elutriator test sites.

⁹ U.S. Environmental Protection Agency (EPA), "Abatement Area Sampling," 40CFR763, Subpart E, Appendix A, Unit III.B.7. July 1, 2003.

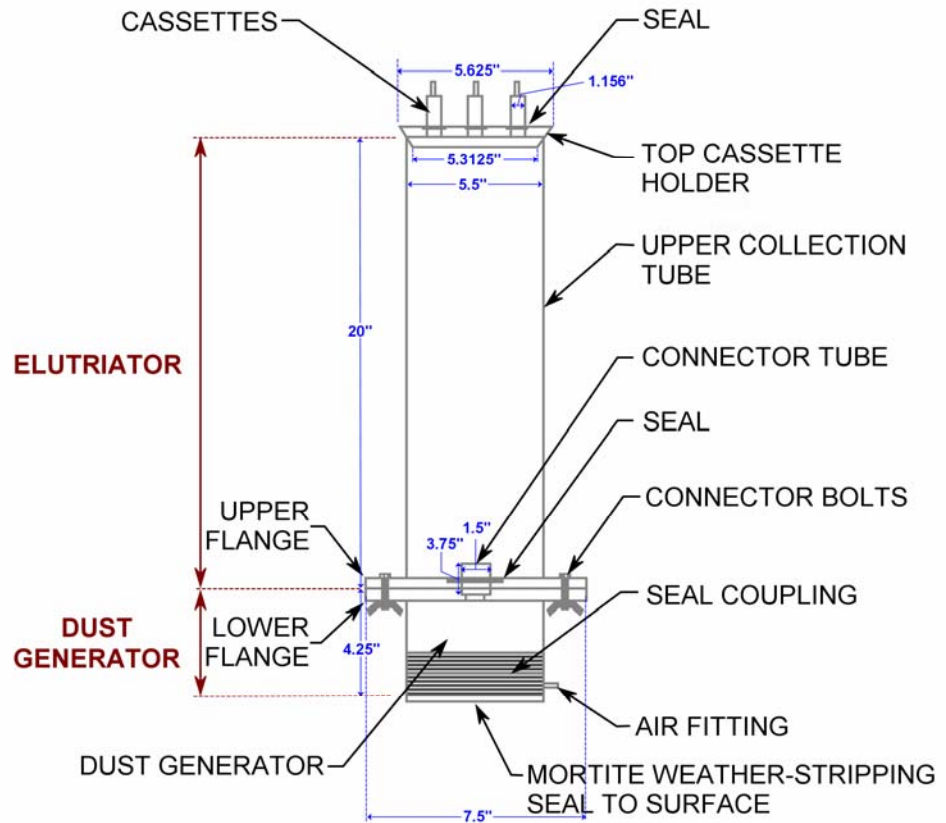


Figure 1. Elutriator Assembly

3.0 Results

The elutriator was used to measure respirable dust at twenty locations in the Building. Detailed results of the measurements are in the Appendix.

- Resuspended dust was identified as WTC Dust in 75% of the sample locations.
- More than 98% of the resuspended particles collected by the elutriator were 10 microns or less in diameter and therefore respirable as defined by the EPA.¹⁰
- The two dominant WTC Hazardous Substances observed in the respirable dust were lead and asbestos.

¹⁰ The EPA defines PM 10 as “particles less than 10 micrometers in diameter, that include both fine and coarse dust particles. These particles pose the greatest health concern because they can pass through the nose and throat and get into your lungs.” U.S. Environmental Protection Agency (EPA), “PM 10 Fact Sheet,” http://www.epa.gov/wtc/pm10/pm_fact_sheet.html, May 2003; accessed March 4, 2004.

- The average concentration of respirable lead in resuspended dust from the surface was 4.90 $\mu\text{g}/\text{m}^3$; the maximum concentration of lead in resuspended dust was 42.8 $\mu\text{g}/\text{m}^3$. Measured respirable lead concentrations exceeded the EPA clearance⁸ lead level of 0.7 $\mu\text{g}/\text{m}^3$ for indoor air in 63% of the samples.
- Average respirable lead concentrations in resuspended surface dust increased in direct proportion with average surface wipe lead concentrations in the three Building sectors tested; the correlation coefficient between the airborne respirable and surface lead was 0.99.

The resuspension effectiveness (RE) values are a measure of how the air concentration relates to the surface concentration; the lead RE values are calculated by dividing the air concentration in $\mu\text{g}/\text{m}^3$ by the surface concentration in $\mu\text{g}/\text{m}^2$. Higher RE values imply that a given activity will generate higher percentages of resuspended surface contaminants than in a circumstance with smaller RE values. For lead, these values range from 2.5 to 64.7 times 10^{-4} . This means 2.5 to 64.7 μg of respirable lead out of ten thousand micrograms of lead on the surface will be resuspended into the air. These lead RE values are based on only 19 elutriator air samples, but they form a tight data set within one order of magnitude.

Table 1. Average respirable Lead in air as compared to Average surface Lead.

Building Sector	Average Concentration		Resuspension Effectiveness ($\mu\text{g}/\text{m}^3$) / ($\mu\text{g}/\text{m}^2$)
	Respirable Pb in Air, $\mu\text{g}/\text{m}^3$	Pb on Surface Wipe, $\mu\text{g}/\text{ft}^2$	
Above Gash	0.44	162	*2.5 x 10^{-4}
Opposite Gash	1.52	235	64.7 x 10^{-4}
Below Gash	9.02	852	9.8 x 10^{-4}

*2.5 x 10^{-4} is equal to 0.00025

- Using direct TEM preparation techniques with an AHERA-equivalent protocol, 45% of the samples contained airborne asbestos concentrations greater than 0.02 S/cm³.¹¹
- Using the NIOSH 7402 TEM method¹², one sample exhibited a concentration of 3.46 fiber/cm³. On a 30-minute time-weighted basis, this concentration is equal to 0.87 fiber/cm³, which is very close to the OSHA 30-minute excursion limit of 1.0 fiber/cm³.

¹¹ 0.02 S/cm³ is the equivalent air concentration calculated using the AHERA clearance level of 70 s/mm² and the recommended air volume of 1200 liters for each sample.

¹² National Institute of Occupational Safety (NIOSH), "Asbestos by TEM," NIOSH Manual of Analytical Methods, Fourth Edition, NIOSH Method 7402. August 15, 1994.

- Using an indirect preparation protocol, the average concentration of respirable asbestos structures resuspended from the surface was 64.87 S/cm³; the maximum concentration of asbestos structures resuspended was 640.0 S/cm³. Ninety percent of the samples had concentrations of asbestos fibers that exceeded 0.02 S/cm³.¹¹ Two samples contained asbestos fibers longer than 5 μm.
- The average airborne respirable asbestos concentration in this study, 1.30 S/cm³ ¹³, is significantly higher than that found in studies of airborne asbestos concentrations in public buildings, average S/cm³ 0.00073,¹⁴ residential properties, average S/cm³ 0.0001,⁵ and schools, mean S/cm³ 0.0039.¹⁵

Average respirable asbestos concentrations from resuspended surface dust increased directly with average surface wipe asbestos concentrations in three Building sectors; the correlation coefficients between the airborne and surface asbestos were 0.99 for direct preparation TEM AHERA equivalent (Table 2) and 0.99 for indirect preparation TEM AHERA (Table 4). A perfect correlation has a value of 1.0.

The asbestos RE values are a measure of how the air concentration relates to the surface concentration for a given activity. The asbestos RE values for direct preparation TEM range from less than 0.7 to 5.0 times 10⁻⁷. The asbestos RE values for direct preparation TEM (Table 2) are as much as two orders of magnitude smaller than those for indirect preparation TEM (Table 4). This two orders of magnitude differential between direct and indirect preparation TEM is comparable to that found by Chatfield¹⁶ in his evaluation of airborne asbestos-containing building materials.

¹³ Samples were analyzed by direct preparation TEM AHERA. 1.30 S/cm³ represents the average of 19 samples; one sample was overloaded and excluded from the average.

¹⁴ U.S. Environmental Protection Agency (EPA), "Assessing Asbestos Exposure in Public Buildings," EPA 560/5-88-002. May, 1988.

¹⁵ Van Orden, D.R., et al., "Evaluation of Ambient Asbestos Concentrations in Buildings Following the Loma Prieta Earthquake," Regulatory Toxicology and Pharmacology, Vol 21, pp 117-122. 1995.

¹⁶ Chatfield, Eric J., "Correlated Measurements of Airborne Asbestos-Containing Particles and Surface Dust," Advances in Environmental Measurements for Asbestos, ASTM STP 1342, M.E. Beard and H.L. Rook, Eds., American Society for Testing and Materials, West Conshohocken, PA. 1999.

Table 2. Average respirable Asbestos in air by direct preparation AHERA equivalent as compared to Average Asbestos on surfaces.

Building Sector	Average Concentration		Resuspension Effectiveness (S/cm^3) / (S/cm^2)
	Respirable Asbestos in Air by Direct TEM prep (S/cm^3)	Asbestos on Surface Wipe by Indirect TEM prep (S/cm^2)	
Above Gash	<0.019*	257,100	$<1.4 \times 10^{-7}$
Opposite Gash	0.40	799,400	$**5.0 \times 10^{-7}$
Below Gash	2.69	6,738,000	4.0×10^{-7}

*Based on an average of three air samples computed using half of the detection limit.

** 5.0×10^{-7} is equal to 0.0000005.

The asbestos RE values from the airborne direct preparation TEM ISO data of Chatfield and Kominsky have been calculated.¹⁷ These asbestos concentration data were collected at apartment buildings north and south of the World Trade Center in September 2001. Chatfield and Kominsky's low exposure location appears to have visually light or moderate surface dust loading similar to that observed in the *above gash* sector of the Building. Their high exposure location appears to have visually heavy dust loading similar to that observed in the *below gash* sector of the Building. The asbestos RE values calculated from their data range from 2.1 to 80 times 10^{-7} ; this means that from 2.1 to 80 fibers out of ten million fibers on the surface will be resuspended into the air. Considering the number of factors affecting the resuspension of surface dust, the RE values calculated from the Chatfield and Kominsky study are in good agreement with those measured in the Building.

Table 3. Average Asbestos in air by direct preparation TEM ISO as compared to Average Asbestos on surfaces for Low and High Exposure buildings near the WTC complex based on data reported by Chatfield and Kominsky.¹⁷

	Average Concentration		Resuspension Effectiveness (S/cm^3) / (S/cm^2)
	Airborne Asbestos in Air by Direct TEM prep (S/cm^3)	Asbestos on Surface Wipe by Indirect TEM prep (S/cm^2)	
Low Exposure at 45 Warren 5th Floor	0.048	224,944	$*2.1 \times 10^{-7}$
Low Exposure at 45 Warren 2nd Floor	0.10	116,748	8.6×10^{-7}
High Exposure at 250 South End Ave.	2.96	367,015	80×10^{-7}

* 2.1×10^{-7} is equal to 0.00000027.

¹⁷ Chatfield, Eric J. and Kominsky, John R., "Summary Report: Characterization of Particulate Found in Apartments after the Destruction of the World Trade Center," October 12, 2001.

Table 4. Average respirable Asbestos in air by indirect preparation TEM AHERA as compared to Average Asbestos on surfaces for three Building sectors.

Building Sector	Average Concentration		Resuspension Effectiveness (S/cm ³)/ (S/cm ²)
	Respirable Asbestos in Air by Indirect TEM prep (S/cm ³)	Asbestos on Surface Wipe by Indirect TEM prep (S/cm ²)	
Above Gash	0.094*	257,100	**3.6 x 10 ⁻⁷
Opposite Gash	8.522	799,400	1.1 x 10 ⁻⁵
Below Gash	136.54	6,738,000	2.0 x 10 ⁻⁵

*Based on an average of three air samples.

**3.6 x 10⁻⁷ is equal to 0.00000036.

- Respirable asbestos concentrations from resuspended surface dust increased with corresponding surface wipe asbestos concentrations. The correlation coefficient between airborne and corresponding surface asbestos was 0.68 for indirect preparation TEM AHERA (Table 5). A perfect correlation has a value of 1.0.

Table 5. Respirable Asbestos in air by indirect preparation TEM AHERA as compared to Asbestos on surfaces by surface type.

Building Sector	Building Floor	Surface Type	Concentration	
			Respirable Asbestos in Air by Indirect TEM prep (S/cm ³)	Asbestos on Surface Wipe by Indirect TEM prep (S/cm ²)
Above Gash	35	Induction Unit Cover	<0.141	13,572
	35	Ceiling Tile	<0.141	135,723
Opposite Gash	14	Wood Table	0.564	713,717
	10	Desk Top	20.88	168,484
	10	Concrete Pad	8.17	5,241,727
Below Gash	5	Table	1.28	14,742,359
	3	Marble Floor	124.81	12,168,296
	3	Floor Tile	640.01	17,550,428

- Respirable dust concentrations in this study correlated with surface dust loadings in the three Building sectors tested. The correlation coefficient between resuspended respirable dust and surface dust was 0.61. A perfect correlation has a value of 1.0 (Table 5).

The WTC Dust respirable RE values are a measure of how the air concentrations relate to the surface concentrations when the dust is disturbed. Higher RE values imply higher percentages of surface contaminants will become airborne for a given activity. For WTC Dust, these values range from 5.5 to 15, times 10^{-4} .

This means 5.5 to 15 micrograms of dust out of ten thousand micrograms of dust on the surface will be resuspended into the air. These data are illustrated in Table 6. The RE values for respirable WTC Dust particles are larger than those for the individual lead or asbestos particles within the WTC Dust. Historical RE values are in the 10^{-8} range (about 10,000 times lower than the values measured in this study).^{18,19} This means that the dust particles discussed in the literature were not as likely to resuspend as the WTC Dust particles in the Building.

Table 6. Average respirable Dust in air as compared to Average surface Dust.

Building Sector	Average Concentration		Resuspension Effectiveness (g/m^3) / (g/m^2)
	Respirable Dust in Air (g/m^3)	Dust on Surface (g/m^2)	
Above Gash	0.0011	1.99	5.5×10^{-4}
Opposite Gash	0.0061	4.04	15×10^{-4}
Below Gash	0.0387	24.63	15×10^{-4}

** 5.5×10^{-4} is equal to 0.00055*

4.0 Discussion

In Libby, Montana, EPA Region 8 scientists used asbestos in dust as evidence of a pathway for inhalation and ingestion.²⁰ Observed surface and airborne asbestos concentrations, far lower than those observed in this study, were the primary basis for declaring the Libby area a Superfund site. In contrast, after the WTC Event, EPA studies concentrated almost exclusively on airborne measurements as an indicator of potential pathway exposure. While there is disagreement on the significance of surface dust,²¹ there is

¹⁸ Gaborek, Bonnie J., "Pentagon Surface Wipe Sampling Health Risk Assessment," Toxicology and Industrial Health, Vol. 17: 254-261, 2001.

¹⁹ Sansone, E. B. "Redispersal of Indoor Surface Contamination and Its Implications." Treatise on Clear Surface Technology, Vol. 1. Ed. K. L. Mittal, pp. 261-290. 1987.

²⁰ U.S. Environmental Protection Agency (EPA) Memorandum, Subject "Fibrous Amphibole Contamination in Soil and Dust at Multiple Locations in Libby Poses an Imminent and Substantial Endangerment to Public Health: an Addendum to my Memorandum of May 10, 2000," from Christopher P. Weis to Paul Peronard. July 9, 2001.

²¹ Fowler, D.P. and Chatfield, D.J., "Surface Sampling for Asbestos Risk Assessment," Ann. Occup. Hyg., Vol. 41, Supplement 1. pp 279-286, 1997.

general agreement that resuspension of dust creates an exposure pathway for human health.²²

Although this study collected respirable dust from 20 sample locations, the correlations shown here indicate the average respirable concentration is directly proportional to the average surface concentration for lead and asbestos. However, there was greater scatter in the data between individual air samples and surface wipe data sets as expected because of the intrinsic unpredictability of surface dust.¹⁹

For the average results, resuspension effectiveness values can be estimated from average surface and airborne concentrations. This is in contrast to other buildings where surface concentrations were not predictive of airborne concentrations.⁵

In this test, respirable asbestos concentrations in the resuspended dust were 10 to 1,000 times higher than airborne asbestos concentrations in homes containing damaged ACM⁵ and 100 to 10,000 times higher than airborne concentrations in public buildings containing at least one area of damaged ACM.¹⁴

Respirable asbestos concentrations in this study also greatly exceed asbestos concentrations in prior studies during activities such as sweeping asbestos debris²³ or when aggressively simulating household activities in homes damaged by the Northridge, California earthquake.⁵

This study demonstrated that WTC Dust and WTC Hazardous Substances are resuspended into the air given a minimal amount of air movement. This means that any WTC Dust and WTC Hazardous Substances remaining in the Building, even in inaccessible areas, have the potential to be resuspended and recontaminate occupied areas of the Building that have been remediated.

²² Sawyer, R.N. and Spooner, C.M., "Sprayed Asbestos-Containing Materials in Buildings: A Guidance Document," U.S. Environmental Protection Agency (EPA), EPA 450/2-78-014, Part 2. 1978.

²³ Wickman, Arthur R., et al., "Exposure of Custodial Employees to Airborne Asbestos," Missouri Department of Health, Bureau of Environmental Epidemiology. EPA Project No. J100746B-01-0, pp. 1-22.

Appendix A

Table 7 lists the locations and surfaces in the Building from which respirable dust measurements were obtained using the elutriator. Respirable airborne lead and asbestos concentrations are listed along with the respirable dust weights. Respirable dust weights on PC filters generally correlated with surface dust loads within the Building; dust concentrations are highest on the lower floors of the Building and decrease on higher floors.

Table 7. Respirable Lead and Asbestos concentrations.

Building Sector	Building Surface	Floor	Respirable Airborne Pb Concentration [$\mu\text{g}/\text{m}^3$]	Respirable Airborne Asbestos measured by Indirect Prep TEM AHERA [S/cm^3]	Respirable Airborne Asbestos measured by Direct Prep AHERA Equiv. [S/cm^3]	Respirable Dust Weights on 4 PC Air Filters [mg]
<i>Below Gash</i>	Induction Unit	2	<0.33	2.976	0.146	0.173
	Concrete Floor	3	13.5	246.16	19.1	2.373
	Ceiling Tile	3	1.63	25.275	0.434	3.882
	T-Shirt	3	4.3	110.31	*OL	4.908
	Floor Tile-Bathroom	3	12.7	640.01	<0.62	2.458
	Carpet	3	2.13	71.43	0.289	1.781
	Marble Floor	3	42.8	124.807	1.24	1.671
	Table	5	0.607	1.28	<0.146	0.535
	Concrete Floor	7	3.48	6.594	0.289	2.259
<i>Opposite Gash</i>	Ceiling tile	9	3.04	7.143	1.01	1.145
	Induction Unit Cover	9	<0.33	10.989	0.143	1.48
	Desk (Formica)	10	1.97	20.88	2.03	0.706
	Keyboard	10	0.5	1.27	<0.145	0.244
	Concrete Floor	10	1.59	8.17	<0.289	0.613
	Carpet	10	NA	14.09	<0.289	0.191
	Telephone	10	1.48	5.07	<0.145	0.214
	Wooden Table	14	2.09	0.564	<0.289	0.228
<i>Above Gash</i>	Induction Unit Cover	35	0.397	<0.141	<0.037	0.09
	Ceiling Tile	35	0.558	<0.141	<0.037	0.095
	Fireproofing	35	0.362	0.282	<0.037	0.214

Asbestos Concentrations in bold contain fibers > 5 μm .

*OL indicates that the filter was overloaded.

NA indicates not analyzed.