

**Signature Assessment
130 Liberty Street Property**

**Technical Memorandum
*S4: Resuspension and Settling of WTC Dust
over a Three-Day Period***

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Technical Memorandum

S4: Resuspension and Settling of WTC Dust over a Three-Day Period

Summary

The World Trade Center ("WTC") destruction commencing on September 11, 2001 ("WTC Event") resulted in the contamination of the building located at 130 Liberty Street, New York, NY (the "Building") with WTC Dust and WTC Hazardous Substances.¹ Other studies demonstrated that WTC Dust and WTC Hazardous Substances on surfaces in the Building can be resuspended by aggressive air disturbance and building maintenance activities and that the resuspended dust from Building surfaces was respirable.^{2,3,4,5} This study was undertaken to evaluate the resuspension and settling of WTC Dust and WTC Hazardous Substances over a three-day period. Aggressive air disturbances were found to produce elevated levels of resuspended WTC Dust and WTC Hazardous Substances exceeding EPA background levels⁶ and that once resuspended, respirable asbestos fibers can remain airborne for days.

Key Findings

- Aggressive air disturbance resuspends respirable (breathable) WTC Dust and WTC Hazardous Substances to concentrations exceeding the EPA background levels⁶.
- Resuspended asbestos fibers or bundles with widths of $<0.05 \mu\text{m}$ were observed in area air samples taken from each test location. Data from Chatfield⁷ indicate that fibers of this size can remain in suspension up to eight weeks after aggressive air tests.

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

² RJ Lee Group, "Technical Memorandum S2: *The Relationship between Surface and Airborne Concentrations of WTC Dust Under Known Conditions*," May, 2004.

³ RJ Lee Group, "Technical Memorandum R2: *Test Cell Remediation and Recontamination*," May, 2004.

⁴ RJ Lee Group, "Technical Memorandum S1: *Aerosolization of Ultra Fine Fibers and Particles from WTC Dust*," May, 2004.

⁵ RJ Lee Group, "Technical Memorandum S3: *Resuspension Characteristics of WTC Dust Under Controlled Conditions*," May, 2004.

⁶ U.S. Environmental Protection Agency (EPA), "World Trade Center Residential Dust Cleanup Program - Draft Final Report," March, 2004.

⁷ 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, 2000.

- Resuspended asbestos fibers or bundles with widths of $<0.5 \mu\text{m}$ were observed in cascade impactor samples taken from each test location. Data from Chatfield⁷ indicate that fibers of this size can remain airborne up to three days after aggressive air tests.
- Normal air disturbance caused by minimal activities during sampling resuspends respirable WTC Dust and WTC Hazardous Substances to concentrations exceeding the EPA background level.⁶

Conclusion

This study demonstrates that minor activity such as walking into a room resuspends WTC Dust and WTC Hazardous Substances. Respirable fibers ($>0.5 \mu\text{m}$ in width) were easily resuspended. Once suspended, asbestos fibers, including fibers $>5 \mu\text{m}$ in length, remain suspended for a significant period of time. This study demonstrates that unremediated WTC Dust is a hazard because of its potential to be resuspended and recontaminate the Building when disturbed.

1.0 Purpose

The purpose of this study was to measure the resuspension and settling properties of WTC Dust and WTC Hazardous Substances in the Building for a period of three days. After aggressive air testing, measurements were made of the:

- respirable airborne PM10⁸ and PM2.5⁹ particle mass and particle counts
- respirable airborne contaminants
- settled particles in dust fall pans

2.0 Description of System

The test locations were three of the rooms where the study⁵ was performed during the summer of 2003. The three rooms in this test were:

- Floor 3: an executive dining room in the east side (heavy dust).
- Floor 11: a conference room in the southeast corner (moderate dust).
- Floor 37: a conference room in the central section (light dust).

⁸ 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), "PM10 Fact Sheet," http://www.epa.gov/wtc/pm10/pm_fact_sheet.html, May 2003; accessed March 4, 2004.

⁹ EPA defines PM 2.5 as fine particles that are less than or equal to 2.5 micrometers in diameter, U.S. Environmental Protection Agency (EPA), "EPA ROE Glossary Definition" <http://www.epa.gov/indicators/roe/html/roeGlossP.htm>, June 30, 2003; Accessed April 8, 2004.

3.0 Procedure

Area air samplers collected airborne particles and cascade impactor samplers⁴ collected five size fractions of respirable airborne particles finer than 2.5 μm . Dust fall pans collected particles that settled back to the surface and a dust wipe was used to sample the particles from the dust fall pan.

Two Met One Aerosol Particle Profilers¹⁰ were also deployed at the beginning of the test on each floor. Air entering these Profilers at a rate of 0.1 cfm (2.83 lpm) draws in particles to be sized. One Profiler was set to record particle diameter and mass, and the other Profiler was set to count concentration in particles per liter of air sampled. The Profiler is capable of measuring particles 0.5 μm and larger. Met One particle counters were operated continuously during the entire test procedure, except for brief periods around 24 hours and 45 hours from the start, when data were being downloaded from these units.

Aggressive Air Tests. Aggressive air procedures were used to disturb surface dust at each of the three locations within the Building. Prior to aggressive air testing, samples were acquired to assess ambient conditions in the test rooms. Immediately after aggressive air disturbance was terminated, area air and cascade impactor samplers were started. After approximately two hours, the room was re-entered, the air sampling was terminated, the dust fall pans were collected and new, clean dust fall pans were set out. All sampling activities, except for the automated Met One station, ceased at this time and the room was vacated. All samples collected following the two hour sampling period are called "post aggressive samples" as shown in Table 1.

After approximately 24 hours from the start of air disturbance, the room was revisited, and additional area air, cascade impactor and dust fall pan samples were acquired. New, clean dust fall pans were also deployed at that time. This sampling period is referred to as Day 1 (Table 1).

Approximately 48 hours later, the room was revisited and additional area air, cascade impactor and dust fall pan samples were acquired. This sampling period is referred to as Day 3 (Table 1).

Table 1 illustrates sampling times after aggressive air disturbance as well as the types of samples collected.

¹⁰Met One Instruments, Inc. Model: AEROCET 531.

Table 1. Sampling times and samples/data collected after aggressive air disturbance.

Sample Designation		Time After Aggressive Air Disturbance	Samples and Data Collected
Time	Floors		
Post Aggressive:	3, 11, and 37	2.0-3.4 Hours	Area air, Cascade Impactor, Dust Fall Pan Wipe
Day 1:	3, 11, and 37	22.7-28.3 Hours	Area air, Cascade Impactor, Dust Fall Pan Wipe
Day 3:	3 and 37 11	67.3-74.4 Hours 55.2-59.5 Hours	Area air, Cascade Impactor, Dust Fall Pan Wipe

4.0 Results

Met One Data - Particle Mass. In Figure 1 to Figure 3, the vertical axis represents the mass of PM10 particles per cubic meter of air samples. The horizontal axis is the time, in hours, after the aggressive air disturbance. Figure 1 shows the mass data for the duration of the test on floor 3 and Figure 2 shows the first six hours of the floor 3 test at an expanded vertical scale. These figures are annotated to show the relationship between sampling activities and suspended particulate. Figure 3 is a graph of the mass of suspended PM10 particles for the duration of the test on all three floors tested. These figures demonstrate that:

- During floor 3 tests, the mass of PM10 particles exceeded the Met One's range of 9.9 mg/m³ and drops off within 1.75 hour after aggressive air disturbance.
- The trends in the Met One mass data for the tests on floor 11 and 37 were similar to those observed in the floor 3 tests.
- In all three test floors, there are significant spikes, as high as 2 mg/m³, in the mass of airborne PM particles during periods when the room is entered for sampling, indicating that the settled surface dust is being resuspended by minimal disturbance.
- Under passive conditions in the Building where no ventilation is present except for the minimal air flow created during normal sampling activity, WTC Dust (PM10 size) is resuspended to levels exceeding the EPA screening level for sensitive groups,¹¹ 0.15mg/m³, for all three sampling times on floor 3, and the Post Aggressive and Day 1 sampling times on floor 11.

¹¹ "The PM10 screening level for sensitive groups is 0.15 mg/m³ for a 24-hour average exposure. This level is based on EPA's Air Quality Index. Above this level, we recommend that sensitive groups reduce their exposure." U.S. Environmental Protection Agency (EPA), "Benchmarks, Standards and Guidelines Established to Protect Public Health," <http://www.epa.gov/wtc/benchmarks.htm>, March 1, 2004; accessed March 26, 2004.

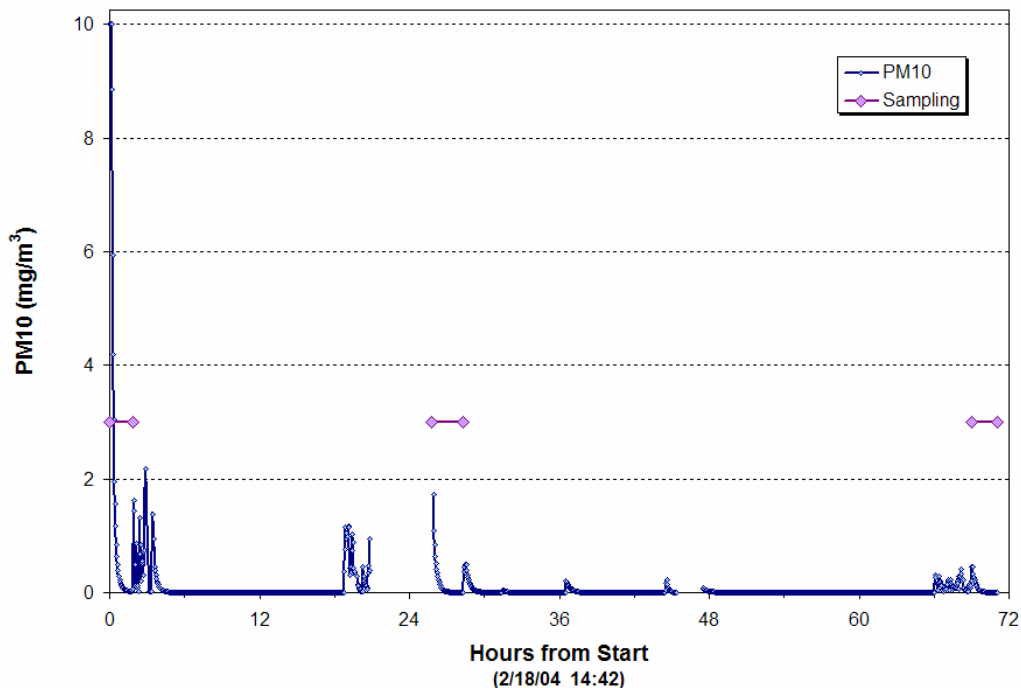


Figure 1. Met One particle mass data for 3rd floor test. Air sampling periods are also shown.

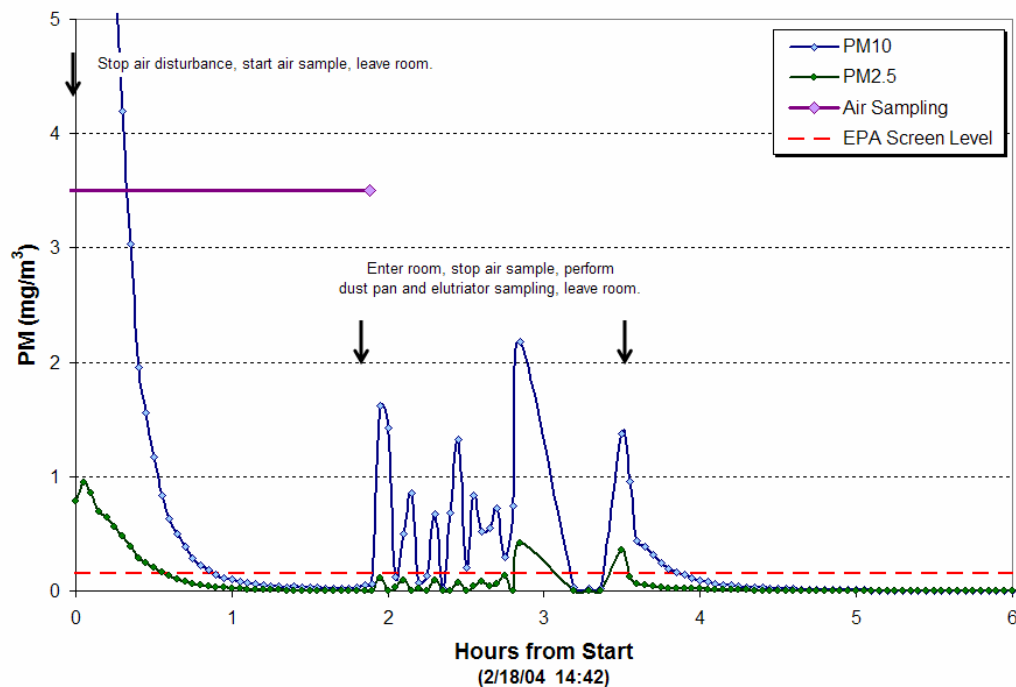


Figure 2. Met One particle mass data for 3rd floor (expanded vertical scale and hours 0-6 only).

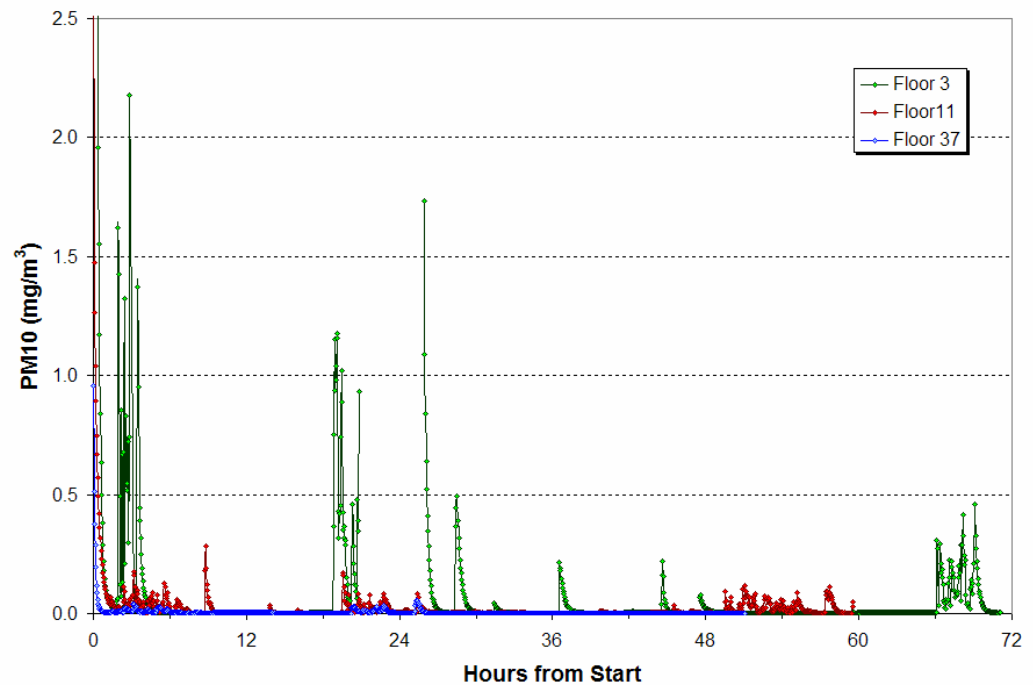


Figure 3. Met One particle mass data for 3 floors studied (expanded vertical scale).

Met One Data - Particle Concentration. The particle count data for the Aggressive Air tests on the three floors are shown in Figure 4 to Figure 6. Figures 4 and 5 show an expanded vertical scale. These figures demonstrate that:

- The highest concentration occurs during the Aggressive Air disturbance (at time 0) and drops to values between 3000 and 5000 particles per liter in 1.3 to 2.3 hours.
- Periods of higher particle concentrations occur during times that workers are in the room sampling (at approximately 24 and 55-70 hours).
- At no time in the three day study did the number of particles counted fall lower than 1254 (floor 3) 422 (floor 11) or 228 (floor 37) particles per liter.
- Data in floor 37 show a broad hump at about 12 hours from the start of the test. This hump is not related to direct worker activity, but does indicate that some process is capable of suspending quantities of dust.

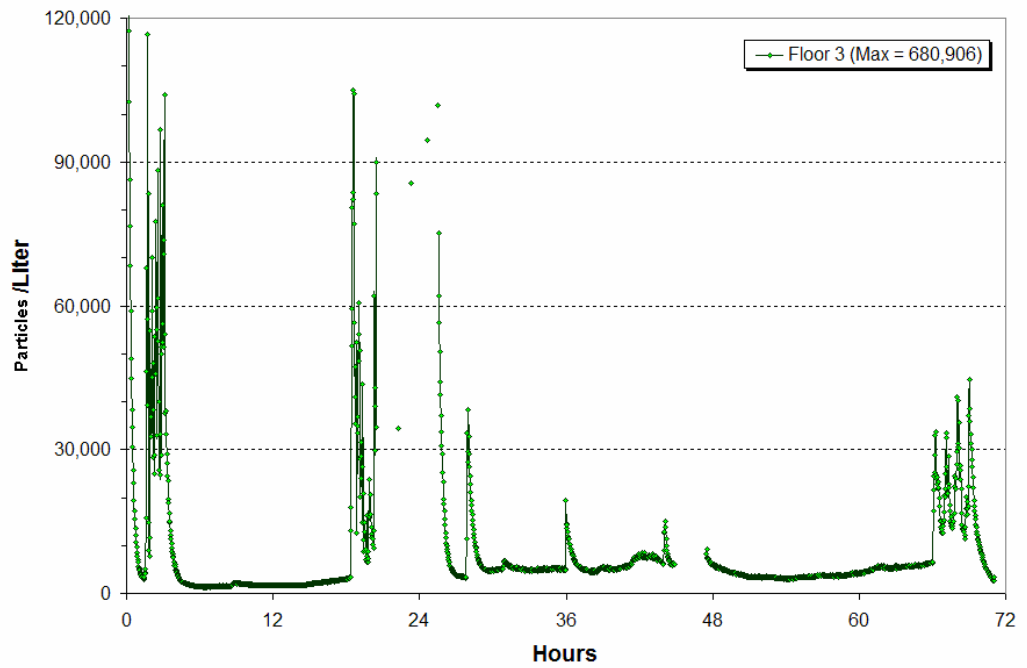


Figure 4. Met One data for particle concentration during 3rd floor testing.

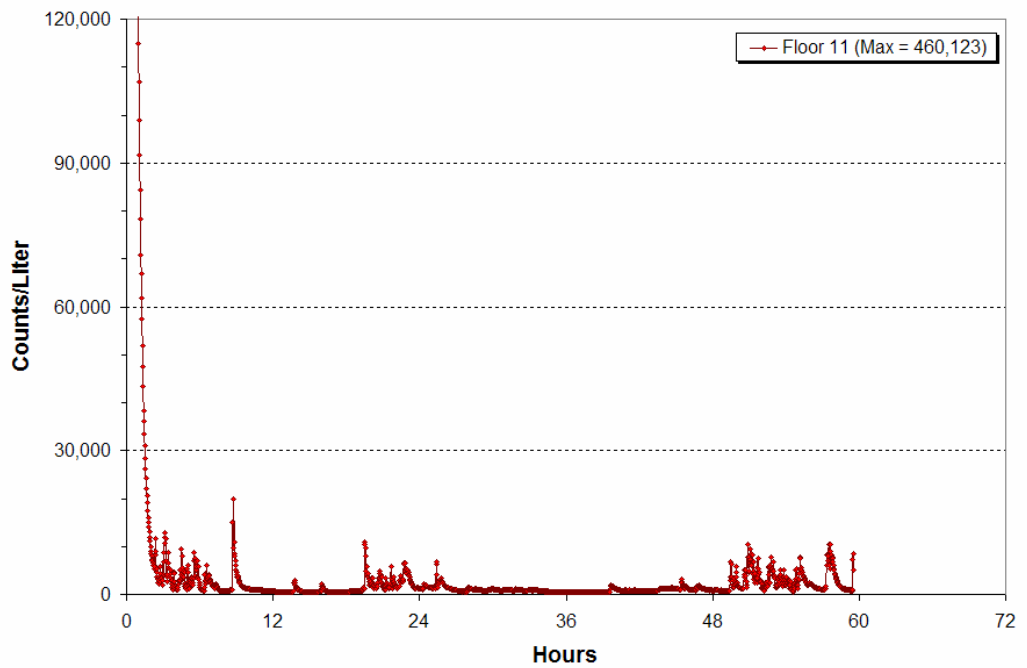


Figure 5. Met One data for particle concentration during 7th floor test.

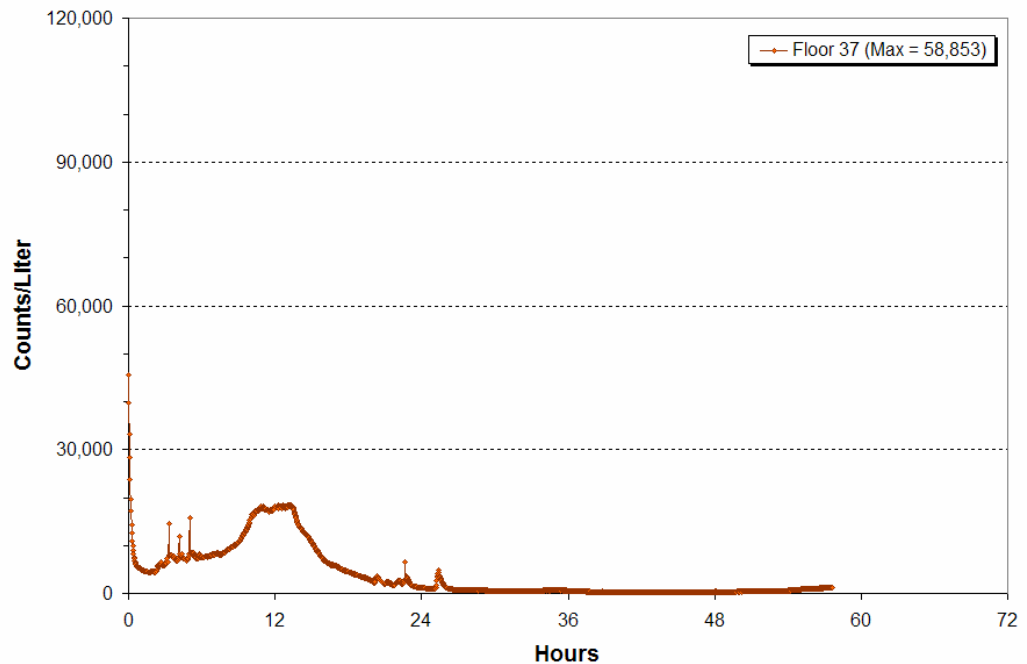


Figure 6. Met One data for particle concentration during 37th floor test.

Area Air Concentrations. The results of the analysis of air samples are presented in Table 2 and summarized below.

- Asbestos fibers were present in samples prepared using direct preparation and analyzed by TEM on all floors tested.
- Airborne asbestos concentrations remained elevated in Day 1 and Day 3 samples.
- Asbestos fibers >5 μm in length were observed on all floors tested.
- Asbestos fibers or bundles with widths of 0.1 μm or less were observed in every sample prepared by direct preparation and analyzed by TEM.
- The dust that was resuspended was confirmed to be WTC Dust by SEM.

Table 2. Area air results by TEM.

		Average Asbestos Concentration (S/cm ³) (Indirect)	Asbestos > 5 μm length (Indirect)	Asbestos Concentration (S/cm ³) (Direct)	Minimum Asbestos width (μm) (Direct)
Post	Floor 3	32.479	Y	0.5233*	*
	Floor 11	0.140	Y	0.0049	0.05
	Floor 37	0.137	Y	0.0011	0.05
Day 1	Floor 3	0.949	Y	0.3900*	*
	Floor 11	0.005	N	0.0016	0.05
	Floor 37	ND	N	Not tested	Not tested
Day 3	Floor 3	0.243	Y	0.0235	0.1
	Floor 11	0.434	Y	ND	ND
	Floor 37	ND	N	Not tested	Not tested

* Direct preparation concentrations estimated from indirect preparation data.¹²

ND indicates non-detect.

Cascade Impactor Concentrations. The results of the analysis of cascade impactor samples are presented in Table 3, and are summarized below.

- Asbestos fibers were present in all post air disturbance samples prepared using indirect preparation and analyzed by TEM.
- Asbestos in the <0.5 μm width size range was present on all floors.
- The dust that was resuspended was confirmed to be WTC Dust by SEM.

Table 3. Cascade Impactor Results by TEM.

		Average Asbestos Concentration (S/cm ³)	Asbestos width < 0.5 μm
Post	Floor 3	4.435	Y
	Floor 11	0.062	Y
	Floor 37	0.021	Y
Day 1	Floor 3	0.424	Y
	Floor 11	0.002	Y
	Floor 37	0.003	N
Day 3	Floor 3	0.148	Y
	Floor 11	0.211	Y
	Floor 37	0.018	Y

Note: Two to three sets of cascade impactor samples were collected from 3 locations in each test room. Each cascade impactor consists of 5 filters. The data for each sample are the sums of results for the five filters. Average values for the test locations are reported here.

Surface and Settled Dust. The results of the analysis of dust on Building surfaces and dust fall pans are presented in Table 4 and summarized below.

- The pre-aggressive air disturbance wipe samples contained asbestos at levels between 20,000 and 718,000 S/cm². This is 130 to 4,600 times the Appropriate Level (156 S/cm²).¹
- The dust fall pans that collected settled particles for approximately two to three hours following the aggressive air disturbance contained asbestos at levels between 9,000 and 5,159,000 S/cm². This is 60 to 33,000 times the Appropriate Level (156 S/cm²).
- The dust fall pans that collected settled particles from approximately three hours following the aggressive air disturbance to approximately one day following the aggressive air disturbance contained asbestos at levels between 69 and 56,000 structures per cm². This is up to 360 times the Appropriate Level (156 S/cm²).
- The dust fall pans that collected settled particles from approximately 24 hours following the aggressive air disturbance to approximately three days following the aggressive air disturbance contained asbestos at levels between 205 and 199,000 S/cm². These are over 1000 times the Appropriate Level (156 S/cm²).

Table 4. Surface Dust and Dust Fall Pan Results.

Time (Collection Method)	Average Surface Asbestos TEM Concentration (S/cm ²)			
	Floor 3	Floor 11	Floor 37	Average
Pre (Surface Wipe)	718,169	20,882	189,263	309,438
Post (Dust Pan)	5,159,513	21,572	9,367	1,730,150
Day 1 (Dust Pan)	56,666	601	69	19,112
Day 3 (Dust Pan)	161,715	199,015	205	120,312

Note: Two wipe samples were collected from furniture in each test room to represent the pre-test condition. Three sets of clean dust pans were deployed in each test room at each sampling period.

Resuspension Effectiveness. The asbestos resuspension effectiveness (RE) values are a measure of how the air concentration relates to the surface concentration. The asbestos RE values (Table 5) for indirect preparation analyzed by TEM range from less than 7 to 452 times 10⁻⁷. These values are within one order of magnitude of those reported in another study.⁵ The correlation coefficient between average resuspended airborne asbestos and average pre-aggressive surface asbestos is 0.97; the value for a perfect correlation is 1.0.

The direct preparation concentration in Table 6 was estimated based on the calculations detailed in another report,¹² the numbers are in good agreement with other studies and with those of Chatfield and Kominsky.¹³

Table 5. Average Post Aggressive area air asbestos by indirect preparation AHERA compared to average pre-test asbestos on surfaces.

Test Floor	Average Concentration of Resuspended Asbestos in Disturbed Air by Indirect Preparation Analyzed by TEM (s/cm ³)	Average Concentration of Asbestos on Surface by Indirect Preparation Analyzed by TEM (s/cm ²)	Asbestos Resuspension Effectiveness (s/cm ³) / (s/cm ²)
Floor 3	32.479	718,169	45.2 x 10 ⁻⁶ *
Floor 11	0.140	20,882	6.70 x 10 ⁻⁶
Floor 37	0.137	189,264	0.724 x 10 ⁻⁶

* 45.2 x 10⁻⁶ is equal to 0.0000452.

¹² RJ Lee Group, "Technical Memorandum S6: Impact of Indirect Preparation Techniques on the Number of Asbestos Fibers Observed in WTC Dust," May, 2004.

¹³ Chatfield, E.J., and Kominsky, J.R., "Summary Report: Characterization of Particulate Found in Apartments after the Destruction of the World Trade Center," 2001.

Table 6. Average Post Aggressive area air asbestos by direct preparation AHERA compared to average pre-test asbestos on surfaces.

Test Floor	Average Concentration of Resuspended Asbestos in Disturbed Air by Direct Preparation Analyzed by TEM (s/cm ³)	Average Concentration of Asbestos on Surface by Indirect Preparation Analyzed by TEM (s/cm ²)	Asbestos Resuspension Effectiveness (s/cm ³) / (s/cm ²)
Floor 3	0.87	718,169	1.21 x 10 ⁻⁶ *
Floor 11	0.005	20,882	2.39 x 10 ⁻⁷
Floor 37	0.001	189,264	5.28 x 10 ⁻⁹

* 1.21 x 10⁻⁶ is equal to 0.00000121.

5.0 Discussion

The major spikes in the mass of airborne particles that are less than 10 µm after aggressive air testing occur at times when workers enter the test area for sample collection. In the test on floor 3, the workers doing normal (non-aggressive) sampling activity such as changing air filters and collecting and setting out new clean dust fall pans resuspended more than 2000 mg/m³ of PM10 dust. This level is more than 13 times the level established by the EPA as a screening level for sensitive groups.¹¹ The work activity is not aggressive, but is similar to what would be encountered in normal occupied building activity. This test demonstrates the ease with which WTC Dust and WTC Hazardous Substances can be resuspended. Although the level of respirable particles that are less than 10 µm dropped off quickly after workers left the area, it was resuspended when the worker returned to collect additional samples.

Because particle resuspension occurs as a result of workers collecting samples, there is no direct evidence indicating whether asbestos samples collected on Day 1 and Day 3 were resuspended by workers during sampling or if the asbestos had remained suspended since the original aggressive air disturbance. Data presented by Chatfield⁷ shows settling rates for asbestos as a function of fiber diameter. Asbestos size has been measured in the directly prepared and analyzed by TEM area air samples indicating that fibers could remain in suspension for three days to eight weeks.⁷ The cascade impactor data show asbestos in the range of 0.5 µm and 0.25 µm in width and smaller indicating that they could remain suspended for one to three days.⁷

The relationship between airborne and surface asbestos concentrations was established in another study.² The presence of respirable asbestos fibers in the air on floors 3, 11 and 37 demonstrates that airborne asbestos is present either on a continuous basis for at least three days or when the room is entered for sample collection.

Analysis of dust fall pan wipes demonstrates that a portion of the resuspended asbestos settles onto clean surfaces over time. The concentration of settled asbestos is highest on the third floor where the surface dust load was the highest and lowest on Floor 37 where the dust load was the lowest.