Damage Assessment
130 Liberty Street Property

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WTC Dust Signature Report
Asbestos

Summary Report

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1.0 Summary

The World Trade Center destruction commencing on September 11, 2001 ("WTC Event") physically destroyed significant portions of the interior and exterior of the building located at 130 Liberty Street, New York, NY (the "Building"). A gash was created in the north side of the Building; the plaza in front of the Building was crushed which exposed the Level A and Level B Basement areas and the first floor; approximately 1,500 windows were broken; and the Building was exposed to the elements as well as being filled with a combination of soot, dust, dirt, debris, and contaminants. For a period of time following the WTC Event, the Building owner, Deutsche Bank Trust Company Americas (the "Bank"), was precluded by the City of New York from entering the Building. After the Bank gained access to the Building, the Bank retained the services of engineering firms to assess the physical damage. Additionally, an environmental firm was retained to conduct limited sampling for asbestos, heavy metals, and biological contaminants.

In April of 2002, RJ Lee Group was retained by the law firm of Pitney Hardin Kipp & Szuch LLP, on behalf of the Bank, to oversee and investigate the presence, type, amount, and extent of environmental contaminants in the Building and to recommend remediation strategies. The findings set forth in this report are based upon RJ Lee Group's review of the results of its own extensive set of analyses, its background, experience, and education in this area, as well as its study of recognized scientific literature.

1.1 Investigation

The collapse of a major building can produce significant quantities of dust and debris comprised of the construction materials and the contents of the building. Fires in commercial office buildings can produce combustion products including soot, partially combusted aerosolized particles and organic vapors. The amounts and portions of the various products of combustion will depend upon the source materials, the combustion temperatures, the availability of oxygen and other oxidants, the duration of the fires, and other factors. The WTC disaster uniquely combined several cataclysmic destructive processes in a single event. This report evaluates the features of the WTC Dust and WTC Hazardous Substances deposited in the Building as a result of the collapse, ground impact, fires, pressure forces, and other phenomena arising from the WTC Event.

As a result of this investigation, it was determined that WTC Dust contains various solid phases that include asbestos and minerals, metals and mercury, organic pollutants and particles of various sizes and different morphological characteristics. The distinctive composition, solid phases, and unique morphological features have allowed for the development of a "WTC Dust Signature": dust containing particles that, when occurring together, can be considered to act as identifying source tracers. The WTC Dust Signature can be compared with dusts of unknown provenance using conventional source apportionment methodologies, forensic tags derived from microscopic observations, or statistical analysis. These techniques are a scientifically recognized methodology used to determine source impact by comparing dust from an unknown source to reference source signatures. In this case, the dust of unknown origin can be compared to the WTC Dust Signature to determine what component or fraction of the material is the result of the WTC Event.

To evaluate the validity of the WTC Dust Signature as a unique identifier, dust samples were collected from a number of representative office buildings, "Background Buildings", in typical urban locations including Midtown Manhattan, New York City, NY, Washington, D.C., Pittsburgh and Philadelphia, PA, and Florham Park, NJ. See RJ Lee Group "Background Levels in Buildings" report. Additionally, dust samples collected from the New York City area collected and analyzed prior to 9/11/2001 were reevaluated. The pre-WTC Event samples, collected in the spring of 2000, included materials from both the interiors of the World Trade Center Towers as well as exterior samples, taken in close proximity to the Towers. The Background Building samples and the pre-WTC Event samples were compared to known WTC Dust for the forensic evaluation, using the source apportionment methodologies to determine the extent of the WTC Dust impact.

This WTC Dust evaluation represents the most extensive microscopic investigation related to WTC Dust ever performed. Over 400,000 particles were classified using SEM techniques with approximately 80,000 images collected.

[12] See Report to Insurers

2.0 Background

The purpose of this report is to describe the asbestos contamination in the Building, and those attributes of the asbestos released by the WTC Event that make it a marker for WTC Dust in the Building, and a component of the "WTC Dust Signature". In addition, this report deals with those aspects of WTC asbestos that differentiate it from asbestos in the environment, and from asbestos deposited on surfaces, or suspended in the air in buildings which contain asbestos containing materials.

This comparison is based on the extensive sampling of ambient air and dust in buildings with asbestos containing surfacing materials (Lee et al., 1992), and on data produced by RJ Lee Group in 2000, of air and dust samples in and around the WTC in a matter entitled Port Authority of New York and New Jersey, et al, v. Affiliated FM Insurance Co., et al.

Finally, this report deals with the impact of sample collection and preparation methods on the WTC Asbestos—because of the well-known tendency for the methods used in this study to break-up non-respirable particles containing asbestos into apparently respirable fibers, and the propensity of the asbestos in WTC Dust to result in asbestos that is in the respirable size range.

2.1 Chrysotile Asbestos Occurrence

The collapse of the WTC and the associated mechanical pulverization of the building components, coupled with the fires and extreme heat produced by those fires, resulted in the generation of a finely fibrilized asbestos. The source of the asbestos was in part gypsum-based fireproofing in the lower floors of WTC 1, the surface coating in the elevator shafts which contained over 80% asbestos (Langer and Morse, 2001), and other miscellaneous sources such as pipe wrapping and floor tiles that were consumed in the conflagration. It has been estimated that over 300-400 tons of asbestos was used in the WTC construction and systems (NRDC, Feb. 2002).

In contrast, there were no asbestos surfacing materials in the Building, which are historically the major source of asbestos in dust in buildings. There was only a limited amount of asbestos found in carpet mastics, floor tiles, and caulking, pipe wrap and other asbestos-containing material (ACM) potentially in the Building at the time of the WTC Event.[2] Other studies have found that in New York City buildings that did not contain asbestos surfacing materials, the apparent surface concentration of asbestos in occupied areas, as determined by micro-vacuuming the surfaces, was on the order of 1,000 s/cm^2 (Ewing, 2001).

In addition to the Building, samples have also been analyzed from other buildings in New York City as well as buildings in Pittsburgh, PA, Philadelphia, PA, Florham Park, NJ, and Washington DC.

Other related reports deal with the concentration of each of the contaminants, and their variation in each division of the Building. The mean concentrations of the contaminants and their statistical relationship to each other are summarized in the RJ Lee Group "WTC Dust Signature" reports.

2.2 WTC Dust Signature

The term "WTC Dust Signature" describes the unique mixture and morphology of the particles, as well as their associated metals and organics, that permit the recognition of contaminants from the WTC Event.

The particles in WTC Dust have a unique size, morphology and association, not observed in ordinary building dusts. The asbestos, metals, organics, and quartz are found in abundances that are outside of normally expected ranges for a class A office building. This has been discussed in companion reports: WTC Dust Signature: Composition and Morphology; and WTC Dust Signature: Metals and Organics. The concentrations of asbestos, metals, organics, quartz and total dust are highly correlated, and are reiterated in this report for completeness.

The composition and structure of the particles in WTC Dust have been modified by the processes accompanying the WTC Event in a manner that is not observed in particles of typical building dust. The composition and modification of dust has been discussed for non-asbestos particle types in the companion reports. This report focuses on the differences of the composition of asbestos in comparison to that found in ordinary building dust or in the environment. Also addressed is the presence of a reduced size fraction of the asbestos particles liberated by the WTC Event. Reduced size increases the respirability of WTC asbestos relative to ordinary building dusts, and increases its propensity to become airborne. The components that make up the essence of the WTC Dust Signature are summarized below.

Asbestos, metals, and organics are found in concentrations in WTC Dust not observed in ordinary building dusts.

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The average, maximum, and upper confidence limit on the concentration of the major contaminants found in the Building are summarized in **Table 1**, and compared with the estimates of those contaminants in regularly cleaned spaces in other non-affected buildings. Statistical scrutiny of these data determined these differences to be significant.

Table 1. Summarization of Results for the Building and Background Buildings

	130 Liberty		Background Buildings	
Analyte	Average	Maximum	Average	Maximum
Asbestos (s/cm^2)	2,023,000	70,392,000	106	691
Barium (µg/ft^2)	165	5,050	0.356	3.10
Beryllium (µg/ft^2)	1.28	57	0	0
Cadmium (µg/ft^2)	10.43	425	0.022	0.383
Chromium (µg/ft^2)	94	2,310	0.226	1.61
Copper (µg/ft^2)	466	13,500	1.01	5.05
Lead (µg/ft^2)	249	7,940	0.134	2.53
Manganese (µg/ft^2)	609	23,700	0.253	2.73
Mercury (µg/ft^2)	0.50	20.40	0.004	0.038
Nickel (µg/ft^2)	36	4,110	0.22	3.45
Zinc (µg/ft^2)	6,341	1,460,000	4.77	21
PCB (ug/100 cm^2)	0.049	2.72	0.00085	0.015
PNA (µg/100 cm^2)	3.18	134	0.00482	0.125
Dust (g/m^2)	7.90	460	0.003	0.Th
Quartz (µg/ft^2)	0.20	14.90	0.00006	0.001
TEQ (pg/100cm^2)	49	2,954	0.00007	0.0009

Graphically, these relative abundances can be displayed as absolute values by using the appropriate units as a measure of concentration for each contaminant, thus illustrating graphically the WTC Dust Signature as illustrated in **Figure 1**.

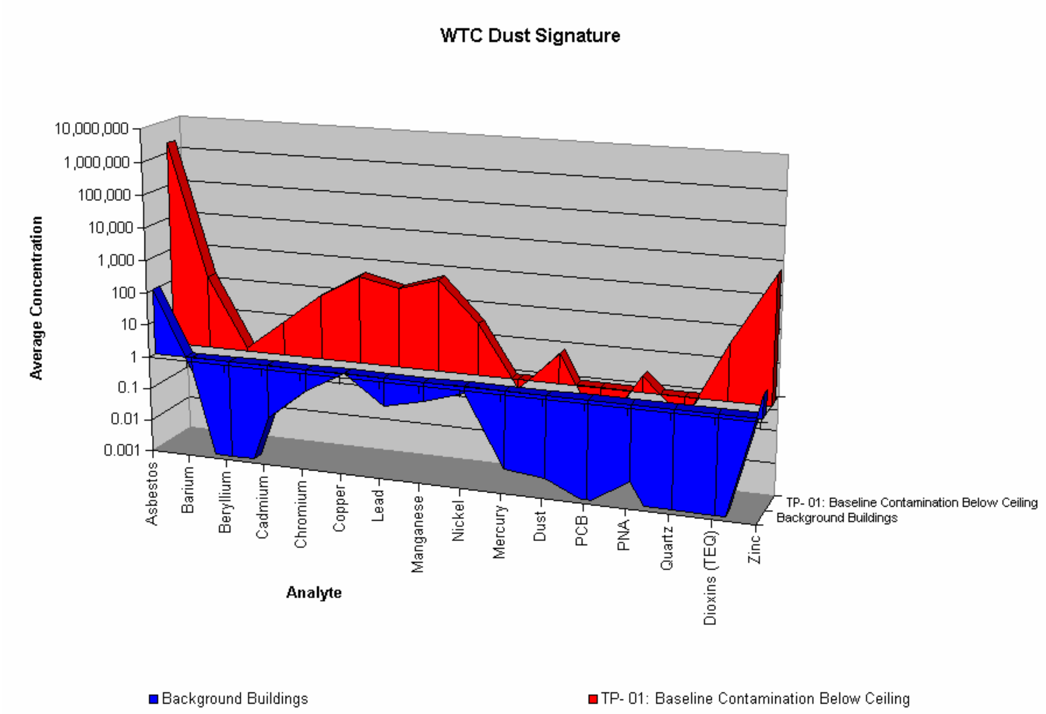


Figure 1. WTC Dust Signature (TP-01) compared to Background Buildings

2.2.1 The concentrations of the contaminants are highly correlated in WTC Dust and not correlated in ordinary building dusts.

Correlation matrices illustrating the highly correlated nature of the contaminants in the Building and the absence of such correlations in the Background Buildings can be found in the RJ Lee Group "WTC Dust Signature Report: Metals and Organics". The numerical values of the correlation coefficients are shown in the matrices of **Tables 2** and **3** of that report. Values approaching 1 indicate a higher degree of correlation. It is apparent that even when a correlation exists in other buildings, the same correlation is much stronger in the WTC Dust. It is this strong correlation among the contaminants that makes the relative concentrations shown in **Figure 1** to have scientific certainty and predictive value.

2.2.2 The morphology and composition of asbestos in the WTC Dust are unique.

Chrysotile asbestos has a characteristic composition and internal structure in which eight magnesium (Mg) atoms are paired with seven silicon (Si) atoms. **Figure 2** contains a TEM brightfield image and selected area electron diffraction (SAED) pattern collected from a standard reference chrysotile fiber. **Figure 3** displays an EDS spectrum collected from a standard reference chrysotile fiber. The magnesium to silicon peak height ratio is approximately 1:1 with a quantitative evaluation of approximately 40% to 60% Mg to Si by weight.

Figure 4 and **Figure 5** contain information similar to **Figure 2** and **Figure 3**, but for WTC chrysotile. The peak height ratio of magnesium to silicon is approximately 1:3 with a quantitative evaluation of approximately 20% to 60% Mg to Si by weight. The magnesium concentration is also low in the WTC chrysotile. In addition, elements such as aluminum, iron and in some cases zinc, vaporized during the conflagration and condensed on the chrysotile surface, an effect only observed in fire damaged circumstances.

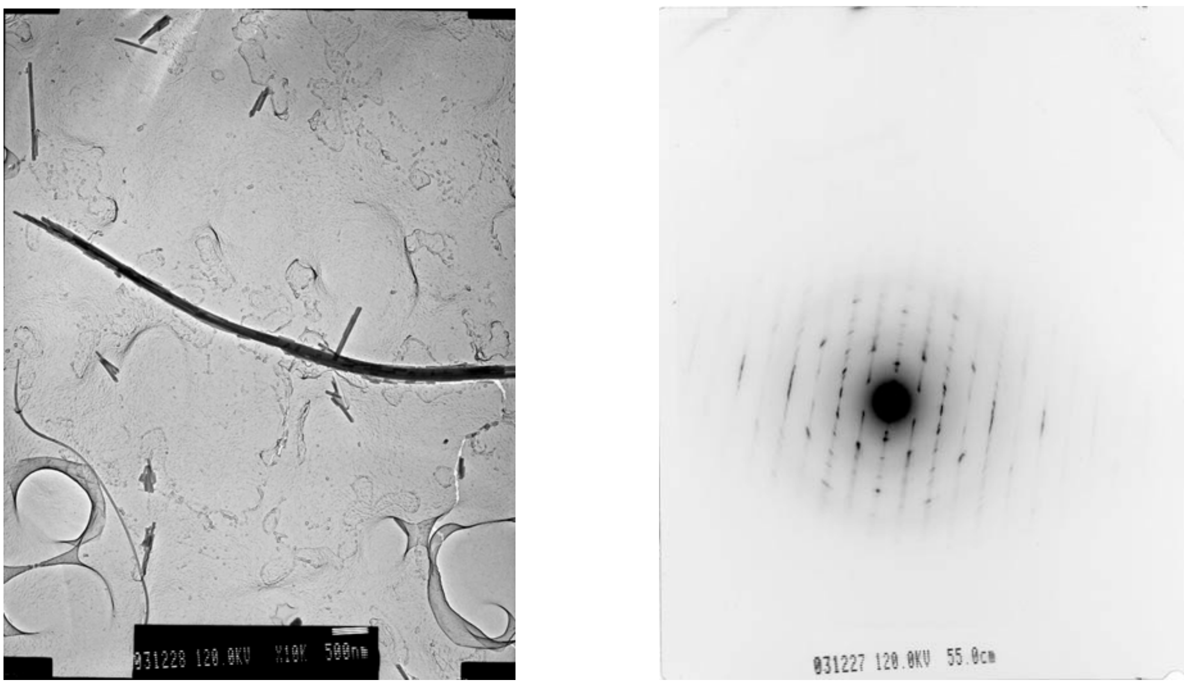


Figure 2. TEM brightfield image and SAED pattern collected from standard reference chrysotile. Fibers exhibit typical morphology with smooth edges and internal passages

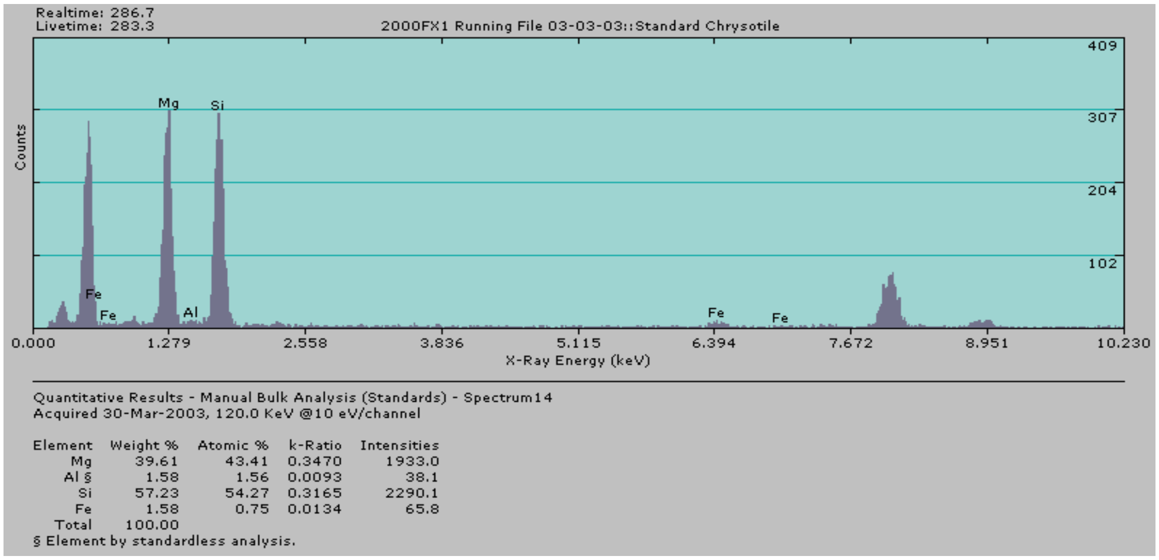


Figure 3. EDS spectrum collected from standard reference chrysotile

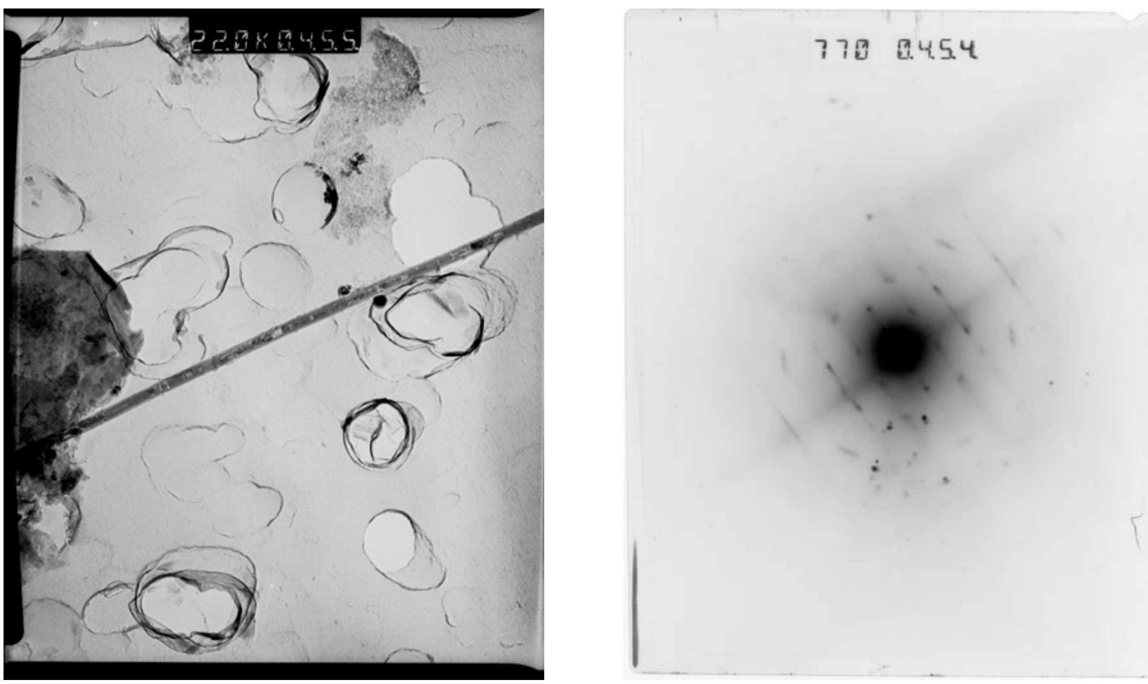


Figure 4. TEM brightfield image and SAED pattern collected from WTC chrysotile fiber. Internal structure is altered and diffraction pattern indicates signs of transformation

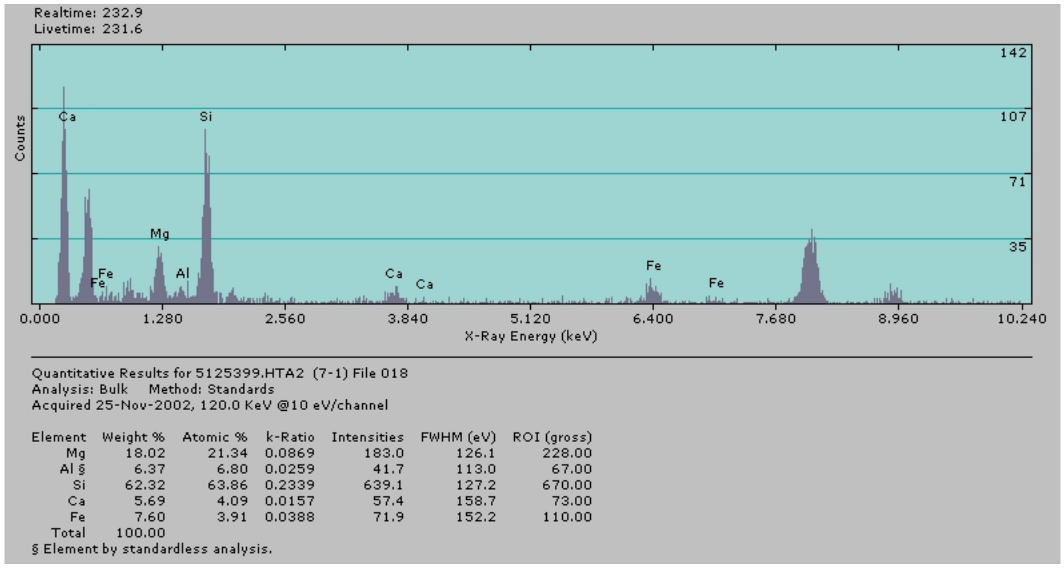


Figure 5. Example EDS spectrum collected from WTC chrysotile fiber. Note Mg/Si ratio is low while Fe and Al are high as compared to standard reference chrysotile (Figure 3)

2.2.3 There is a difference in the chrysotile of WTC Dust as compared to standard reference chrysotile as seen in the SEM EDS data.

Relative elemental concentrations can be estimated from the peak areas in the energy dispersive spectrometry (EDS) performed as part of the scanning electron microscopy (SEM) analysis of the dust in the Building. An example SEM image and EDS spectrum of chrysotile is shown in **Figure 6**. This spectrum shows a Mg/Si ratio of 1.0. These data are compared to the composition of standard reference chrysotile (NBS 1866) as illustrated in **Figure 7**. This spectrum shows a Mg/Si ratio of 1.19. **Figure 8** is a bar graph of the Mg concentration divided by the Si concentration of 141 asbestos fibers observed in seven of the testing protocols. This graph illustrates a difference in the composition of the standard reference chrysotile versus the WTC chrysotile observed in the Building. There is a shift in the Mg/Si ratios from an average of about 1.17 in the standard reference chrysotile to about 0.95 in the WTC chrysotile, which provides a unique signature for this material.

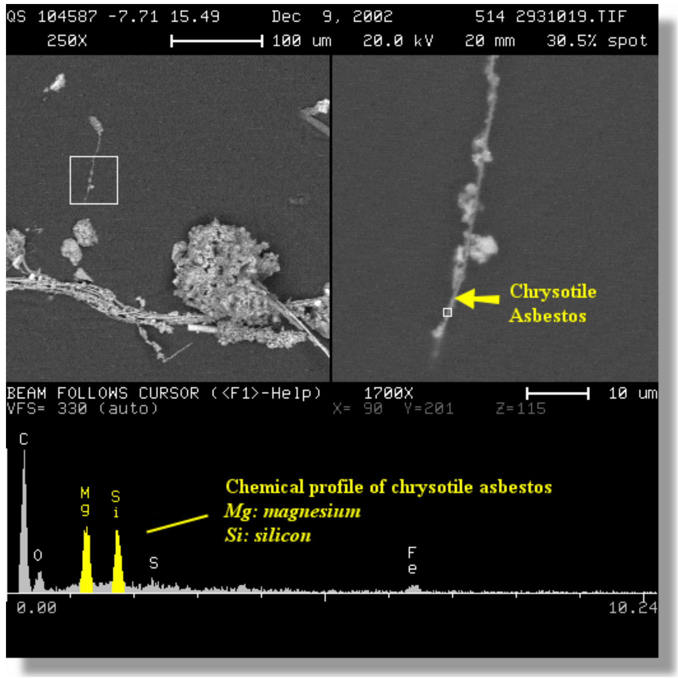


Figure 6. SEM image and EDS of chrysotile from a TP-01 sample

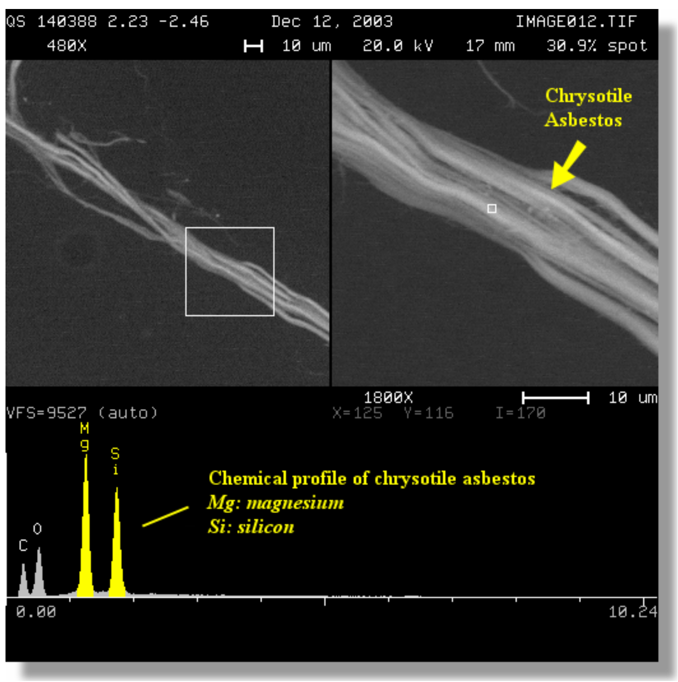


Figure 7. SEM image and EDS of chrysotile from Standard Reference Chrysotile (NBS 1866)

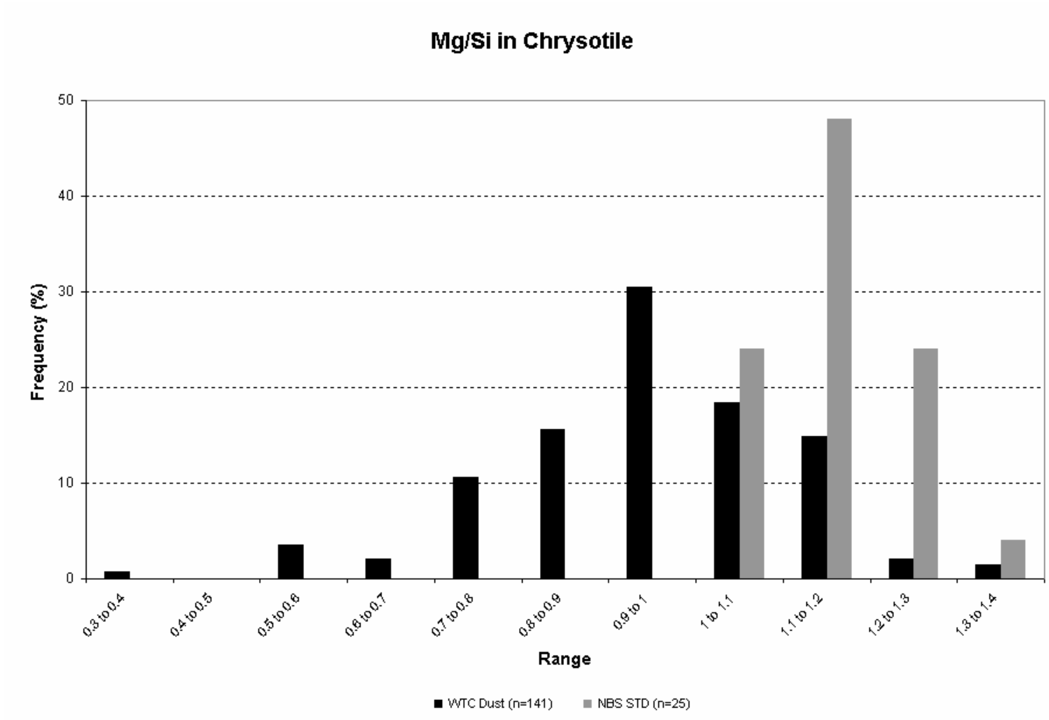


Figure 8. Graph showing the SEM/EDS Mg/Si ratio in WTC chrysotile as compared to standard reference chrysotile

2.2.3.1 WTC Asbestos vs. ordinary building dust: size and morphology

Ordinary building dust contains very small quantities of fine environmental asbestos. The fibers are typically less than 2 micrometers in length and on the order of 0.05 micrometers in diameter. Buildings with asbestos containing surfacing products may also contain debris particles on some surfaces. These debris particles, if present, may often be on the order of millimeters in size. They typically would only be found immediately adjacent to surfacing material that had been disturbed. These debris particles would not generally be respirable, and even disturbance of the debris would not typically generate any significant airborne asbestos concentrations. (Chatfield, 1999) This is reflected by data that indicate the airborne asbestos concentrations in asbestos-containing buildings differ very little from outdoor air. (Lee et al., 1992)

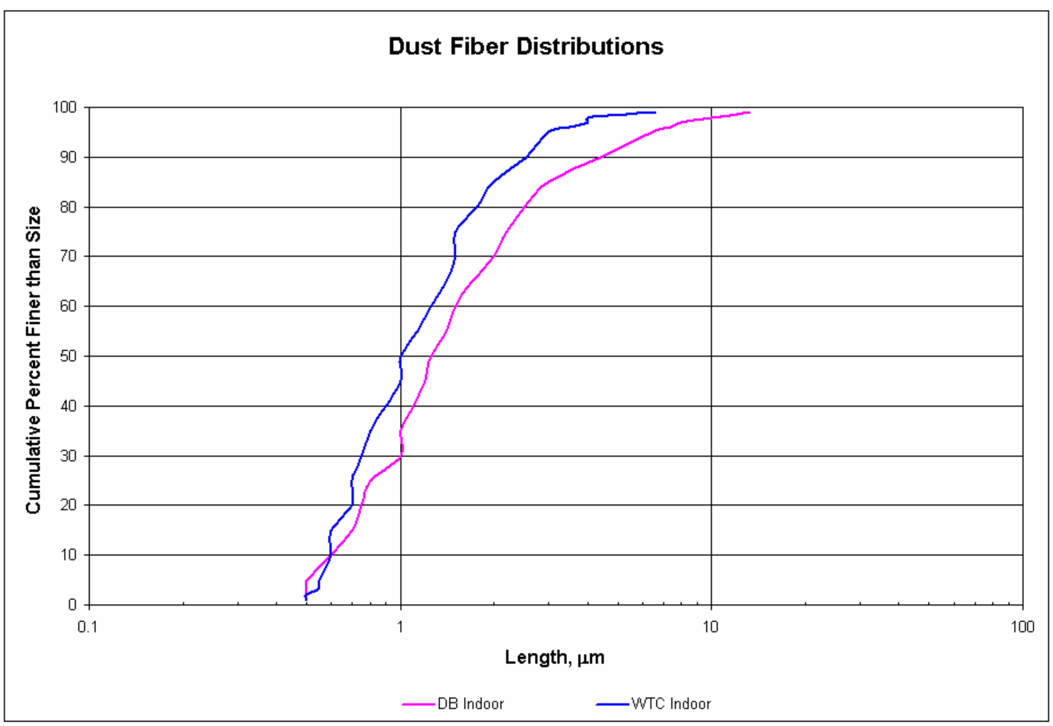
The explosive nature of the collapse reduced many of the large bundles making up the ACM in the WTC to find respirable dust. In contrast, in debris falling onto surfaces from surfacing materials, the bundles are encapsulated in binder materials, making them even less likely to be retrained (Millette, 2003 and Chatfield, 2003).

Dust samples collected from the WTC Event were analyzed for the size of chrysotile fibers as measured in the TEM. These measurements were also performed on samples collected from the Building post-WTC Event. Samples were prepared for TEM analysis by the indirect method, which is known to affect the length and width of asbestos fibers as discussed below. Samples were also prepared by the direct preparation process, and are described below.

The data for mean length and mean width are shown in **Table 2**. The chrysotile fibers in dust from the Building are longer than dust observed in the WTC Towers pre-WTC Event (**Figure 9**). For example, the percentage of fibers longer than five micrometers in the dust in the Building was 9.2%, whereas the percentage of fibers longer than five micrometers in the WTC Dust in 2001 was 1.5%.

Table 2. Fiber Size statistics for dust samples collected from the Building

Building	Matrix	Location	Preparation	Number	Mean Length	Mean Width	% > 5 ųm
The Building	Dust	Indoor	Indirect	20,038	2.113	0.092	9.2
WTC	Dust	Indoor	Indirect	342	1.373	0.065	1.5



The reduction of asbestos to long, thin fibers affects the size of airborne fibers as well.

Direct measurements of the airborne concentrations were made during health and safety operations, and during experiments designed to evaluate potential airborne concentrations in comparison to background or outdoor levels. These measurements indicate that the airborne fibers resulting from disturbance of the WTC Dust are much longer than those found in asbestos-containing buildings or in outdoor air. In addition, the length of fibers observed in outdoor samples in the vicinity of the Building is much longer than those found in previous studies of outdoor air in cities around the country.

Generally, less than one percent of fibers in ordinary building air exceed 5 microns in length (Lee et al., 1992). In fact, outdoor air samples previously collected from various areas in and around New York City exhibited no fibers larger than 5 microns in length.

Approximately 20% of fibers found on indoor air samples in the Building exceeded five micrometers in length. Of the 20%, more than half are greater than 10 microns in length. This size differential makes the airborne asbestos from WTC Dust much more toxic than that from ordinary building dust.

2.2.3.2 *WTC Dust is less susceptible to the effects of in-direct preparation than ordinary building dusts.*

Asbestos exposure is determined through the collection and analysis of air samples. Preparation techniques have engendered a long-term debate within the analytical community. The core issue centers around the fact that asbestos is the only carcinogen whose potency is directly related to the numerical concentration of airborne asbestos to which a person is exposed (HEI, 1991). That fact makes it imperative that the exposure determination accurately reflect the airborne concentration of respirable asbestos fibers. Therefore, if the method of preparing the samples for examination in the optical or electron microscope modifies the length or diameter of fibers, the estimate of exposure is biased, thus generally overestimating the concentration of airborne asbestos fibers.

The debate is about the two methods by which asbestos samples are prepared. These are referred to as direct and indirect preparation.

Direct preparation techniques are used for assessing exposure to airborne asbestos and are the conventional techniques used to assess risk from asbestos exposure. Direct preparation is accomplished by depositing a layer of carbon on the filter on which air samples are collected, and dissolving the filter media, leaving the particles that were captured on the filter entrained.

Indirect preparation is generally unsuitable for exposure assessment, because the process affects the size distribution of the asbestos fibers sampled, often breaking non-respirable fibers into respirable size fractions. This effect is minimized for long, thin fibers, but cannot be eliminated.

Proponents of indirect preparation often do not recognize the effect of the disruption, nor account for the disruption in their measurement process. (Millette & Hays, 1994 and Beard et al., 1996). As a result, they have produced grossly inflated estimates of the exposure of building occupants (Lee 2.4, Port Authority, HEI, (Burdette, 1985). They also advocate use of estimates of the surface concentrations of asbestos as a predictor of past or future exposures (Millette et al., 1990). In ordinary building dust, the asbestos surface concentrations have no relationship to airborne concentrations (Lee et al., 1999).

As described above, air sampling has been conducted in conjunction with surface dust measurements during normal and simulated activities in the building. These samples have been prepared using both direct and indirect preparation methods.

The effect of the indirect preparation on the size of asbestos fibers in the air in the Building is shown in **Table 3**. The median length and width found by the indirect preparation method are about 50% of the median length and width of the fibers found by the direct method of preparation. This indicates that on average, the indirect estimates of airborne concentration are about 8 times higher than the actual exposures. In contrast, estimates of the inflation of the apparent concentration in ordinary building dust range as high as a thousand-fold increase (Lee et al., 1995, Port Authority, 2000).

Table 3. Dimensions of Indoor Air Samples From The Building

		Mean		Median		Percent
Preparation	**Number**	**Length**	**Width**	**Length**	**Width**	**≥ 5µm**
Indirect	2516	1.418	0.067	1.000	0.050	2.9
Direct	742	3.851	0.148	2.000	0.100	21.6

This is not to say that indirect preparation has no place in assessing contamination (Burdette, 1985). In comparing the direct and indirect techniques, it can be noted that the direct methods provide a measure of exposure, and the indirect methods provide a measure of pollution. The ASTM dust method cautions that the surface measurements should be regarded as an index of concentration, rather than an absolute measure. The Draft ASTM Guide for the use of the method recognizes the limitation of surface dust measurements if insufficient samples are collected. The Guide recognizes the utility of the method in determining the extent of contamination, pre- and post-cleaning values, and comparing the extent of contamination in different buildings or following disasters, such as fires or earthquakes, if the number of samples collected permits an analysis of the statistical significance of the results.

2.2.3.3 WTC Dust has a higher potential for re-entrainment than Background Building Dust.

As mentioned above, past studies have shown that indirect preparation methods are useful for quantifying the extent and amount of asbestos dispersed on surfaces, but do not correlate with airborne concentrations. In contrast, estimates of surface concentrations of asbestos using SEM-based surface samples collected using adhesive lifts correlate with airborne exposures resulting from dust on surfaces (Lee et al., 1995). In that study, the presence of free asbestos fibers (>5 m) on surface dust samples, correlated with elevated airborne asbestos concentrations in simulations of normal household activities. More than 52 percent of dust samples from the interior spaces in the Building collected by adhesive lifts contained free asbestos fibers. This indicates the WTC Dust has potential for elevated airborne concentrations when the dust is disturbed. In contrast, zero percent (zero of 25) of samples in the Background Buildings contained asbestos.