

**Damage Assessment  
130 Liberty Street Property**

**Report Date: December 2003**

**WTC Dust Signature Report  
*Composition and Morphology***

**Summary Report**

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## WTC Dust Signature Report: *Composition and Morphology*

### 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.

## 1.2 WTC Event Dust Constituents

Building materials from which the WTC Towers were constructed include structural steel, asbestos-containing insulation material, other insulating fibrous material (mineral wool and glass fibers), cement and aggregate (concrete), wallboard, ceiling tiles, ducts, wiring, paint, plate glass, and other components. Building contents of the WTC included computers and other electronic equipment, fluorescent lights, furniture, office supplies, and a myriad of other items. The brittle and friable components of these materials were pulverized during the collapse and the combustible components were partially burned in the ensuing fires.

The catastrophic structural collapse of the WTC resulted in coarse fragmentation as well as fine particle dust generation including asbestos and various chemicals of concern. The hazardous materials in the dust originated from many common sources. The National Resources Defense Council (NRDC) report estimated more than 1.2 million tons of building materials collapsed during the WTC Event containing an estimated 300 to 400 tons of asbestos. (NRDC, 2002) Additionally, 50,000 personal computers were destroyed, with each containing approximately 4 pounds of lead. (NRDC, 2002) Additionally, thousands of fluorescent light bulbs, thousands of light switches and other mercury-containing items were destroyed, releasing thousands of grams of mercury into the surrounding environment. These materials, properly contained and applied in their consumer products and form, presented no particular environmental or health hazard. It was, however, the pulverization of these items caused by the WTC collapse that liberated and rendered them bio-accessible, thus creating an environmental hazard.

The conflagration activated processes that caused materials to form into spherical particles such as metals (e.g., Fe, Zn, Pb) and spherical or vesicular silicates or fly ash. The heat generated during the WTC Event caused some plastics to form residual vesicular carbonaceous particles, and paints to form residual spherical particles. Some metals, plastics and other materials were vaporized thus producing new chemicals that were deposited onto the surfaces of solid particulate matter, such as asbestos, quartz, and mineral wool. These dust and heat-processed constituents are not typically found associated with typical office building environments. To prove that the Building has been contaminated with the fallout from the WTC collapse, RJ Lee Group undertook a statistical sampling approach in collecting samples from various regions of the Building and analyzed them for the types and levels of contaminants.

### 1.3 Testing Protocol

Samples were collected from the Building beginning June 08, 2002 using "TP-01: Protocol for the Monitoring of Non-Biological Indoor Environmental Contaminants at 130 Liberty Street" dated May 10, 2002. Samples were also collected from Background Buildings beginning February 04, 2003 using the general guidelines of TP-01, Interior Spaces. Sampling kits were taken to each predetermined location for sampling. Sampling kits, each containing media for eight samples, were taken to each predetermined grid location for sampling. Each kit contained:

- Asbestos Wipe
- Silica Microvac
- Metals Wipe

- Mercury Wipe
- Dust Lift
- PNAs Wipe
- PCBs Wipe
- Dioxins/Furans Wipe

The sample location selection procedures involved and a summary of the statistical analysis are set forth in the Addenda. The test protocols set forth the complete methodology and a detailed discussion of sampling design, and statistical analysis are contained in the Insurance Claim Report dated May 2003, Volume III: Statistical Analysis.

Samples were analyzed using industry standard analytical laboratory methods as follows:

- Samples were analyzed for asbestos using transmission electron microscopy (TEM) in accordance with ASTM D-5755.
- Samples were analyzed for metals in accordance with NIOSH 7300 method, using inductively coupled argon plasma (ICP) spectrometry.
- Samples were analyzed for mercury in accordance with EPA Method SW 846 7471A, using cold vapor atomic absorption (CVAA).
- Samples were analyzed for PCBs in accordance with EPA Method SW 846 8082 using gas chromatography with electron capture detectors (GC/ECD).
- Samples were analyzed for PNAs in accordance with EPA Method SW 846 8270C using gas chromatography with mass spectrometry (GC/MS).
- Samples were analyzed for dioxins/furans in accordance with EPA Method SW 846 8290 using gas chromatography with high-resolution mass spectrometry (GC/HRMS).
- Samples were analyzed for particle characteristics using scanning electron microscopy (SEM), coupled with energy dispersive spectroscopy (EDS) techniques.
- Samples were analyzed for silica using X-ray Diffraction (XRD) in accordance with NIOSH 7500 and NIOSH 0600 methods.

## 1.4 Findings

Detailed characterization of WTC Dust revealed that it possessed a unique set of characteristics by which it could be identified and differentiated to a reasonable degree of scientific certainty from dust that had other origins. Thus, dust that was found as a pervasive contaminant in the Building was unequivocally identified as coming from the WTC Event. The conclusions reached in this report regarding dust found in the Building are as follows:



- Particulate with the WTC Dust Signature was observed throughout the Building.
- The identity, concentration, and characteristics of the particles and the chemical composition of the WTC Dust constitute a complex, recognizable pattern or “signature.”
- The identification of WTC Dust is not based on an individual characteristics, but rather on a profile comprised of the WTC Dust Markers.
- The presence of WTC Dust in a sample of Building dust can be established using conventional forensic and statistical methodology with a high degree of scientific certainty.

The analytical results are as follows:

- Chrysotile asbestos was pervasively present in the Building. The WTC towers were built, in part, using fireproofing materials that contained chrysotile asbestos. In contrast, the Building was not constructed with asbestos-containing surfacing materials. Chrysotile asbestos is a distinguishing WTC Dust Marker for WTC Dust.
- Mineral wool was pervasively present in the Building. Mineral wool is a WTC Dust Marker for WTC Dust. The WTC towers used construction materials that contained mineral wool.
- Gypsum, also designated as a WTC Dust Marker for WTC Dust based on its high abundance and small particle size (not its mere presence), was ubiquitously present in the Building.
- Particles of partially burned or melted plastic (vesicular carbonaceous particles), not expected in “normal” dust, were commonly observed in WTC Dust due to the fire that accompanied the WTC Event. Additionally, the concentrations of various burned phases and the characteristics of specific phases, also proved to be excellent “fingerprints” for WTC Event dusts.
- Particles of materials that had been modified by exposure to high temperature, such as spherical particles of iron and silicates, are common in WTC Dust because of the fire that accompanied the WTC Event, but are not common in “normal” interior office dust.
- The investigation has established that WTC Dust is a carrier of toxic substances.

To facilitate the comparison between WTC Dust and typical background dust, the respective dust constituents based on SEM data were plotted on a “ternary” diagram and data was grouped into three distinct classes to reflect differences in origin (**Figure 1**).

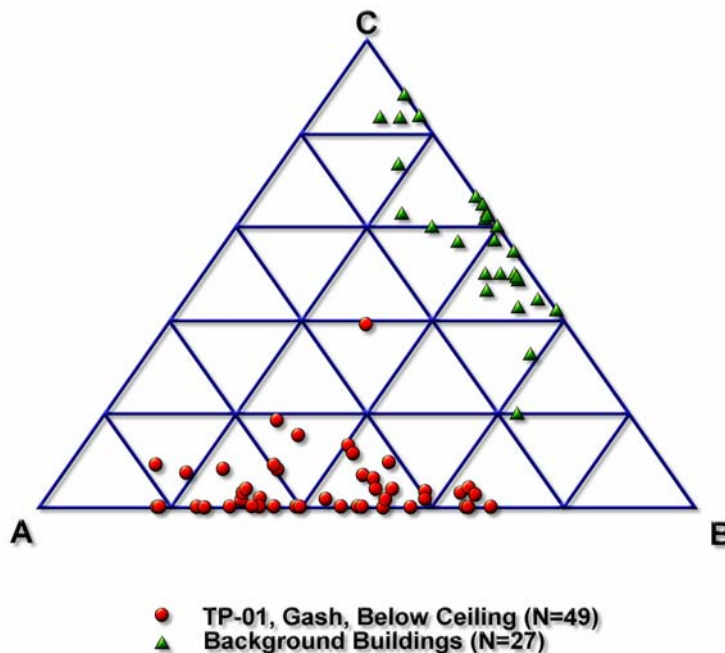


Figure 1. Ternary plots of TP-01 *gash* below ceiling and Background Building samples.

Class A consists of the major building materials and particles influenced by high temperature. These particles include characteristic particulate derived from the WTC Event. Class B consists of carbonate and silicate minerals. These are commonly derived from soil, but also represent building materials and could have been derived from the WTC Event. Class C consists of carbon-rich materials. This class includes fibers, flakes, or particles representing hair, cellulose, pollen, skin flakes, and other biological components. These particles represent a major portion of common Background Building dust.

The composition, as observed in **Table 1**, shows that the dust collected from the Background Buildings which were not affected by the WTC Event is considerably different than that collected from the Building. These Background Building samples were dominated by the carbon-rich occurrences supplemented by the aluminosilicate components commonly derived from soil. These results show that the samples collected within the Building are distinctly different in composition and were derived from a different type of source than the dust from the Background Buildings.

Table 1. Average concentrations of analytes in WTC Dust and Background Building dust

Analyte	Units	WTC Dust <sup>1</sup>	Background Building dust
Asbestos	(s/cm <sup>2</sup> )	2,255,433	107
Barium	(ug/ft <sup>2</sup> )	232	0.419
Beryllium	(ug/ft <sup>2</sup> )	1.32	0.025
Cadmium	(ug/ft <sup>2</sup> )	27	0.187
Chromium	(ug/ft <sup>2</sup> )	152	0.571
Copper	(ug/ft <sup>2</sup> )	741	1.64
Lead	(ug/ft <sup>2</sup> )	424	0.325
Manganese	(ug/ft <sup>2</sup> )	693	0.567
Nickel	(ug/ft <sup>2</sup> )	48	1.17
Mercury	(ug/ft <sup>2</sup> )	1.81	0.466
Dust	(g/m <sup>2</sup> )	8.62	0.002
PCB	(ug/100 cm <sup>2</sup> )	0.048	0.002
PNA	(ug/100 cm <sup>2</sup> )	2.91	0.001
Quartz	(g/m <sup>2</sup> )	0.252	<0.001
Dioxin/TEQ	(pg/100 cm <sup>2</sup> )	51	0.000
Zinc	(ug/ft <sup>2</sup> )	24,614	7.40

As described above, the typical office dust is composed heavily of organic and other carbon-rich particulate materials. WTC Dust, conversely, contains very little pristine organic fibrous or particulate material. Much of the organic or polymeric content of the WTC Dust has been heat hydrolyzed and partially consumed or burned. Therefore, a residual vesicular type of carbonaceous component persists in the WTC Dust. In addition to the vesicular carbon components, the high heat exposure of the WTC Dust has also created other morphologically specific varieties of particulate matter including spherical metallic, vesicular siliceous and spherical fly ash components. These types of particles are classic examples of high temperature or combustion by-products and are generally absent in typical office dust.

<sup>1</sup> Interior Spaces data (TP-01)

## 2.0 WTC Dust Composition

A variety of analytical methods were used to characterize the dust collected from the Building and to develop an understanding of the composition of WTC Dust. The analytical techniques discussed in this report including optical microscopy (reflected and transmitted light), scanning electron microscopy (SEM) with associated energy dispersive spectroscopy (EDS) and X-ray Photoelectron Spectroscopy (XPS) were utilized during the evaluation of the dust samples. A variety of particle compositions and morphologies were identified during this analytical sequence that aids in differentiation of the Building dust samples from the Background Buildings. The following discussion sets forth the major analytical results from the SEM/EDS characterization:

### 2.1 Background Dust Characteristics

An important aspect of the characterization of WTC Dust is the ability to distinguish WTC Dust from “background dust”, i.e., particulate matter that is typical in a normal office environment. This section discusses the analytical results from efforts to define the composition, morphology, and abundance (particle loading) of background or typical office environmental particulate content. (See RJ Lee Group’s *Background Levels in Buildings* report, December, 2003)

Typical interior office dusts possess a different morphological and mineralogical character from those that generated produced from the WTC disaster. For example, many of the components typically associated with office dust are internally generated by daily activities within the facility. One of the largest contributors to the typical environmental particulate population is the occupying personnel. Indoor dust commonly consists of skin flakes, hair, natural and synthetic textile fibers, plant and insect parts, windblown soil-derived dust (silicate minerals), and various amounts of other materials.

Carbonaceous particulate and fiber components comprise a significant portion of the typical office dust population. This description is based upon knowledge of indoor air quality and the analysis of numerous background samples and other research performed over the course of many years. An understanding of the characteristics of typical office dust is critical to the development of a WTC Event driven dust signature because it allows the identification of uncommon constituents in the dust.

Typical interior office dusts are sparsely distributed on surfaces compared to the heavy loading of WTC Dust in the Building. The environment in a typical office complex is subjected to significant amounts of control and conditioning such as filtering, heating and various distribution techniques. The environment within the Building was rendered completely uncontrolled

due to the unhindered access of dust, debris and moisture through the *gash* and through numerous broken windows

**Figure 2** shows a typical loading on a lift sample collected from a Background Building and **Figure 3** shows the particle loading of a lift sample collected from a WTC Dust impacted location within the Building. The images in these figures depict the same magnification. The shear amount or dust loading differential between the two samples is obvious. At higher magnifications, it can be seen that materials residing on the WTC Dust lifts possess morphological characteristics that are different from the Background Building samples. The particulate components on the WTC Dust sample appear angular or pulverized and accompany spherical heat affected particles. Also, the fibrous component exhibited in the WTC Dust sample is largely absent from the Background Building sample.

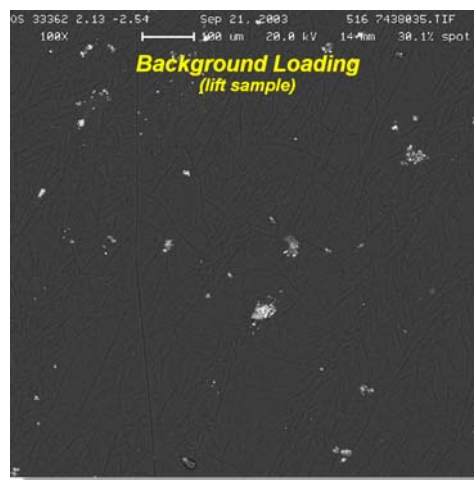


Figure 2. Typical dust loading on Background Building samples

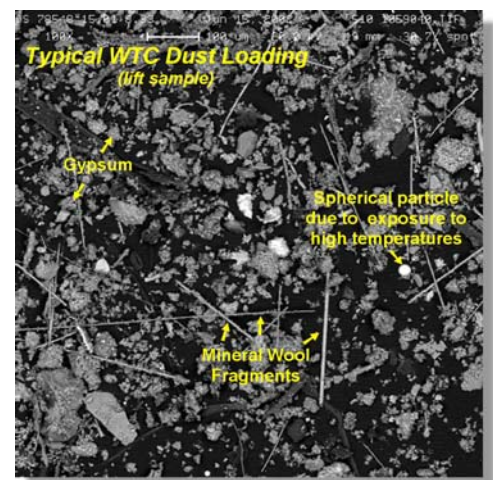


Figure 3. Dust loading from a WTC Dust impacted location

**Figure 4** shows examples of the organic components that comprise a significant portion of the total particulate and fibrous material associated with the Background Building samples. This type of matter comprises only a trace amount within the WTC Dust. The WTC Dust contains hydrolyzed or partially consumed components of carbonaceous material exhibiting a vesicular typically sub-spherical morphology.

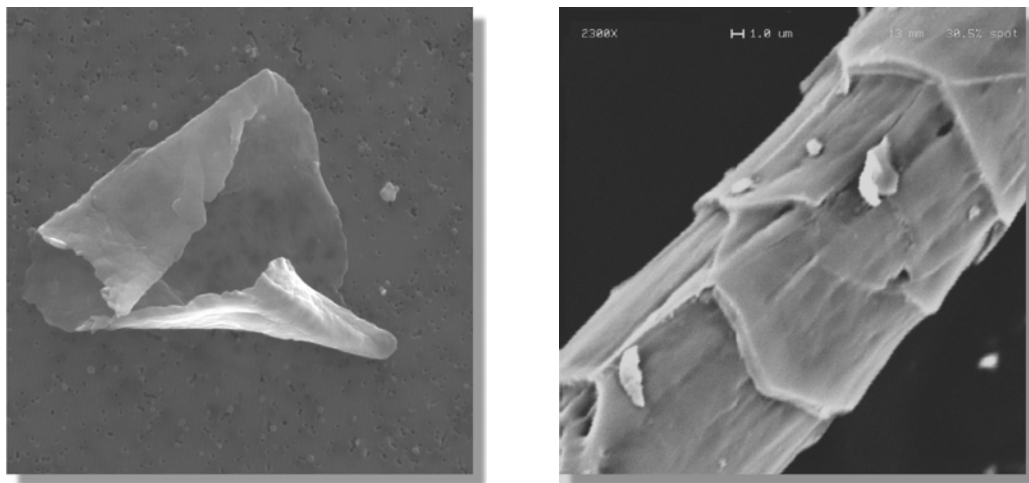


Figure 4. SEM image of skin flake and a hair fiber found in Background Buildings.

## 2.2 Pre-WTC Event Dust Characteristics

Samples collected within the WTC towers in the spring of 2000 were examined to provide further evidence of the particle types expected within buildings surrounding the WTC site prior to the WTC Event. **Figure 5** and **Figure 6** include SEM images of “typical” dust particles that were indicative of the particles types present at the WTC site prior to the WTC Event. The left image of each photomicrograph shows a field of view with a white box. The right image is at a higher magnification and is the region within the box of the left image. The lower portion of the figure shows the elemental spectrum acquired inside the small box seen in the right image. These background particles include common soil/mineral particles such as quartz, clays and even rust particles.



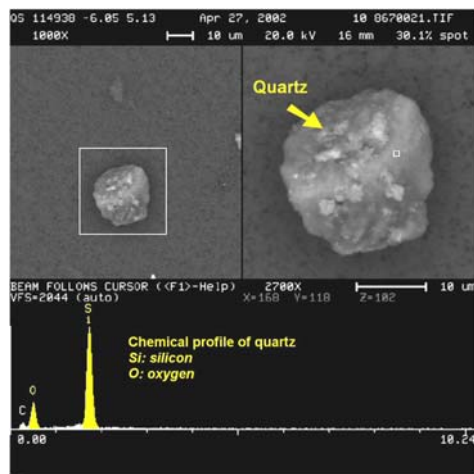


Figure 5. SEM image with EDS of silicon-rich particle (i.e., quartz)

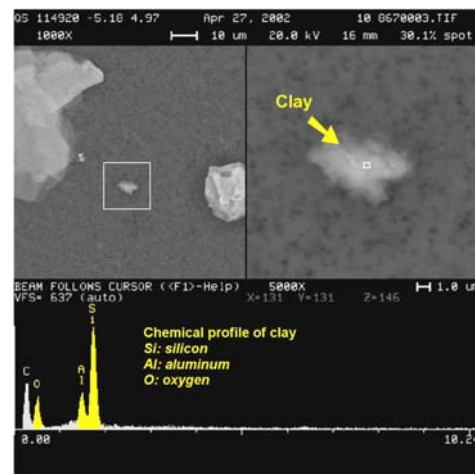


Figure 6. SEM image with EDS of silicon/aluminum-rich particle (i.e., clay).

## 2.3 WTC Dust Characteristics

### 2.3.1 Chrysotile Asbestos

Chrysotile asbestos was found to be a consistent component of the WTC Event contamination. Chrysotile was used in a number of applications at the WTC. For example, some of the lower floors of WTC-1 (North Tower) contained fireproof coatings that were sprayed onto structural steel and ceilings above and below each mechanical equipment floor. Elevator shafts were covered with a 90% chrysotile cement. Many floors in the WTC Towers were covered with vinyl asbestos resilient flooring. The NRDC report indicated that more than 300 to 400 tons of asbestos was present in the WTC buildings.

Chrysotile asbestos was positively identified in the WTC prior to the WTC Event as evidenced in studies performed by RJ Lee Group in 2000 (**Figure 7**). **Figure 8** shows chrysotile asbestos associated with gypsum within the WTC Dust (post-WTC Event).

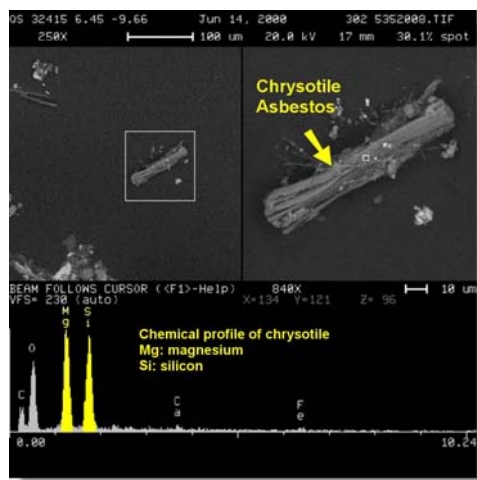


Figure 7. SEM image and EDS of chrysotile asbestos fiber bundle in WTC-1 (Pre-WTC Event)

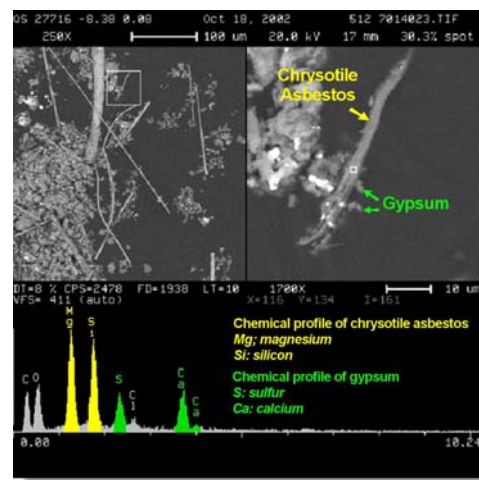


Figure 8. SEM image and EDS of WTC chrysotile with gypsum (Post-WTC Event)

As a result of the extreme forces produced by the WTC Event, the chrysotile fiber bundles within the WTC Towers were commonly broken down to thin bundles and fibrils.

Further, TEM analysis of dust in the Building also showed the asbestos concentration reaching over 70 million structures/cm<sup>2</sup> (s/cm<sup>2</sup>) in TP-01 samples from the *gash* region, directly adjacent to the WTC site. An unprecedented level of 1 billion s/cm<sup>2</sup> was also observed in the Building and 2 billion s/cm<sup>2</sup> on the roof of the Building where debris was deposited from direct fallout as well as suspension, as the WTC Event occurred.

### 2.3.2 Gypsum

Calcium-sulfate minerals are major constituents in building materials such as wallboard, plaster, and fireproofing. Wallboard is constructed with gypsum (calcium sulfate) and is commonly found in buildings. A significant portion of the gypsum that has been detected in the Building appeared in the form of fine dust that was pulverized to a degree not seen in ordinary building dust.

**Figure 9** illustrates gypsum is coarse and fewer fine particles are observed in the pre-WTC Event debris. **Figure 10** shows a typical SEM image of gypsum debris from within the WTC Dust.



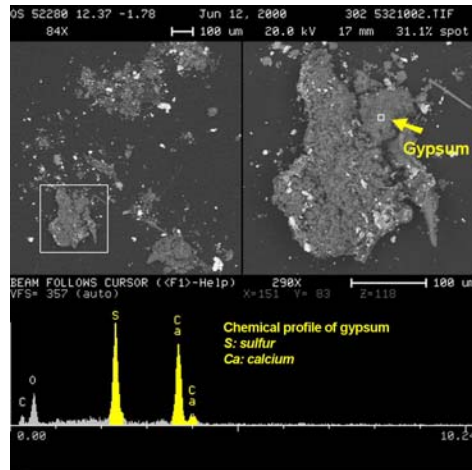


Figure 9. Image and EDS of gypsum in the WTC (Pre-WTC Event)

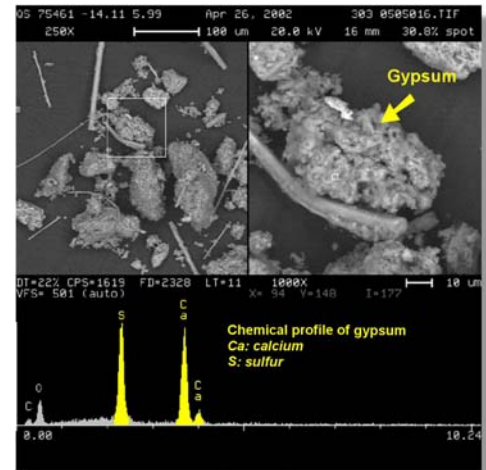
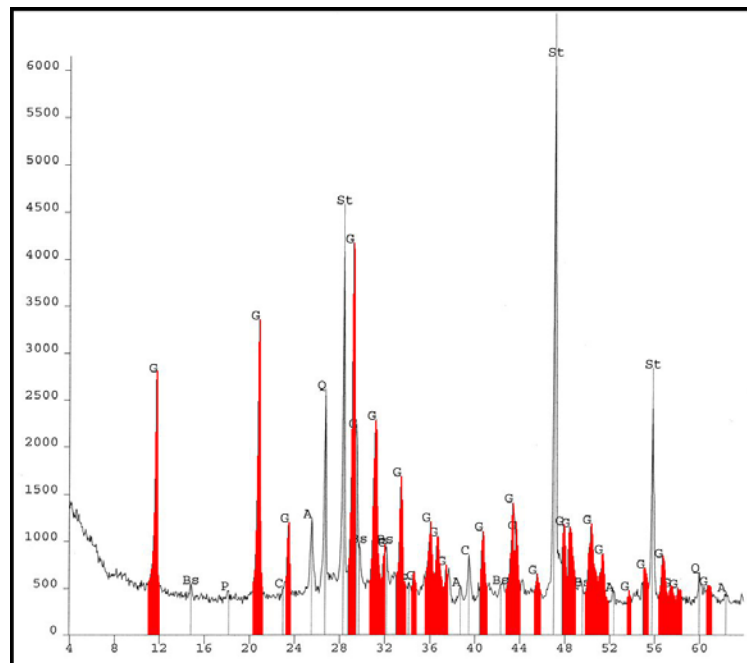


Figure 10. SEM image and EDS of WTC gypsum (Post-WTC Event)

**Figure 11** shows an X-ray diffraction (XRD)<sup>2</sup> pattern of the bulk WTC Dust. Gypsum and other calcium sulfate phases were found to comprise up to 30% of the WTC Dust by mass. Other crystalline phases were quartz and calcite with concentrations of approximately five weight percent.



<sup>2</sup> X-ray diffraction allows for the quantification of crystalline phases.

Figure 11. XRD spectrum of WTC Dust.

### 2.3.3 Synthetic Vitreous Fibers

Synthetic vitreous fibers (SVFs) or man-made vitreous fibers (MMVF) are a class of insulating materials used widely in commercial buildings. They are made primarily from glass, rock, slag, or clay. Typical mineral wool applications include use in structural fire protection and ceiling tile. Mineral wool has also been widely reported as a major constituent of WTC Dust. Mineral wool found in Background Buildings typically existed as long fibers as opposed to the short, fractured fibers found in WTC Dust. **Figure 12** shows a typical mineral wool fiber observed in the WTC prior to the WTC Event. After the WTC Event, many of the mineral wool fibers were observed to have a short and fractured nature, which can be attributed to the catastrophic failure of the WTC as compared to normal degradation (Figure 13 through **Figure 14**).

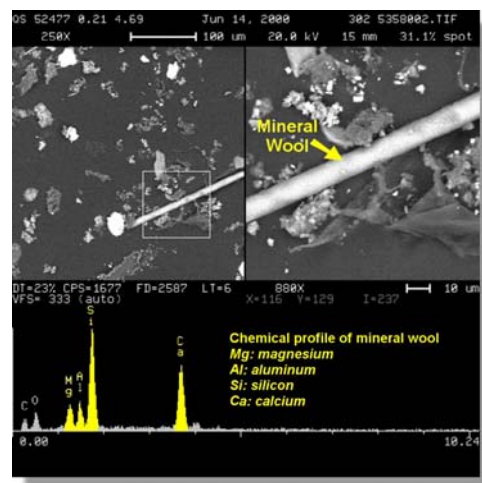


Figure 12. SEM image and EDS of mineral wool in the WTC-2 prior to the WTC Event.

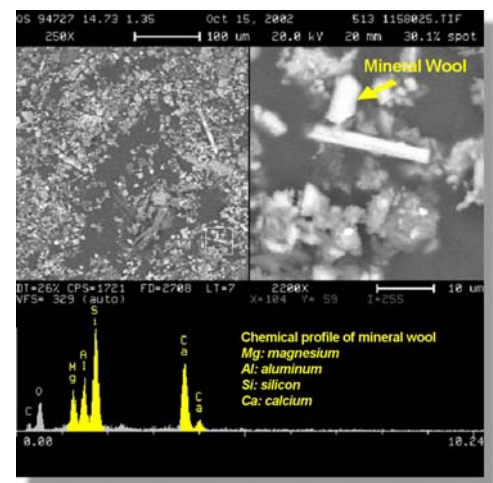


Figure 13. SEM image and EDS of WTC mineral wool fragment after the WTC Event.



Figure 14. Optical microscopy image of mineral wool fragment.

In addition to mineral wool, fractured glass fibers are also a WTC Dust Marker for WTC Dust. The major uses of glass fibers are in thermal insulation, noise-control (acoustic) products, linings for air-handling ducts, pipe insulation and air filters. Representative glass fibers from the WTC Dust are shown in **Figure 15** and **Figure 16**.

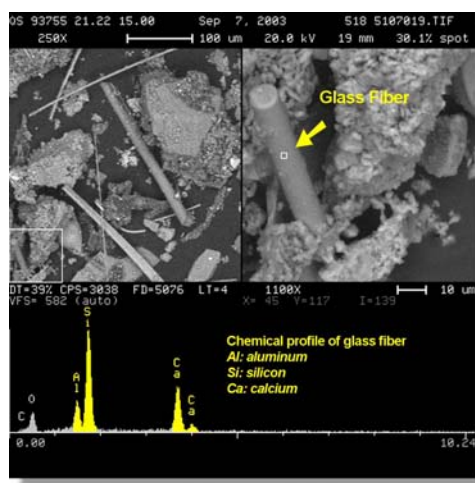


Figure 15. Glass fiber in WTC Dust

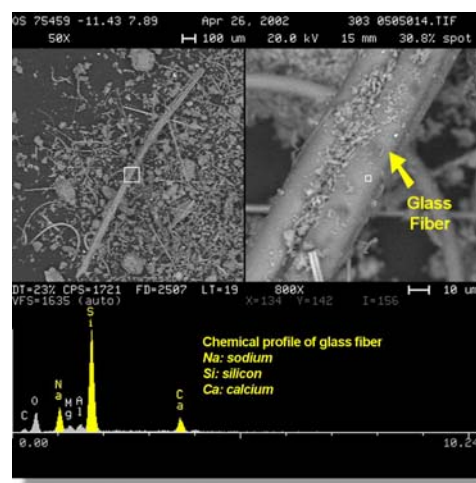


Figure 16. Glass fiber in WTC Dust.

#### 2.3.4 Vermiculite

Vermiculite is a mica-like mineral which exfoliates (expands) on rapid heating to produce an inert, low-density material with significant thermal

qualities. The mineral does not burn and provides excellent heat resistance properties. Vermiculite was present in the plaster on exterior walls within the WTC towers and is commonly observed in the WTC Dust. **Figure 17** is an SEM micrograph of the vermiculite observed in the WTC Dust.

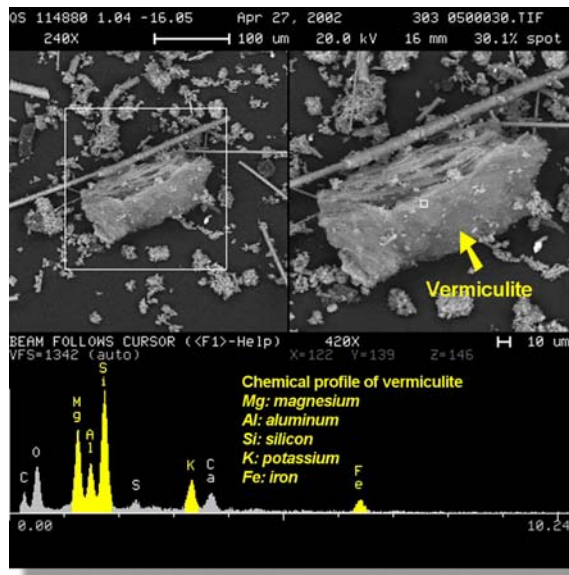


Figure 17. Vermiculite particle in WTC Dust

### 2.3.5 Heat affected particulate and combustion products

Particles that either were formed as a consequence of high temperature or were modified by exposure to high temperature are important WTC Dust Markers for WTC Dust. Fires that were a part of the WTC Event produced combustion-modified products that traveled with other components of WTC Dust. Considering the high temperatures reached during the destruction of the WTC, the following three types of combustion products would be expected to be present in WTC Dust. These products are:

- Vesicular carbonaceous particles primarily from plastics
- Iron-rich spheres from iron-bearing building components or contents
- High temperature aluminosilicate from building materials

There were considerable amounts of plastics in the WTC buildings, that upon heating and liberation of volatiles produced spherical (or nearly so) carbon-rich particles with vesicles related to emission of volatiles. **Figure 18** shows typical carbonaceous materials from a Background Building and **Figure 19** shows porous heat affected particulate in the WTC Dust. **Figure 20** shows a PLM image of porous heat affected particulate in the WTC Dust.

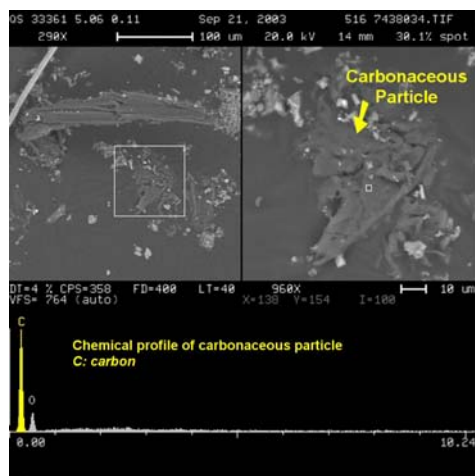


Figure 18. SEM image and EDS of carbonaceous material in Background Building

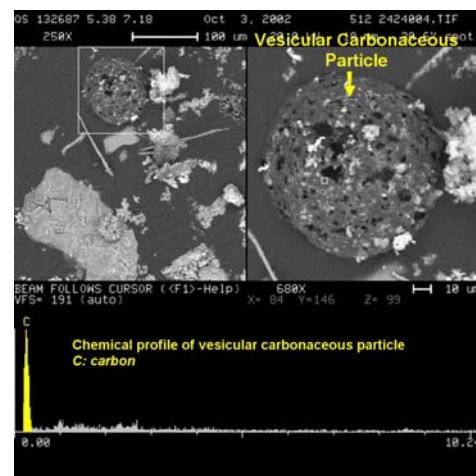


Figure 19. SEM image and EDS of a vesicular carbonaceous particle

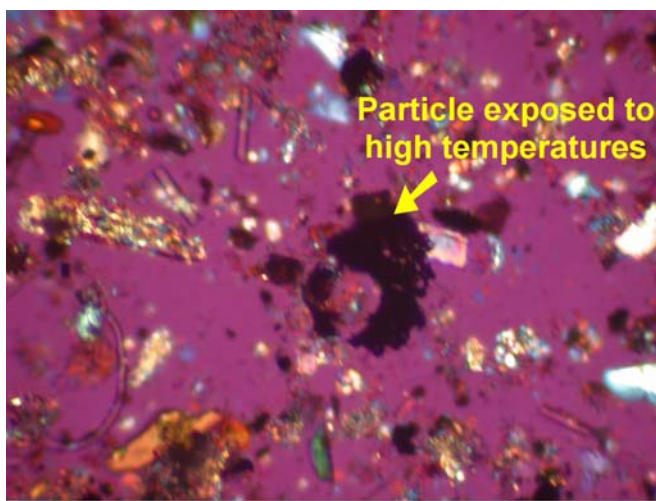


Figure 20. Optical microscopy image of a particle formed by high temperature.

Various metals (most notably iron and lead) were melted during the WTC Event, producing spherical metallic particles. Exposure of phases to high heat results in the formation of spherical particles due to surface tension. **Figure 21** and **Figure 22** show a spherical iron particle resulting from the melting of iron (or steel).



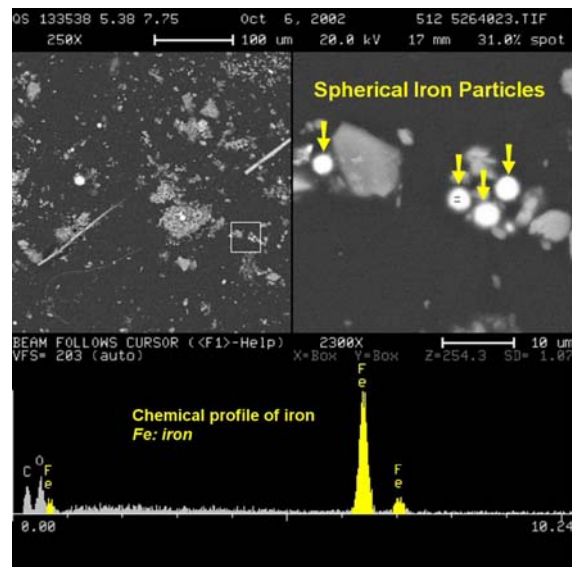


Figure 21. SEM image and EDS of spherical iron particle

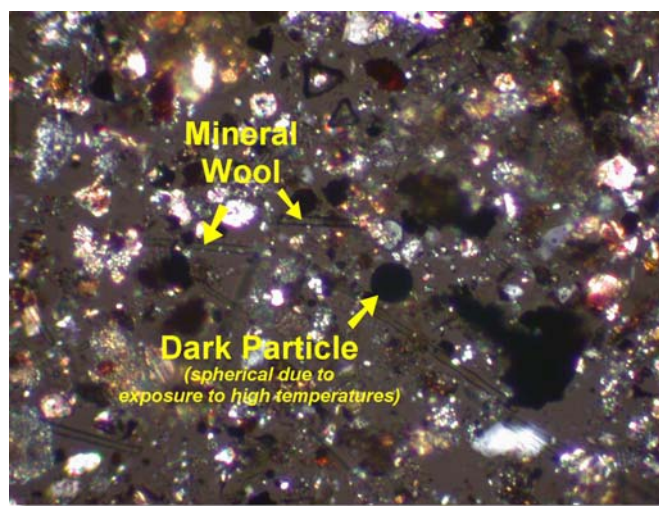


Figure 22. Optical microscopy image of a dark particle formed by high temperature.

Silicates (abundant in building materials) can be melted producing spherical or vesicular silicate particles. **Figure 23** and **Figure 24** show the difference between an angular non-porous non-heat affected particle within a Background Building and a porous WTC Dust silicate heat-affected particle.

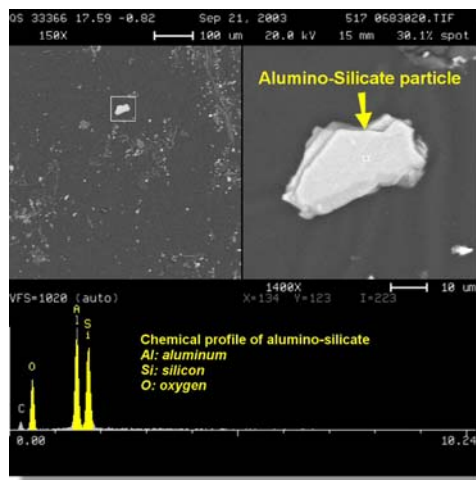


Figure 23. SEM image and EDS of alumino-silicate in Background Building

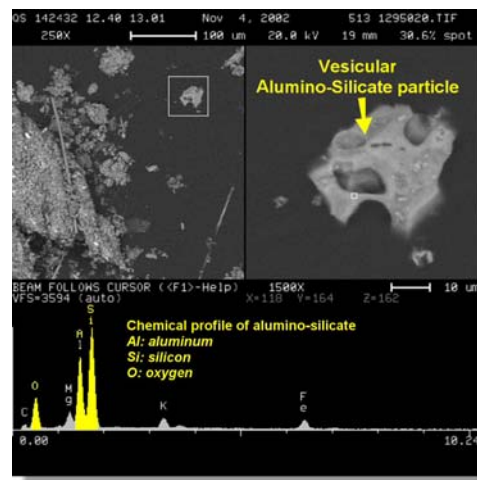


Figure 24. SEM image and EDS of vesicular alumino-silicate

In addition to the spherical iron and aluminosilicate particles, a variety of heavy metal particles including lead, cadmium, vanadium, yttrium, arsenic, bismuth, and barium particles were produced by the pulverizing, melting and/or combustion of the host materials such as solder, computer screens, and paint during the WTC Event.

Combustion-related products are significant WTC Dust Markers, particularly if seen in combination. However, it is worth noting that fly ash and partially combusted products can occur in trace concentrations in ordinary building dusts, but not in the concentrations observed in WTC Dust.

## 2.4 Other Particle Types

Many other particle types were observed in WTC Dust including cellulose, wood and others. Composite wood products could contain preservatives, retained volatile solvents or free monomers and plastisizers from adhesives or coatings applied to them. These components are indicative of WTC Dust, but also occur in ordinary building products. Thus, in and of themselves, they are not WTC Dust Markers, but are indicative of the WTC Dust.

## 2.5 Summary

The differences within the WTC Dust and typical background dusts include the fineness and evidence of heat, the size and concentration of the chrysotile, and the length and concentration of the mineral wool and other

fibers, as well as the frequency of occurrence of spherical particles produced by fire and heat, char and soot, and other building products.



### 3.0 Other WTC Dust Characteristics: Coatings

The amount of energy introduced during the generation of the WTC Dust and the ensuing conflagration caused various components to vaporize. Vapor phase components with high boiling point and high melting point would have, as they cooled, tended to form precipitated particles or thin film deposits on available surfaces through condensation mechanisms. The results of this process would be the presence of a thin layer of deposited material on the surfaces of the dust particulate matter. Many of the materials, such as lead, cadmium, mercury and various organic compounds, vaporized and then condensed during the WTC Event.

A variety of analytical techniques were applied to characterize the surface chemistry of WTC materials. These analytical techniques included scanning electron microscopy/energy-dispersive spectroscopy (SEM/EDS), X-ray microprobe, and X-ray photoelectron spectroscopy (XPS). The SEM and microprobe techniques provided details that sparked interest in a closer look at the surface characteristics. XPS is a surface analysis technique that not only can detect most of the elements of the periodic table, but can also determine their oxidation state or binding energy. Thus XPS can provide chemical species information for elements. XPS is capable of analyzing components in the top 100 angstroms of surface. Because of the sensitivity to surface components, XPS is highly useful in the characterization of chemistry of the surface of the dust particles.

The XPS results indicate the presence of a thin contaminating film or coating associated with the surface of particles. These surface species could be a significant factor affecting the toxicity of the WTC Dust if the coatings on particles and fibers are composed of hazardous substances. The coatings vary in thickness from nanometers (monolayer) to finely dispersed sub-micron particles. The particles and coatings have been detected by low accelerating voltage back-scattered electron imaging, X-ray microprobe analysis, and high resolution XPS. For example, lead peaks from the surface of mineral wool were identified by XPS. The high-resolution, narrow-range XPS scan (**Figure 25**) led to the identification of two lead peaks representing lead oxide or lead sulfate. The presence of lead oxides on the surface of mineral wool indicates the exposure of high temperatures at which lead would have undergone vaporization, oxidation, and condensation on the surface of mineral wool. In addition to the trace amounts of lead, **Table 2** indicates the presence of carbon, nitrogen, oxygen, sodium, silicon, sulfur, chlorine and calcium on the surface of the mineral wool.

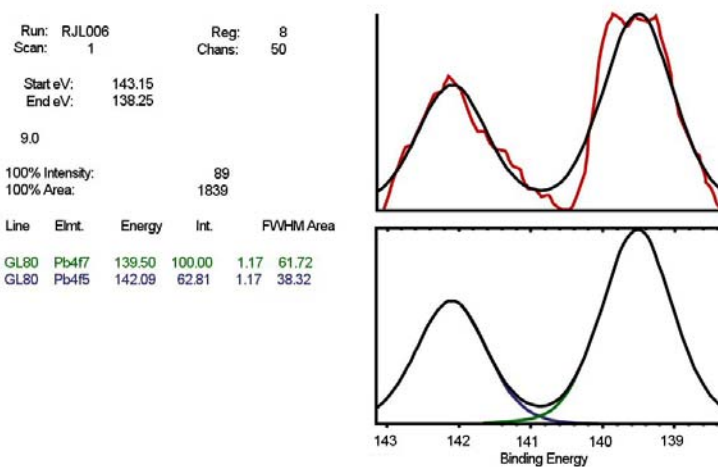


Figure 25. Lead peaks on mineral wool by high resolution XPS. The red trace represents the observed spectrum. The black trace represents the best fit derived from the observed spectrum.

Table 2. Average concentration (atomic percent and weight percent) within 2-4 nm outer Layer of a mineral wool fiber

Element	C	N	O	Na	Si	S	Cl	Ca	Pb
Atom %	67.0	1.25	24.3	0.41	4.65	0.99	0.34	1.22	0.04
Weight %	56.0	1.21	27.0	0.64	9.00	2.17	0.83	3.37	0.52

## 4.0 Statistical Analysis

Statistical analyses were performed to compare the distribution of particle types within TP-01 occupied spaces of the Building to those found in the Background Buildings by various statistical methods. Background Building samples were analyzed by SEM in the same manner as the samples collected within the *gash* of the Building. The same field technicians, sampling media, equipment, and laboratory technicians were used in all stages to minimize variability.

The data were evaluated using a two-tailed heteroscedastic analysis of means test. This type of test allows for unequal variances in the two populations tested, a condition which often occurs when one population has a substantially higher mean than the other. The statistical analysis was conducted for each of thirteen particle types as well as for composites of Class A and Class C particles. Eleven particle classes were derived from major building products or were influenced by high temperature (Class A particles). An additional two particle types included carbon-rich particles and flakes and carbon-rich fibers such as skin, cellulose, and hair (Class C particles). A summary of the results obtained for this analysis is provided in **Table 3**.

Class A particles are common WTC Dust Markers and Class C particles are common Background Building dust particles. The statistical analysis indicates that the dust in the below ceiling space in the *gash* is different from that observed in Background Buildings. The material collected in the *gash* is consistent with building materials derived from the destruction of the WTC; the carbon-rich particulate is abundant in typical office buildings. The data clearly shows statistically significant differences with the mean values in the two classes of particles, hence the WTC Dust can be distinguished from Background Building dust.

Table 3 Statistical P-values for the comparison of TP-01 dust and dust in Background Buildings.

Class	Particle Type	Mean of Composition (%)	
		Background Buildings	TP-01
A	Mineral Wool	1.05	13.70
A	Glass Fragments	0.52	0.50
A	Glass Fiber	0.23	1.27
A	Perlite	0.26	0.45
A	Vermiculite	0	2.36
A	Ca/Si	0.35	5.11
A	Fe Sphere	0.04	5.87
A	Vesicular Carbonaceous	0.05	1.23
A	Hi Temp Si/Al-rich	0.08	0.54
A	Vermiculite/Gypsum	0	2.72
A	Chrysotile	0	1.84
C	C fiber	5.20	1.02
C	C flake	35.95	1.14
<b>Class A Combined</b>		2.57	35.58
<b>Class C Combined</b>		41.15	2.16

The probability of the statistical evaluation of the above data demonstrates that the WTC Dust and background dust have different sources.

## 5.0 Addenda

### 5.1 Sampling Design and Statistical Analysis

A detailed discussion of sampling design and statistical analysis is presented in the Insurance Claim Report dated May 2003, Volume III: Statistical Analysis.

Sampling for contaminants of concern was performed in stages for each sampling protocol. Statistical analyses of the data were performed on data sets as they became available throughout sampling activities. The work scope and extent of field sampling activities and laboratory analyses to be executed were decided based upon information provided by the on-going statistical evaluation of analytical results.

This was essentially an iterative process. As data were reviewed, the number, type and location of additional samples were projected. The number of samples obtained was evaluated to determine if there were statistically significant differences between the mean values of building segments. This was performed using a predetermined level of precision (e.g., 95% confidence interval) for specified subdivisions of the Building.

Initial Building-wide evaluation of the contaminant data demonstrated that the contaminant concentrations are well approximated by a log normal distribution. Therefore, statistical evaluations were performed on log-transformed data sets using the following approach:

- Initial sampling was performed at random locations within predetermined grid locations of the Building.
- A statistical analysis (e.g., average, standard deviation) of the analytical results for each analyte was performed.
- The standard errors of the average values were estimated based upon the standard deviations and number of samples analyzed.
- Using the central limit theorem, the total number of samples (and number of additional samples) required ensuring the desired level of precision with 95% confidence was calculated.

## 5.2 Sampling

Samples were collected from the Building using “TP-01: Protocol for the Monitoring of Non-Biological Indoor Environmental Contaminants” dated May 10, 2002. Two kits, each containing media for eight samples, were taken to each predetermined grid location for below-ceiling and above-ceiling sampling. Each kit contained:

- Asbestos Wipe
- Silica Microvac
- Metals Wipe
- Mercury Wipe
- Dust Lift
- PNAs Wipe
- PCBs Wipe
- Dioxins/Furans Wipe

The test protocol sets forth the complete methodology in Volume III: Protocols.

## 5.3 Sample Location Selection

Upon arrival in the predetermined grid location, a below-ceiling undisturbed area was selected. The sampling areas included, for example, file cabinets, tables or credenzas. In the same vicinity of the below-ceiling sample, an above-ceiling sampling area was selected. These areas were often the tops of drop ceiling lights (**Figure 26**).

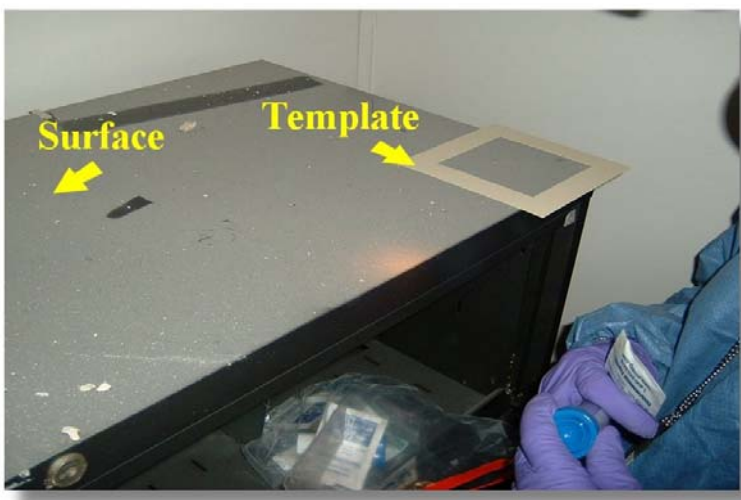


Figure 26. Typical drop ceiling light used for above-ceiling samples

Most above-ceiling and below-ceiling samples were taken from horizontal surfaces; however, a suitable horizontal surface from which to sample was not always available, in which case samples were taken from vertical surfaces.

#### 5.4 Sampling Procedures

In order to sample a finite area, a disposable template (usually 100 cm<sup>2</sup>) was utilized (**Figure 27**). The actual area sampled was documented for each wipe and microvac sample collected.



**Figure 27.** Below-ceiling sampling surface and template

Samples collected throughout the Building were documented using a Personal Data Assistant (PDA). Each sample was given a unique identification number using adhesive bar code labels that were affixed to the sample container. Information regarding the sample including location, area sampled, component sampled, matrix, and visual observations of the area were recorded. Additionally, each sample location was photographed and documented on a grid map.

Three types of sampling media were used (wipe, microvac, and lift), as described below.



## 5.5 Lift Samples

Dust characterization samples were collected using adhesive “lift” samples. A lift sample is a plastic strip with an adhesive coating on one side as shown in **Figure 28**.

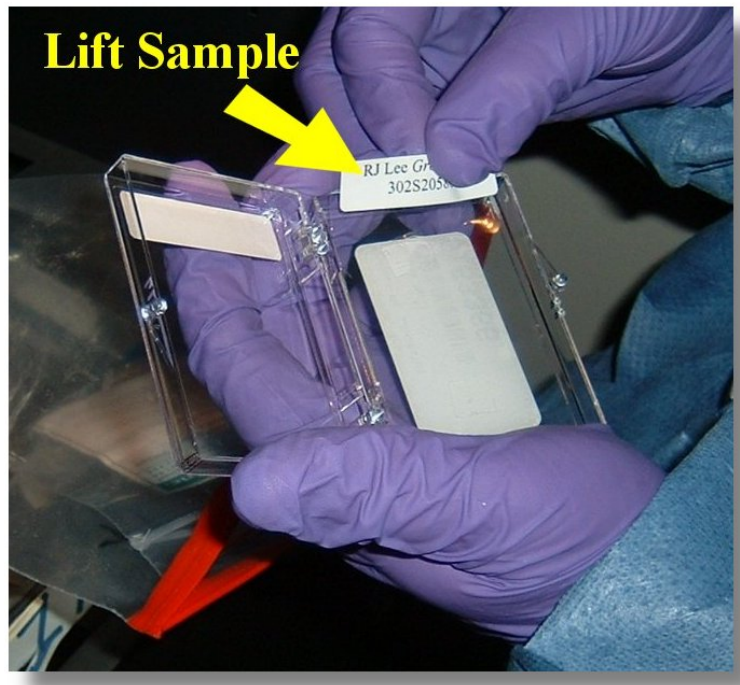
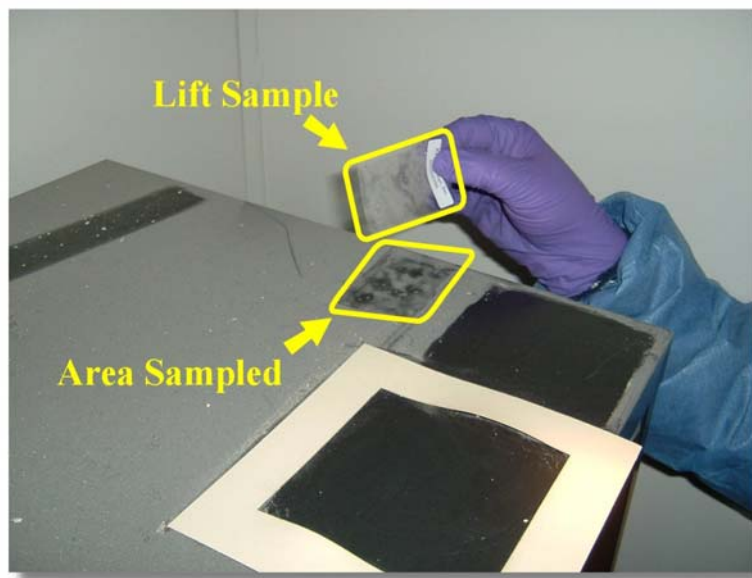


Figure 28. Lift sampling media



The lift was placed on the surface to be sampled, adhesive side down. Using finger pressure, the lift was pressed onto the surface, allowing dust to adhere to the lift (**Figure 29**). The lift was placed in a plastic box that was then put into a plastic bag.



**Figure 29.** Dust adhered to lift sampling media

## 5.6 Sample Analysis

Samples were analyzed using industry standard analytical laboratory methods as follows.

- Microvac samples were analyzed for asbestos using transmission electron microscopy (TEM) in accordance with ASTM 5755.
- Samples were analyzed for metals in accordance with NIOSH 7300 method, using inductively coupled argon plasma (ICP) spectrometry.
- Samples were analyzed for mercury in accordance with EPA Method SW846 7471A, using cold vapor atomic absorption (CVAA).
- Samples were analyzed for PCBs in accordance with EPA Method SW 846 8082 using gas chromatography with electron capture detectors (GC/ECD).
- Samples were analyzed for PNAs in accordance with EPA Method SW 846 8270C using gas chromatography with mass spectrometry (GC/MS).
- Samples were analyzed for dioxins/furans in accordance with EPA Method SW 846 8290 using gas chromatography with high-resolution mass spectrometry (GC/HRMS).

- Samples were analyzed for dust, particle characteristics, and WTC Signature using scanning electron microscopy (SEM), coupled with energy dispersive spectroscopy (EDS) techniques.
- Samples were analyzed for silica using X-ray Diffraction (XRD) in accordance with NIOSH 7500 and NIOSH 0600 methods.