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Final Technical Report of the Public Health Investigation to Assess Potential Exposures to Airborne and Settled Surface Dust in Residential Areas of Lower Manhattan

September 2002

New York City Department of Health and Mental Hygiene
and
Agency for Toxic Substance and Disease Registry
U.S. Department of Health and Human Services

As a part of the
World Trade Center Environmental Assessment Working Group

September 11, 2001

In remembrance of those who were lost on September 11, 2001, and to the families and friends who will love them forever and keep their memories alive.

In grateful recognition of the countless responders and the many who supported their efforts.

New York City Department of Health and Mental Hygiene

U.S. Agency for Toxic Substances and Disease Registry

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EXECUTIVE SUMMARY

From November 4 through December 11, 2001, environmental samples were collected in and around 30 residential buildings in lower Manhattan. In addition, four buildings above 59th Street were sampled and used as a comparison area for this investigation. The New York City Department of Health and Mental Hygiene (NYC DOHMH) and the U.S. Agency for Toxic Substances and Disease Registry (ATSDR) conducted this limited investigation with support and collaboration from the U.S. Public Health Service Commissioned Corps Readiness Force and the World Trade Center Environmental Assessment Working Group. The purpose of the sampling was to assess the composition of both outdoor and indoor settled surface and airborne dust within residential areas around the World Trade Center. This information was used to help determine whether additional public health actions are needed to address any remaining World Trade Center-related dust inside residential areas. The information collected could also be used to compare the findings from the locations that were known or were likely to have received dust directly from the collapse of the World Trade Center towers, to findings from areas that were unlikely to have received dust directly from the disaster (comparison areas).

Attention was given to those materials reasonably expected to be in the original dust cloud and in dust generated by ongoing activities at the World Trade Center. The focus was on building materials that have been shown to have irritant properties (e.g., synthetic vitreous fibers [SVF] and gypsum) and be associated with long-term health concerns (i.e., crystalline silica and asbestos). The samples collected during this investigation were analyzed for the following materials: asbestos, SVF, mineral components of concrete (crystalline silica, calcite, and portlandite), and mineral components of building wallboard (gypsum, mica, and halite). Efforts were made to get as much

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information as possible with the sampling that could be conducted, given accessibility and equipment limitations.

Results from this investigation do not necessarily reflect conditions that would be found in other buildings, at other times just following the collapse, or after the sampling period. The measurements reflect conditions present at the time of the sampling (November 4-December 12, 2001) in the buildings and areas sampled. The limited number of results obtained from the comparison areas above 59th Street was an attempt to determine the New York City–specific background levels of asbestos, SVF, mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum, mica, and halite).

Sampling Overview

U.S. Public Health Service Commissioned Corps Readiness Force Officers were detailed to the New York City Department of Health and Mental Hygiene and composed the sampling teams for this investigation. The teams completed a survey form for each sampling location. The information collected by the survey was obtained from direct observations and from owners or representatives of building management when available. The survey form and photographs were reviewed along with the analytical results to put the sampling results into the context of where and how the samples were obtained and to determine the general conditions of the sampling locations.

Air and settled surface dust samples were collected and analyzed for the following materials used in WTC construction components: asbestos, SVF, crystalline silica, calcite, portlandite, gypsum, mica, and halite. SVF (e.g., fiberglass) is used in thousands of products because of its chemical resistance, strength, and ability to insulate against heat and sound. All of the crystalline minerals analyzed in this project are commonly used in building construction materials. *Quartz,* a form of crystalline *silica*, is a naturally occurring mineral and is a component of cement. *Cristobalite* and*tridymite* are different crystalline forms of silica. *Calcite and portlandite* are naturally occurring, high pH minerals used in cements and mortars. *Gypsum* is a naturally occurring mineral used in plaster, wallboard, and in some cements. *Mica* is a group of naturally occurring minerals that are used in paint, joint cements, plastics, roofing, and rubber. *Halite* (also known as rock salt or sodium chloride) is used in ceramic glazes, fire extinguishing, metallurgy, and highway de-icing and table salt.

In addition to analyzing the samples for the fibers and minerals found in common building materials, when a sufficient quantity of settled surface dust was present, it was mixed with water and the pH of the resulting mixture was measured.

Air Samples

Air samples were collected using vacuum pumps to draw air through a filter positioned at an adult's breathing level. In addition to a filter for fiber analysis, multiple particulate samplers were

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placed at each sampling location to collect different particle sizes including respirable (PM4 and PM2.5), thoracic (PM10), and total inhalable (PM100). This resulted in the collection of overlapping, or nested, particulate size fractions.

The particle size determines how deeply a particle can travel into the respiratory tract. Respirable particles with diameters of 4 microns or less (PM4) are very small particles that can be breathed in and can travel deeply into the air sacs of the lung. At some locations another sampler was used that collected a smaller set of respirable particles, those with diameters of 2½ microns (PM2.5) or less. Another sampler collected particles with diameters of 10 microns (PM10) or less. This sampler would collect not only respirable particles, but also those slightly larger particles that tend to land in the upper regions of the respiratory tract, including the throat. A fourth sampler collected a larger set of particles, those 100 microns (PM100) or less in diameter. The larger particles in this fraction can land in the nose and throat. Where a particle lands determines what types of health effects might be experienced. Particles too large to travel into the narrower passages of the lower respiratory tract might deposit in the upper airways (e.g., the nose and throat) and cause irritation. Similarly, larger particles might cause eye irritation. If the settled surface dust contains sufficient amounts of particles of a very small size, then effects consistent with particles reaching the lower respiratory tract might occur (coughing, shortness of breath).

Each of the particulate air sample fractions was analyzed for crystalline minerals (quartz, cristobalite, tridymite, calcite, portlandite, gypsum, mica, and halite). X-ray diffraction analysis (XRD) identifies a mineral by the unique diffraction pattern given off when the x-ray strikes its surface. The diffraction pattern serves as a "fingerprint" to identify the mineral present.

Other air samples were screened for fibers using phase contrast microscopy (PCM) to count the total number of all fibers present. If the concentration of total fibers was higher than the maximum concentration of fibers found in the comparison homes (0.003 fibers per cubic centimeter of air) the sample was re-analyzed for asbestos by transmission electron microscopy (TEM). Additionally, scanning electron microscopy (SEM) was used to look for SVF if the PCM fiber counts was higher than 0.003 fibers per cubic centimeter (f/cc) and if the settled surface dust sample from that area contained SVF.

Settled Surface Dust Samples

The composition of settled surface dust reflects particles and fibers that have been tracked into an area or that were present in the air and have with time, deposited on surfaces. Settled surface dust was collected indoors using a specialized vacuum cleaner. Outside settled surface dust was collected by scooping any visible dust-type material into a container. As with the air samples, the settled surface dust samples were analyzed to assess the presence of fibers and minerals. The analysis performed does not allow the determination of what size particles are present in the dust. The composition of the settled surface dust was evaluated to

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determine if, on the basis of its composition, it could be an irritant if it became airborne or came in contact with skin or eyes during cleaning activities.

The dust samples were analyzed for the presence of asbestos and SVF using polarized light microscopy (PLM). PLM can distinguish between fiber types by their unique appearance and color when viewed under different wavelengths of light. In addition, TEM analysis was conducted on all dust samples that showed asbestos content by PLM as less than 1%. TEM analysis is very specific, can detect smaller fibers of asbestos, and is subject to less interference than PLM.

The dust samples were also analyzed for mineral content using XRD as described previously for the air samples. For the dust samples, the mineral and the fiber results are expressed as a percent, indicating the weight percent each component represents in the portion of the dust sample analyzed. The different analytical techniques, XRD and microscopy (PLM, TEM, SEM), help to characterize what was in the settled surface dust; however the results from the two methods each performed on a portion of the dust collected, cannot simply be added together to "sum up" what was in the dust. XRD results are based upon the weight of the dust sample analyzed. While, PLM, TEM, and SEM results are based on the surface area viewed under the microscope.

Limitations

While the goal of the sampling was to evaluate the air and dust samples for a range of contaminants, there is no one sample collection method or analysis that can provide all of the determinations that were desired. The analysis strategy was to identify what components were present in order to provide the public with information quickly if any of the analyses revealed a significant concern. In order to strive for both of those goals, some modifications to conventional protocols were made which limited some analyses from determining the precise level of the materials in the sample (e.g., XRD conducted on air and dust samples). Whenever an analysis is expanded beyond its specific intent, there is the potential loss of sensitivity and an increase in the variability in the data. Those particular analytical results are reported as estimated values and marked with a "J."

Results for the airborne particulate matter were rejected due to issues found during the quality assurance analysis. However, the XRD analysis for airborne minerals that used the same filter samples as the particulate matter analysis are considered valid because the analysis method does not depend on the filter sample weighing process used to determine the particulate matter concentration. The XRD mineral air concentrations are based on individual mineral weight standard curves—not the weight of the dust sample collected on the filters. These standard curves are not impacted by pre- and post-sampling filter weight variability.

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Air Sampling Results

Total fiber counts of air samples taken in lower Manhattan were similar to the comparison areas above 59th Street sampled during this investigation. The six lower Manhattan areas that had elevated total fiber counts were re-examined by TEM and SEM to determine the types of fibers. The TEM and SEM results indicated that neither asbestos nor synthetic vitreous fibers (e.g., fiberglass) contributed to the elevated total fiber counts.

Air sampling results for minerals detected quartz (a form of crystalline silica) and other building-related materials in lower Manhattan. The other forms of crystalline silica were not detected in any air samples except for a one-time detection of cristobalite. The estimated concentrations of these minerals in air were low. In some locations, mineral components of concrete (quartz, calcite, and portlandite) and mineral components of building wallboard (gypsum, mica, and halite) were detected in air samples at higher estimated levels in lower Manhattan residential areas than in samples taken at comparison residential areas above 59th Street. The levels of minerals seen in airborne dust do not pose potential health hazards even for a continuous year of exposure at the highest levels detected.

Settled Surface Dust Results

Results of the settled surface dust analysis indicate the composition of settled surface dust in lower Manhattan is different than the dust analyzed from the comparison areas above 59th Street. Although the materials found are consistent with materials expected from the World Trade Center collapse, these results cannot determine the actual source of the materials present because these materials are common building components and can come from other sources in a busy urban area.

In lower Manhattan, asbestos was found in indoor dust in 15 of 83 (18%) samples from residential units and common areas at levels ranging from less than 1% (<1%) to 1.5%. Asbestos was detected in 6 of 14 (43%) outdoor samples at levels ranging from <1% to 3.4%. Indoor settled surface dust contained SVF in 40 of 83 (48%) locations ranging from 2% to 35% of the dust content. SVF was detected in 11 of 14 (79%) outdoor locations at levels ranging from 1% to 72%. No asbestos or SVF was detected in dust in the comparison areas above 59th Street.

The XRD analysis for crystalline minerals in settled surface dust is semiquantitative (estimated values, indicated by "J"). However, quartz, calcite, portlandite and gypsum appear to make up a higher percentage of dust in some buildings in lower Manhattan when compared to settled surface dust samples from buildings above 59th Street. Quartz was detected up to an estimated 31%J versus up to 2%J found in the comparison areas above 59th Street. Neither cristobalite nor tridymite was detected in any of the settled surface dust samples. Similarly gypsum was found at a maximum estimated concentration of 30%J in settled surface dust, higher than the 4%J estimated in the comparison areas above 59th Street. Calcite and portlandite had maximum concentrations of 21%J and 8%J respectively. At lower Manhattan

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locations sampled, quartz was detected in 81% of common areas and 53% of residences. Gypsum was seen in 88% of common areas and 79% of residences. Minerals were found in all lower Manhattan outdoor settled surface dust samples at estimated values ranging as high as 27%J quartz, 19%J calcite, 6%J portlandite, and 27%J gypsum. No visible settled outdoor dust was available in the comparison areas above 59th Street.

Several of the minerals detected in the settled surface dust samples, such as portlandite and calcite, can make the dust more alkaline, or raise the pH. Only two dust samples provided enough material for the determination of pH. The samples, collected from two outdoor locations in lower Manhattan, had pH levels of 8.6 and 9.8. On the pH scale, values less than 7 are considered acidic, a value of 7 is neutral, and values above 7 are alkaline or basic. Based on the results of the pH analyses, these dust samples are slightly alkaline. This is consistent with the detection of portlandite and calcite (alkaline minerals present in concrete) in the mineral analysis of the dust sample from the same location.

Conclusions

Based upon the analytical results of samples taken between November 4 through December 11, 2001, and information collected during the sampling effort, the New York City Department of Health and Mental Hygiene and the U.S. Agency for Toxic Substances and Disease Registry make the following conclusions (not in order of importance).

· Total fiber counts of air samples taken in lower Manhattan were similar to the comparison areas above 59th Street sampled during this investigation. The six lower Manhattan areas that had elevated total fiber counts were re-examined by transmission electron microscopy (TEM) and scanning electron microscopy (SEM). The TEM and SEM results indicated that neither asbestos nor SVF contributed to the elevated fiber counts.

· Low levels of asbestos were found in some settled surface dust, primarily below Chambers Street. Many of the lower Manhattan locations sampled had been previously cleaned prior to this investigation. No asbestos was detected in the comparison indoor dust samples taken north of 59th Street. The City of New York has conducted follow-up activities at the locations where asbestos was detected in settled surface dust. Only two follow-up locations, outdoor areas, required professional asbestos abatement. Following-up activity at the other locations did not find any asbestos containing materials.

· When compared with the results obtained from the comparison sampling locations, the lower Manhattan residential areas sampled by this investigation tended to have a greater percentage of SVF (primarily fiberglass), mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum, mica, and halite) in settled surface dust. However, the frequency of detections and prevalence patterns of

these minerals are similar in both residential areas.

· Exposure to significant amounts of synthetic vitreous fibers (SVF), mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum) may cause skin rashes, eye irritation, and upper respiratory irritation, all of which have been voiced as concerns by citizens and first responders. If the reported irritant effects are associated with World Trade Center related materials, these effects will subside once exposure to SVF, mineral components of concrete, and mineral components of building wallboard end. Some people with pre-existing heart or lung disease (e.g., asthma) or a previous history of very high levels of exposures (occupational) to SVF, mineral components of concrete, and mineral components may be more sensitive to the irritant effects of SVF, mineral components of concrete, and mineral components of building wallboard.

· Sometimes mineral components of concrete (calcite and portlandite) and mineral components of building wallboard (gypsum, mica, and halite) were detected in air samples at higher estimated levels in lower Manhattan residential areas than in samples taken at comparison residential areas. These detected mineral levels are orders of magnitude below occupational standards. Although the occupational standards do not account for sensitive individuals or extended periods of exposure, they provide a comparison to an established health guidance value. The levels of minerals seen in airborne dust do not pose potential health hazards even for a continuous year of exposure at the highest levels detected.

· Some settled surface dust could become airborne if disturbed. Therefore, people could potentially inhale the asbestos, SVF, mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum, mica, and halite) found in settled surface dust of some lower Manhattan residences. Because we did not determine the weight of dust present in the areas sampled, it is not possible to determine whether any particular residence had an elevated dust loading. Appropriate continued frequent cleaning should minimize exposures.

· Several worst-case assumptions were made in order to assess the potential long-term public health risks of airborne asbestos and quartz. Some of the assumptions were that no cleaning of indoor spaces has occurred or will occur, all fibers found in air were asbestos fibers, and the highest levels detected last fall in air represent long-term air levels. Using these worst-case assumptions, prolonged exposure (decades) to airborne asbestos and quartz *may* increase the long-term, theoretical risk of people developing lung cancer and other adverse lung health effects (more than 1 additional case in 10,000 people exposed). For individuals who conduct frequent cleaning of their residences, as recommended in this report, or participate in the U.S. Environmental Protection Agency cleaning/sampling program, it is unlikely that their exposure would resemble these worst-case conditions.

· A review of the building sampling results from this investigation indicates that there is not a consistent spatial distribution pattern of asbestos, SVF, mineral components of concrete, and mineral components of wallboard in air and settled surface dust. This indicates that the materials are heterogeneously distributed. There are many factors that may contribute to the heterogeneous distribution, including whether the area was cleaned (indoors and outdoors), cleaning method, date since last cleaning, and how much dust was initially in the area. It is not clear which factors contributed to this pattern.

· Results from this investigation do not necessarily reflect conditions that would be found in other buildings, at other times just following the collapse, or after the sampling period. The measurements reflect conditions present at the time of the sampling (November 4–December 12, 2001) in the buildings and areas sampled. The limited number of results obtained from the comparison areas above 59th Street may or may not reflect the New York City-specific background levels of asbestos, SVF, mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum, mica, and halite).

Recommendations

Based upon the conclusions of this investigation, the New York City Department of Health and Mental Hygiene and the U.S. Agency for Toxic Substances and Disease Registry make the following recommendations.

· Because more asbestos, synthetic vitreous fibers (e.g., fiberglass), mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum, mica, and halite) were found in settled surface dust in lower Manhattan residential areas when compared to comparison residential areas, the New York City Department of Health and Mental Hygiene and the U.S. Agency for Toxic Substances and Disease Registry are recommending that people continue to conduct frequent cleaning with HEPA vacuums and damp cloths/mops to reduce the potential for exposure.

· To ensure that the recommended frequent cleaning is effective and to ensure that the health of the people of New York City is protected, the New York City Department of Health and Mental Hygiene and the U.S. Agency for Toxic Substances and Disease Registry are recommending additional monitoring of residential areas in lower Manhattan. In addition, an investigation should be conducted to better define background levels specific to the city of New York for asbestos, synthetic vitreous fibers, mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum, mica, and halite).

· Lower Manhattan residents concerned about possible World Trade Center-related dust in their residential areas can request cleaning and/or testing from the U.S. EnvironmentalProtection Agency (EPA) by logging on to the agency's World Trade Center Web page at www.epa.gov/wtc or by calling the EPA hotline at 1-

877-796-5471.

ABSTRACT

The New York City Department of Health and Mental Hygiene and the U.S. Agency for Toxic Substances and Disease Registry in collaboration with the U.S. Public Health Service Commissioned Corps Readiness Force and the World Trade Center Environmental Assessment Working Group conducted a limited investigation of residential areas near and around the World Trade Center (WTC). The purpose of the investigation was to assess potential exposures to airborne and settled surface dust that entered residential areas following the collapse of the WTC buildings.

Sampling of the residential areas occurred from November 4 through December 11, 2001, and was conducted by U.S. Public Health Service Commissioned officers detailed to the New York City Department of Health and Mental Hygiene with assistance from the New York City Department of Health and Mental Hygiene.

The results of this investigation do not necessarily reflect levels that would be found in other lower Manhattan buildings or residential areas; the measurements reflect levels that were present at the time of sampling in the specific residential areas sampled. The limited number of results obtained from the comparison areas above 59th Street may or may not reflect the New York City-specific background levels of asbestos, synthetic vitreous fibers (SVF), mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum, mica, and halite).

Low levels of asbestos were found in some indoor and outdoor settled surface dust, primarily below Chambers Street. Many of the lower Manhattan locations sampled had been cleaned prior to this investigation. No asbestos was detected in the comparison indoor dust samples taken north of 59th Street. Not enough visible settled dust was available to collect outdoor samples in the comparison area. When compared with the results obtained from the sampling locations above 59 Street, the lower Manhattan residential area settled surface dust sampling results tended to have higher percentages of SVF, mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum, mica, and halite) in settled surface dust.

Because asbestos, SVF, mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum, mica, and halite) were found at higher levels in settled surface dust in lower Manhattan residential areas when compared to comparison residential areas above 59th Street, the New York City Department of Health and Mental Hygiene and the U.S. Agency for Toxic Substances and Disease Registry are recommending that people continue to conduct frequent cleaning with HEPA vacuums and damp cloths/mops to reduce the potential for exposure and/or participate in the U.S. Environmental Protection Agency cleaning/sampling program.

Total fiber counts of air samples taken in lower Manhattan were similar to the comparison areas above 59th Street sampled during this investigation. The six lower Manhattan areas that had elevated total fiber counts were re-examined by transmission electron microscopy (TEM) and scanning electron microscopy (SEM). The TEM and SEM results indicated that neither asbestos nor SVF contributed to the elevated fiber counts. Sometimes mineral components of concrete (calcite and portlandite) and mineral components of building wallboard (gypsum, mica, and halite) were detected in air samples at higher estimated levels in lower Manhattan residential areas than in samples taken at comparison residential areas. These detected mineral levels are orders of magnitude below occupational standards. Although the occupational standards do not account for sensitive individuals or extended periods of exposure, they provide a comparison to an established health guidance value. The levels of minerals seen in airborne dust do not pose potential health hazards even for a continuous year of exposure at the highest levels detected.

INTRODUCTION

At 8:45 am eastern standard time on September 11, 2001, a commercial jetliner struck the north tower of the World Trade Center (One World Trade Center). At 9:03 am, the south tower (Two World Trade Center) was also struck by a commercial jetliner. The south tower began to collapse at 10:05 am. At 10:30 am, the north tower began to collapse. (1,2,3,4)

The collapse of these structures released massive amounts of dust and debris that covered lower Manhattan. Residents were evacuated from many areas south of Canal Street. On September 19, pedestrian and vehicular traffic restrictions for below Canal Street were modified (5). As residents moved back into the areas, they requested information on the safety of the dust and air in the area and the types of cleaning methods that should be used. The New York City Department of Health and Mental Hygiene provided guidance on cleaning for area residents and requested federal assistance in assessing potential exposures to airborne and settled surface dust that entered residential areas following the collapse of the World Trade Center (WTC) buildings.

BACKGROUND

A. World Trade Center Towers

The World Trade Center was a complex of 7 buildings on 16 acres surrounding a 5-acre plaza in lower Manhattan. The complex was bounded by Vesey Street on the north, Church Street on the east, Liberty Street on the south, and West Street on the west. The twin towers were the center of the complex. Each tower had 110 floors; the north tower was 1,368 feet tall and the south tower was l,362 feet tall. Each tower had approximately 43,200 square feet on each floor. There were seven underground levels that contained services, shopping areas, and a subway station. There were two plaza buildings (WTC 4 and WTC 5) on Church Street that had nine stories. WTC 7 was a 47-story office building. Design and structure details of the towers are shown in Table 1 (1,2,3,4,6). Basic location and U.S. Census population information

about lower Manhattan is provided in Table 2 and Figures 1 through 4.

B. Potential Contaminants

The dust cloud released at the collapse of the buildings was comprised of materials that were used in the construction of the buildings (such as concrete and insulation materials). In addition to the dust cloud from the building collapse, contaminants were released in fires fed by jet fuel and the combustible materials in the buildings.

The dust contained the constituents of concrete, wallboard, and insulation. Concrete is a mixture of cement, aggregate (sand and gravel), and water. Cement contains limestone, clay, gypsum, and metals. Sometimes other minerals (such as fly ash or crystalline silica) are added to concrete to change its properties. Concrete tends to have a high pH, and if dust from the concrete was mixed with moisture, the resulting solution would tend to have a high pH. Asbestos was used as insulation in a portion of the towers. Fiberglass, a synthetic vitreous fiber, was also used as insulation in the buildings and is likely to have been used in building furnishings. Surface dust and debris containing asbestos have been found in lower Manhattan. Asbestos was detected in the personal air samplers of rescue and recovery workers. In addition, low levels of asbestos, fibrous glass, and the constituents of concrete and wallboard have been detected in air samples collected at the WTC site perimeter. These materials are common building components, and there are other sources of these materials in any large urban areas.

C. Monitoring in Lower Manhattan After the Collapse of the World Trade Center

The U.S. Environmental Protection Agency (EPA) and other federal, state, local agencies, and private firms have been conducting environmental monitoring in a variety of media since September 11 (some of the ambient air sampling locations are depicted on Figure 5). In November 2001, EPA tasked the IT Corporation Quality Assurance Technical Support Program contractor to evaluate the environmental monitoring data that had been collected. Through April 24, 2002, there were approximately 263,000 sample results analyzed (7). There were 605 analytics that were included in the database such as asbestos, fibers, particulates, metals, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs). The greatest number of analytical samples was collected for analysis of total fiber concentration, asbestos fiber concentration, or the percentage of asbestos. The overall largest number of samples in the monitoring was for particulate matter. The monitoring stations for particulate matter (roof-top locations) are a part of the New York State Department of Environmental Conservation air quality-monitoring program. Additional stations were added after the WTC towers collapsed.

The analytical results of air samples showed decreasing concentrations that appeared to have reached pre-existing background levels by the end of April 2002 (7). Bulk dust samples

were tested for asbestos, dioxins/furans, PCBs, PAHs, and metals. The levels for some of the analytics (e.g., asbestos) were relatively high; however, only a few samples obtained after mid-October showed elevated levels (7). In general, air monitoring near the WTC has not detected any pollutants from the fire and building collapses at levels that are of public health concern. Within the restricted zone (within one block of the WTC), low levels of asbestos have been found in the airborne dust from the building collapse (7). Bulk dust and air samples (mostly on or near the work site), as well as surface runoff water, river sediment, and river water have been analyzed for other contaminants, including metals, VOCs, PAHs, dioxins and PCBs. These contaminants were found at low levels that did not indicate a need to conduct further sampling for them at the time of the residential sampling (8).

D. Community Exposures

The most likely routes of community exposures to contaminants would be through breathing in airborne dust and through direct contact with surface dust and debris. The sampling plan was developed to determine the potential for exposure to building material-related contaminants in air and dust.

E. Human Health Effects of Concern

The primary health effects of immediate concern are respiratory effects and irritant effects from inhalation of or direct contact with building-related materials. Many of the materials expected to be in airborne dust can cause eye, nose, and throat irritation. In addition, those materials that can be inhaled or respired from airborne dust can cause respiratory irritation and exacerbation of pre-existing problems such as asthma, emphysema, and cardiopulmonary disease. Materials in the surface dust can cause skin irritation on contact. There have been reports of burning throat and eyes from residents returning to the area.

OBJECTIVES

The **overall objective** of this sampling was to provide results upon which public health agencies could further determine the potential for environmental exposures to WTC collapse-related materials and possible health implications of the exposures. Sampling was intended to better characterize ambient and indoor airborne and potentially airborne particles (surface dust) in residential areas of lower Manhattan from the collapse of WTC.

Specifically, the objective was to characterize the makeup and size distribution of airborne breathing zone dust in residential areas—both indoors and outside—near the WTC. This information was used to further determine whether materials were present in air at levels of public health concern and whether settled surface dust contained materials that could potentially be re-entrained and result in continued exposures.

Note: The sampling approach was focused on contaminants that

emanated from the collapse of the WTC towers and that might cause health problems. However, this investigation could not conclude if contaminants or materials found actually came from the disaster. The contaminants that were selected for testing could be present in some areas from other sources. Some typical examples of this include cooking on a stove top, which can increase indoor airborne particulate matter; vehicle exhaust, which can increase outdoor airborne particulate matter; and recent home renovation activities, which can result in an increase in levels of gypsum, fiberglass, and other materials in air and surface dust.

METHODS

Details on the methods used in the residential sampling investigations are included in the residential sampling plan that is on the New York City Department of Health and Mental Hygiene's Internet page (http://www.nyc.gov/html/doh/pdf/alerts/indoor1.pdf). Printed copies of the plan can be requested from the New York City Department of Health and Mental Hygiene.

A. Sampling Approach

A series of three concentric circles was drawn around the WTC location. The circles were then divided by direction or zone from the WTC (north, south, and west). Attempts were made to obtain access to the same number of residential buildings per zone for sampling. Four residential buildings above 59th Street were selected for testing to determine what levels of fibers and minerals might be routinely found in the city.

Once a building was selected, air and settled surface dust sampling occurred in up to four different locations: an area outdoors near a main entryway to the building; an area inside of the main entry (or other common area); and two residential units. Informed consent for sampling was obtained and questions were asked about details that could aid in interpreting the sampling results (such as whether the windows were open on the morning of September 11, 2001).

Both air and settled surface dust samples were collected in high traffic or routinely used areas of the space. For example, settled surface dust was collected from areas where individuals frequently walked, not from behind furniture or underneath kitchen appliances. Air sample inlets were at approximately 4 feet in height above the ground/floor surface to provide results more reflective of what might be inhaled.

Attempts were made during air sampling to obtain data that would reflect what might be in the air during periods of high activity. If the selected area was not occupied at the time of sampling, and if there was no central heating or air conditioning system that could result in contaminant migration into another occupied area, aggressive air sampling was conducted. If the area was occupied, the heating or air conditioning system fan was turned on during the period of sampling. This would not represent a period of high activity, but would present data that might be found during typical

or normal activity.

B. Samples Taken

Sample collection was conducted from November 4, 2001, to December 11, 2001, for the lower Manhattan area and from December 6–10, 2001, for the comparison buildings above 59th Street. Because of the limited and time critical essence of this investigation, thirty buildings in lower Manhattan were sampled, and four comparison buildings were sampled from the area north of 59th Street. In the 30 lower Manhattan buildings, the following locations were sampled: 59 residential units, 29 common areas, and 29 outdoor areas.

There were 127 air samples taken from 117 different areas of the lower Manhattan buildings. Ten of the areas had co-located sampling equipment. In the 59 different residential units, there were 64 air samples taken. Thirty air samples were taken from 29 different common areas.

Samples taken from the four comparison buildings above 59th Street included three outside air samples, three of common areas with both indoor settled surface dust and air, and five residential units with both indoor settled surface dust and air. No outside settled surface dust samples were collected because there was no visible dust to collect.

Tables 3, 4, and 5 show the number of buildings and areas within the buildings that were sampled for asbestos, SVF, and minerals in lower Manhattan and the comparison units above 59th Street. The tables also show whether the samples were settled surface dust and air samples.

C. Field and Laboratory Changes From the Original Sampling Protocol

Once the sampling teams went to the various sampling locations, it was determined that some changes needed to be made to the sampling protocol. The sections below indicate the changes that were made to the original sampling protocol.

1. Field Changes

The sampling protocol indicated that a total of 60 residential units would be tested in lower Manhattan. A total of 59 residential units were sampled.

Indoor settled surface dust was collected using EPA's Environmental Response Team Standard Operating Procedure (ERT SOP) for household dust, as stated in the sampling protocol. However, due to cost and equipment availability constraints, Omega Ultivac vacuums with high efficiency particulate air (HEPA) filters were used instead of Nilfisk™ vacuums. To avoid the need to decontaminate the vacuum hose between each sampling event, a sample collection filter (Alsock, by Midwest Filtration) was inserted into the air-intake end of the vacuum hose. The Alsock has a 97% capture of particles with diameters of 1.1 microns and

larger. The ERT SOP-specified vacuum bag filter has a 4- to 5-micron pore size.

Instead of one settled surface dust sample per unit, two co-located indoor settled surface samples were collected. This change was made as two different laboratory locations were involved in the analysis. The EMSL Analytical laboratory in New York City analyzed samples for fibers (using PCM, PLM, and TEM); the EMSL Analytical laboratory in Westmont, New Jersey, analyzed samples for the remaining materials and conducted the SEM analysis for fibers.

Delays in obtaining equipment resulted in only 10 buildings being sampled for the PM2.5 air fraction.

There was no visible settled surface dust around the comparison homes selected above 59th Street; therefore, no outdoor settled surface dust samples were collected from thecomparison areas above 59th Street.

2. Sample Analysis Changes

Airborne and settled surface dust samples were analyzed for crystalline silica using EMSL Analytical's Material Science Division Operating Procedure MSD 0700, January 2000. XRD analysis was conducted for the nonsilica crystalline minerals in air and settled surface dust samples by EMSL using Material Science Division Operating Procedure MSD 9300, January 2002. The samples were not ashed prior to XRD analysis for the following reasons: ashing samples could have resulted in loss or breakdown of analytes of interest including gypsum; and there was not enough organic material present to result in loss of method sensitivity for crystalline minerals of interest.

SEM analysis was conducted on air samples for fibrous glass and other synthetic vitreous fibers by EMSL using Material Science Division Operating Procedure MSD 0300. This analysis was conducted on all samples collected from the comparison areas above 59th Street and on only those air samples from lower Manhattan with PCM fiber concentrations higher than the comparison PCM fiber concentrations.

Settled surface dust samples were analyzed for fibrous glass by EMSL using New York State Department of Health Environmental Laboratory Approval Program Method 198.1 polarized-light microscopy methods for identifying and quantifying asbestos in bulk samples.

Settled surface dust samples were not weighed, so surface loading of materials could not be calculated. Although settled surface dust samples were sieved, sieving was not conducted as specified in the ERT SOP. Rather, sieving was conducted as specified in MSD 0700 and 9300.

D. Data Management and Quality Assurance/Quality Control Procedures

EPA provided the laboratory used for this investigation. The

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laboratory is part of EPA's "certified" Contract Laboratory Program. It used all of the EPA quality assurance/quality control laboratory methodologies when analyzing the samples collected for this investigation. EPA conducts audits of all the EPA-certified laboratories to assure that appropriate quality assurance/quality control laboratory methodologies are being used.

Chain-of-custody procedures were established and maintained throughout sample collection, transportation, and analysis of samples. These procedures helped to assure that analytical results could be matched to the sampling locations.

Following the sampling effort, more than 5,400 analytical results were individually returned from the laboratory. All results were entered into a Microsoft EXCEL spreadsheet along with the other raw data describing where and how the sample was taken. Asbestos-in-air laboratory results were submitted calculated in concentration and were used as received. The laboratory typically submitted particulates-in-air results as the initial and final filter weights (pre- and post-sampling weights). The total amount of material deposited on the filter and resulting concentrations for the sampling location were estimated from the laboratory results. Results for asbestos, fiberglass, and mineral components in settled surface dust were used as provided by the laboratory: percentage of material analyzed.

All of the results were reviewed as a part of normal data quality analysis. The general purpose of this quality assurance/quality control (QA/QC) review is not to pronounce the data "accurate," but to determine whether the results are obviously affected by sampling or analytical errors. For this investigation, the reported analytical results were accepted, rejected, or used conditionally. Decisions on how to treat a data set were made primarily by comparing the measured results to information gathered from the blanks using graphs and statistical analyses.

Most of the results were used as received from the laboratory. The laboratory reported the asbestos in air results as a concentration of asbestos in the sampled location. The asbestos and fibrous glass in airborne and settled surface dust were used as received.

Results for the airborne particulate matter were rejected due to issues found during the quality assurance analysis. Variability of field blank sample weights was beyond the acceptable limits. A more thorough discussion of why the airborne particulate matter results were rejected is located in Appendix A of this report.

The XRD analysis was conducted on the air samples collected for particulate matter (PM100, PM10, PM4, and PM2.5). The PM results were rejected, but the XRD results were accepted as semiquantitative. The XRD results are considered valid because the analysis method does not depend on the filter-weighing process used to determine PM concentration. The XRD mineral concentrations are based on individual mineral weight standard curves—not the weight of the dust sample collected. These standard curves are not impacted by pre- and post-sampling filter weight variability.

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Minerals were not detected on the blank air samples. This indicates that sample contamination or cross-contamination did not occur during air sampling, shipping, or sample analysis. The XRD information for the air samples provided semiquantitative values (estimated values, indicated by "J"). The PM100 and PM10 results may be potential overestimates, as the crystalline mineral size used for the standard curve is close to PM4 in size. This will result in the XRD overestimating the concentration of minerals present in the larger fractions. Similarly, the PM2.5 results may be potential underestimates of mineral concentrations.

The XRD settled surface dust results are also considered semiquantitative ("J") due to particle sizes used for standard curve/calibration (as described for the air samples) and due to the lack of standard analytical error (SAE) information from the laboratory.

E. Data Analysis

The data were entered into an Excel spreadsheet, and descriptive statistics were developed for the sample results. Basic trend analysis on the analytical data was conducted using the SAS statistical program (version 8.01). The SAS System is an integrated system of software providing complete control over data access, management, analysis, and presentations. Examples of some of the SAS procedures ("Proc") used were the "Proc Mean" and "Proc t-Test."

F. Limitations and Uncertainties

The intent of the sampling was not to characterize the total extent of contamination in lower Manhattan or determine the extent of exposures for all people in lower Manhattan that may have resulted from the collapse of the WTC towers. Rather, it was a preliminary investigation to determine if building collapse-related materials could be present at levels of possible health concern in lower Manhattan. Results from this investigation do not necessarily reflect conditions that would be found in other buildings, at other times just following the collapse, or after the sampling period. The measurements reflect conditions present at the time of the sampling (November 4–December 12, 2001) in the buildings and areas sampled.

Some uncertainties tend to underestimate the risk of exposure while other uncertainties tend to overestimate the risk of exposure.

· The locations selected for sampling within each building may not be representative of the rest of the building; the building-specific results may either *overestimate or underestimate* the levels of WTC-related materials in other areas of the building.

· Sampling was conducted in November and December of 2001. Levels of particulate matter and airborne irritants were likely to have been higher in the days and weeks immediately after the WTC collapse. Levels of settled surface dust were likely higher as well. Outdoor dust contamination would have been reduced by wind, rain, and cleaning (HEPA trucks to vacuum the streets and

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sidewalks). Indoor settled surface dust may have been reduced if appropriate cleaning had been conducted prior to this sampling event. Therefore, these results serve as estimates, and are not necessarily reflective of conditions at earlier time points or of current conditions.

· Likewise, if continued cleaning has occurred since the November–December 2001 sampling event, levels of contaminants should be lower today. Therefore, the results of this sampling effort would tend to *overestimate* the current levels of WTC-related materials in the buildings.

Uncertainty also exists in determining at what level and duration of exposure people might experience irritation or other symptoms from exposure to fibers and crystalline minerals.

· The likelihood of experiencing irritation from individual contaminants or contaminant mixtures is uncertain. A short exposure to a small amount of an irritant may be tolerated, but exposures that continue for a longer period of time or are to a larger amount of an irritant, may overwhelm the body's ability to remove the irritant and increase the likelihood of irritation. Individual differences also play a significant role in whether or not irritation occurs. Using a risk estimate from an occupational situation may *underestimate* risks for more sensitive or susceptible individuals in the general population. Some of the information needed to estimate the risk of irritant symptoms, is not available from this study. When assumptions are made in the absence information (e.g., the duration and intensity of the total exposure) additional uncertainty is introduced.

· Persons with pre-existing respiratory (e.g., asthma, emphysema) or cardiopulmonary problems are more likely than healthy individuals to experience adverse health symptoms at lower levels of airborne particles and contaminants. Airborne dust and crystalline mineral levels based on studies of healthy individuals are levels that *underestimate* the risk for a susceptible individual.

· Individuals who were in the lower Manhattan area when the WTC collapse occurred may have received a bolus inhalation dose of dust, fibers, crystalline minerals, and other materials. Health effects of a bolus dose are not known. Additional exposures would add to the potential for health effects. Therefore, the short and long-term health effects, if any, of such an exposure cannot be determined from the measurements made in this study.

RESULTS

This section of the report will provide an overview of what was determined by this investigation. The overall analytical findings will be presented according to what environmental media was sampled (air or settled surface dust, Figures 7-17).

A. Survey

The primary duty of the sampling team was to coordinate with the building management to identify sampling locations that would

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yield results representative of the area sampled. These duties included identifying unoccupied residences that could have aggressive air sampling conducted. In addition the sampling teams photographed equipment setup and operation, sampling locations, distribution of surface dust, and general conditions around the building.

The sampling team completed building surveys, in part, to gather the information needed to cite sample locations and to provide information to be used in interpreting the results. These surveys were completed on the basis of their observations and on discussions with building management when representatives were available. However, information was not always available to completely answer each survey question. This was especially true when evaluating specifics of the heating and air conditioning systems. The validity of the information is dependent on the memory and experience of the building representatives and, in the case of residential units, may not reflect the condition or treatment of the entire building.

The survey form and photographs were reviewed along with the analytical results to put the sampling results into the context of where and how the samples were obtained and to determine the general conditions of the sampling locations. Given the purpose of this investigation, the limited amount of locations sampled, and the uncertainty in some of the survey results, no attempt was made to correlate survey information with measured concentrations of any of the materials. The table in Appendix B provides a summary of results from the survey form questions that were most consistently answered.

B. Settled Surface Dust

Settled surface dust samples were analyzed for materials consistent with debris from a building collapse. Materials of interest include insulation material (asbestos, synthetic vitreous fibers, components of concrete (portlandite, calcite, and crystalline silica) and components of other building materials (gypsum, mica, and halite). A detailed summary of results is given in Appendix C. To protect the privacy of individuals who allowed sampling in their residences and buildings, specific detailed locations are not shown. Results of the settled surface dust analysis indicate the composition of settled surface dust in lower Manhattan is different from that of the dust analyzed from the comparison areas above 59th Street. Although the materials found are consistent with materials expected from the World Trade Center collapse, these results cannot determine the actual source of the materials present because these materials are common building components and can come from other sources in a busy urban area.

1. Fiber Analysis of Settled Surface Dust

Asbestos and SVF, although not found in homes in the comparison areas above 59th Street, were present in the settled surface dust in some areas of lower

Manhattan.

All settled surface dust samples were analyzed by polarized light microscopy (PLM) for fiber type and content. This technique distinguishes between asbestos fibers, textile fibers, and synthetic vitreous fibers (SVF), which include glass wool and mineral wool. The results are reported as a percent.
Because PLM is an optical method, the amount reported is a visual estimation of the percent of area viewed. Therefore it is neither strictly a weight or a volume percent. These results do provide an indication of the presence of asbestos or SVF in the dust, and some idea of relative amount.

In lower Manhattan, asbestos was only detected in settled surface dust in one indoor and two outdoor locations by PLM (Figure 8). If asbestos was not seen in the sample or reported as <1% by PLM, a second test was done which is more sensitive, transmission electron microscopy (TEM). An additional 4 outdoor and 15 indoor locations contained asbestos when examined by TEM (Figure 9). Chrysotile asbestos was the only form of asbestos identified, either by PLM or TEM, in all settled surface dust samples. In this study TEM is primarily used as an indicator of the presence or absence of asbestos. For the PLM analysis, values <1% are an indicator of the presence of asbestos because this is the detection limit for PLM. For TEM a detection of asbestos is confirmation of its presence. Therefore, values <1% and values greater indicate the presence of asbestos. Results shown in Table 6 and discussed below refer to all samples positive for asbestos, by either the PLM or TEM methods (Figure 10).

Asbestos was found in indoor settled surface dust in 10 of 57 residences sampled in lower Manhattan (18%) (Table 6). The settled surface dust in common areas contained asbestos in 5 of 26 areas sampled (19%), and asbestos was found in outdoor dust in 6 of 14 areas sampled (43%) (Table 6). Asbestos levels ranged from none detected up to 3.4% (the highest level was found in an outside sample). However, without surface-loading information, the percentage of asbestos present does not allow for characterization of potential exposures. No asbestos was found in the comparison homes north of 59th Street. Figure 10 depicts the results of analysis of the asbestos content of settled surface dust in samples from residences in lower Manhattan.

The SVF results, seen in Table 6, show a broad range of SVF content in the settled surface dust from none detected up to 35% in indoor dust samples and as high as 72% outdoors. The location and range of SVF found in settled surface dust is shown in Figure 11 for all areas sampled in lower Manhattan. SVF was found in indoor dust in 26 of 57 residences sampled as analyzed by PLM (46%). The settled surface dust in common areas contained SVF in 14 of 26 areas sampled (54%), and SVF was found in outdoor dust 11 of 14 times sampled (79%). The majority of SVF detected was glass wool. Only four buildings contained mineral wool in settled surface dust, ranging from 1%–7%. Because no surface-loading information is known, the exact percentage is less informative than its presence. No SVF was found in the comparison homes north of 59th Street by PLM analysis. Therefore the SVF content of settled surface dust in some areas of

lower Manhattan is higher than that of the selected comparison areas above 59th Street (Figure 11).

2. Mineral Analysis of Settled Surface Dust

Settled surface dust samples were analyzed for crystalline minerals potentially associated with the material from the collapsed World Trade Centers. The results reported here are expressed as a mass percent of the dust (weight of minerals per weight of dust). Quantification of the minerals in dust is not exact due to variations in particle size and other methodological interference. Therefore, these data will only be considered semiquantitatively and should be considered estimated values, noted by the "J" qualifier.

Quartz, calcite, portlandite, and gypsum were the most abundant minerals detected (see Table 7). Mica was detected with less frequency than the other minerals, and generally estimated at approximately 0.1%J of the dust. Halite (salt) was also detected at trace levels.

Mineral components of concrete (quartz calcite, and portlandite) and other building materials (gypsum, mica, and halite) in the indoor settled surface dust of some areas of lower Manhattan were estimated at higher percentages than for the comparison areas above 59th Street.

Quartz was detected in all 14 outdoor dust samples, 21 of the 26 common area samples, and only 30 of the 57 samples from residences in lower Manhattan. Neither cristobalite nor tridymite, other forms of crystalline silica, were found in any of the settled surface dust samples. For this discussion quartz will refer to the alpha-quartz form of crystalline silica. Levels of quartz were estimated as from 0.05%J to 31%J in residences, and from 0.03%J to 25%J in common areas. Estimated quartz content in outdoor samples ranged from 1%J

to 27%J. Because quartz is a common material (i.e., silica sand), finding this mineral in the city where there is a lot of concrete building material is not unusual. However, quartz in dust from the comparison areas above 59th Street was estimated from nondetect to 1%J in the common areas and from nondetect to 2% J in the residences. Figure 16 shows the locations where the estimated maximum quartz content in settled surface dust was greater than or similar to estimated quartz content in the dust samples from the comparison areas above 59th Street. Fifteen residences, six common areas, and 12 outdoor areas had estimated quartz levels higher than the associated comparison areas above 59th Street. Therefore, quartz was elevated in some indoor areas of lower Manhattan relative to the comparison areas above 59th Street. Outdoor dust samples were not taken from the comparison areas, due to insufficient amounts of dust. Figures 13-16 compare the indoor and outdoor locations in lower Manhattan to the indoor samples above 59th to show the relative

distribution of the minerals.

Calcite (calcium carbonate) and portlandite (calcium hydroxide) are also components of concrete. They occurred with similar frequency in the dust samples and were often co-located with the quartz. Calcite ranged from an estimated 0.8%J to 19%J in outdoor areas, and from 0.02%J to 21%J in indoor areas. Portlandite ranged from an estimated 0.07%J to 6%J in outdoor areas and from 0.04%J to 8%J in indoor areas. In contrast, the maximum levels found in indoor comparison areas above 59th Street were 0.9%J calcite and 0.08%J portlandite. Figures 13 and 15 show the locations where the estimated calcite and portlandite content in settled surface dust was higher than to that estimated in dust samples from the comparison areas above 59th Street. For calcite, 13 residence and 9 common area samples had estimated levels higher than those found in the comparison areas above 59th Street. Similarly for portlandite, 17 residence and 9 common area samples were estimated as higher than values in comparison areas above 59th Street. So although these materials are found in urban areas, perhaps due to erosion of concrete, building construction and maintenance, the estimated percentages of calcite and portlandite were larger in some areas of lower Manhattan relative to the comparison areas above 59th Street (Figures 13 and 15.)

Gypsum (hydrated calcium sulfate) is a major component of dry wall. Gypsum was found in 11 of 14 outdoor settled dust samples at levels estimated as 0.03%J to 27%J. Indoor levels of gypsum ranged from an estimated 0.07%J to 20%J in 23 of 26 common areas and from 0.05%J to 30%J in 45 of 57 residences. These estimated percentages are higher than the estimated maximum of 4%J seen in the comparison areas above 59th Street. Figure 14 shows the locations where the estimated gypsum content in settled surface dust was higher than or similar to the levels in the dust samples from the comparison areas above 59th Street. Nine residence and six common area samples had estimated levels higher than those found in the comparison areas above 59th Street. Gypsum was elevated in settled indoor dust in some areas of lower Manhattan relative to the comparison areas above 59th Street (Figure 14).

The data can also be evaluated in a nonquantitative manner by just inspecting the frequency of detects of mineral in dust for lower Manhattan and the comparison areas. As shown in Table 7, the pattern of prevalence for the minerals appears to be similar in both study areas. In other words, the minerals were detected in both locations with about the same frequency. The data imply that building materials were the source for both areas. This source was likely building materials; however, the magnitude of the impact was greater in areas closer to the World Trade Center.

3. Alkalinity of Settled Surface Dust

Several of the minerals detected in the settled surface dust samples, such as portlandite, can make the dust more alkaline, or raise the pH. Originally, the pH of all of the settled surface dust samples was to be determined. However, enough dust for this analysis was only available at two locations. Both dust samples

were alkaline (pH of 8.6 and 9.8). On the pH scale of 0 (acidic) to 14 (alkaline or basic), these values are slightly alkaline. Mineral analysis of these two settled surface dust samples estimate levels of calcite (15%J, 19%J) and portlandite (6%J, 3%J) were present, respectively. These crystalline minerals along with other components of concrete would have contributed to the measured alkalinity.

C. Air

The settled surface dust results discussed previously indicate the materials present in each area sampled. Fibers and small particles within the dust may become airborne during daily activity or during periods of high activity such as cleaning. Therefore, the settled surface dust sample results are an indicator for areas with a potential for airborne contaminants. Air sampling was conducted to determine the actual levels of fibers, dust, and crystalline minerals in the air at the time of settled surface dust sampling. Where feasible, these results are correlated to the settled surface dust results.

1. Fibers in Air

Samples for airborne fibers were first analyzed by phase contrast microscopy (PCM) to count all fibers present according to the National Institute for Occupational Safety and Health (NIOSH) Method 7400 counting rules. Phase contrast microscopy identifies fibers based on size and shape, but not the specific type of fiber. Therefore, the fibers seen by PCM include asbestos fibers as well as other fibers, such as textiles, fiberglass, and cellulose that might be present. Any sample with airborne fibers above the highest PCM levels found in the comparison locations was re-analyzed by transmission electron microscopy (TEM) and scanning electron microscopy (SEM). The TEM methodology can distinguish what types of fibers are in a sample, particularly asbestos fibers. The SEM method identifies SVF. Some fibers present in the settled dust of the area may become suspended in the air and be present in the air sample.

a. Indoor Air

Fiber levels in air are expressed as the number of fibers in each cubic centimeter (cc) of air or fibers per cc (f/cc). Low levels of fibers were found in the comparison areas above 59th Street homes, where fiber levels ranged from less than 0.001 f/cc (<0.001 f/cc) to 0.003 f/cc. Because no asbestos was detected in the settled surface dust of the comparison areas above 59th Street, these fibers are not likely to have been asbestos. SEM analysis showed they were not SVF. Figure 7 shows all airborne fiber levels determined by PCM in the lower Manhattan area with respect to the fiber levels found in the comparison areas above 59th Street. These data represent all fibers found according to the analytical method used (NIOSH 7400) and are not specific to asbestos or SVF.

The majority of the lower Manhattan air samples from indoor areas without asbestos in the dust were within the range of fibers found in the comparison areas above 59th Street (<0.001 to

0.003 f/cc). Six of these air samples (from 3 common areas and 3 residences) had higher levels of fibers in air than the comparison areas above 59th Street (Table 8). Four of these areas had measurable levels of SVF in the settled surface dust. All six-air samples were re-analyzed by TEM to determine if the fibers present included asbestos fibers. Asbestos fibers were not found in these six air samples (Table 8). A third analysis was done by SEM to determine if SVF fibers were present in those air samples from areas with SVF in the settled surface dust. SVF fibers were found in three of these air samples at concentrations from 0.000037 f/cc to 0.000255 f/cc. Although SEM is a more sensitive method, detecting thinner fibers than PCM, reported SVF levels were well below the PCM method detection limit of 0.001f/cc. SVF fiber concentrations in the comparison areas above 59th Street ranged from none detected to 0.000087 f/cc. Although air samples from comparison areas above 59th Street were not re-analyzed by TEM, no asbestos fibers were noted on the subsequent SEM analysis for SVF. Therefore the six air samples that had total fiber counts greater than comparison areas above 59th Street were not elevated due to either asbestos or SVF fibers.

There were 15 out of the 83 (18%) indoor areas in lower Manhattan with measurable asbestos in the settled surface dust, 10 residences and 5 common areas (Table 9). Nine of these residences were sampled aggressively (the air exhaust of the vacuum used for settled dust sampling was used to stir up all dust into the air before an air sample was taken). Four of these aggressively sampled residences had measurable fiber levels in air ranging from 0.001 f/cc to 0.003 f/cc. One residence was occupied and could not be aggressively sampled. Air sampling at that location indicated <0.001 f/cc by PCM analysis. Because the levels found were within the range measured in the comparison areas above 59th Street, no TEM or SEM re-analysis was performed on these air samples. Therefore the composition of these fibers is unknown (i.e., asbestos, SVF, cellulose).

None of the common areas were aggressively sampled because all of these areas were open to the public. Of the five common areas with some asbestos in the dust, three had measurable levels of fiber in the air ranging from 0.001 f/cc to 0.002 f/cc. One area in building 5 where there was not enough settled surface dust to sample had an airborne fiber count of 0.002 f/cc. No TEM or SEM re-analysis was performed on these air samples, and the composition of these fibers is unknown (i.e., asbestos, SVF, cellulose).

b. Outdoor Air

Six of the 14 lower Manhattan outdoor locations sampled had detectable levels of asbestos in the settled surface dust, indicating a potential in these locations for asbestos fibers to become airborne. Air sampling indicates three of the locations did not have detectable fibers in the air (Table 9). The air samples from buildings 1, 2, and 5 did have fibers detected at levels from 0.001 f/cc to 0.003 f/cc. Of the 15 locations where no settled surface dust samples were taken, the majority of the results showed <0.001 f/cc in the air, with only 4 samples reported at the

detection limit of 0.001 f/cc. Because the levels found were within the range measured in the comparison areas above 59th Street, no TEM or SEM re-analysis was performed on these air samples, and the composition of these fibers is unknown (i.e., asbestos, SVF, cellulose).

2. Minerals in Air

Air samples of different particulate sizes, representing inhalable (PM100), thoracic (PM10), and respirable (PM4 and PM2.5) fractions were collected in selected building locations. Not all size fractions were collected at every location. The samples were analyzed by XRD for the same crystalline minerals seen in the settled surface dust samples. Each of the four size fractions was collected with a separate sampling device. The PM100 fraction collected particles with an aerodynamic diameter of 100 microns and lower. The PM10 fraction collected particles with an aerodynamic diameter of 10 microns and lower and so on. The results reported here are expressed as the mass of mineral per unit volume of air or micrograms per cubic meter of air ($\mu g/m^3$). Quantification of the minerals is not exact due to variations in particle size as compared to the particle size used in the standard curve and other methodological interference. Therefore, these data will only be considered semiquantitative and should be treated as estimated values, noted by the "J" qualifier.

Due to changes in sample volume, the detection limit of minerals in each fraction varied, allowing lower concentrations to be recorded in the PM10 and PM100 fractions compared to the PM4 fraction. Care must be taken when comparing results between fractions for this reason. Additionally, although the PM4 fraction should be a subset of the PM10 and PM100 fractions, PM4 results are sometimes higher than PM10 or PM100 from the same location. Therefore, due to uncertainties in the quantification and general quality assurance/quality control concerns, data will not be associated to a specific building sampling location or correlated between size fractions at the same location.

The comparison air samples, taken in areas above 59th Street, contained no quartz, cristobalite, tridymite, calcite, portlandite, mica, or halite above method detection limits (Table 11). Gypsum was found at least once in all size fractions collected in the comparison areas above 59th Street. Gypsum concentrations were estimated at 3 $\mu g/m^3$J (PM2.5), 5 $\mu g/m^3$J (PM4), 3 $\mu g/m^3$J (PM10), and 3 $\mu g/m^3$J (PM100) (Table 11).

All of the minerals found in the settled surface dust were seen in at least one air sample from lower Manhattan (Table 11). Quartz, calcite, portlandite, and gypsum were detected at similar frequencies in each of the larger size fractions, PM100, PM10, and PM 4. Table 11 shows the frequency of detection and the range of estimated values for each size fraction sampled. Quartz and gypsum were each detected once in the PM 2.5 fraction. The PM 2.5 size fraction was only collected toward the end of the project, and there are fewer samples for this size fraction.

Estimated levels of minerals in air, including quartz, calcite,

gypsum, and portlandite, appear higher in some areas of lower Manhattan than in the comparison areas above 59th Street.

Approximate quartz levels in air ranged from 4 µg/m^3–19 µg/m^{3}J in the respirable fraction (PM4), 3 µg/m^3–12 µg/m^{3}J in the thoracic fraction (PM10) and 3 µg/m^3–13 µg/m^{3}J in the inhalable fraction (PM100). Detection frequencies were similar in these fractions at 11%, 10%, and 14% respectively. However, quartz was only seen in one of the PM2.5 samples (3%) at an estimated 3 µg/m^{3}J. Cristobalite, a different crystalline form of crystalline silica, was found in one lower Manhattan air sample at

15 µg/m^{3}J in the PM100 fraction. Cristobalite was not seen in any other sample, either air or settled surface dust. Across the size fractions, quartz was detected in air samples taken in lower Manhattan; it was not detected in the comparison areas above 59th Street. Therefore, the estimated airborne levels of quartz appear to be higher in some air samples from lower Manhattan than the chosen comparison areas above 59th Street.

Similar observations can be seen in the results for calcite and portlandite. Calcite and portlandite occur at a similar frequency to quartz (Table 11) and tend to be present in the same air samples (Appendix C.) Both minerals are present in PM4, PM10, and PM100 size fractions. Calcite was estimated at 3 µg/m^{3}J–14 µg/m^{3}J and portlandite at 14 µg/m^{3}J–95 µg/m^{3}J in inhalable dust. Mica and halite are not seen with the same frequency, but are detected in several air samples from lower Manhattan. Calcite, portlandite, mica, and halite are all detected in air samples taken in lower Manhattan, but not in air samples from the comparison areas above 59th Street (Table 11). Therefore, the airborne levels of calcite, portlandite, mica and halite appear to be higher in some air samples from lower Manhattan than in the samples from the comparison areas above 59th Street.

Gypsum was the most common mineral detected in air samples from lower Manhattan for all size fractions and was detected in 40 out of 114 respirable fraction (PM4) air samples at levels ranging from approximately 4 µg/m^{3}J–15 µg/m^{3}J. Gypsum was estimated at 3 µg/m^{3}J–14 µg/m^{3}J and detected less frequently in the PM10 (33 of 105) and PM100 (24 of 101) size fractions, even though the detection limits for these fractions were lower. Gypsum was found in one of the PM2.5 samples, at approximately 3 µg/m^{3}J. Across the size fractions, gypsum was detected in air samples taken in lower Manhattan at higher estimated levels than air samples taken from the comparison areas above 59th Street (up to 5 µg/m^{3}J). Therefore, the airborne levels of gypsum seem to be higher in some air samples from lower Manhattan than the chosen comparison areas above 59th Street.

DISCUSSION

This section of the report will provide a more in-depth review of where the various materials were detected. In addition, the public health concerns potentially associated with these materials is also presented.

A. Discussion of Results

Settled surface dust samples obtained from lower Manhattan as part of this investigation contained materials consistent with debris from a building collapse. Both indoor and outdoor settled surface dust samples contained some amount of insulation material (asbestos, glass wool, and mineral wool), components of concrete (portlandite, calcite, and quartz), and components of other building materials (gypsum, mica, and halite). These materials were not present at the same levels in the four buildings above 59th Street sampled for comparison.

Asbestos levels in dust in the lower Manhattan area, ranging from <1% to 3.4%, were consistent with samples taken of outdoor material by EPA after the WTC collapse. SVF levels in the settled surface dust in lower Manhattan were higher than in the comparison areas above 59th Street, ranging from 1% to 72%. No data were available for SVF in lower Manhattan prior to this investigation. Analysis of archived dust samples collected after the WTC collapse by NIOSH, confirms the presence of SVF in bulk samples taken in lower Manhattan.

The minerals found in settled surface dust from residential buildings in lower Manhattan were consistent with minerals reported by the United States Geological Survey (USGS) for outdoor settled surface dust across lower Manhattan after the WTC collapse (9). Thirty-three dust, two concrete, and two steel insulation samples were analyzed by USGS, including two from an indoor area. Quartz, calcite, and gypsum were reported for all of these samples. Each of these was occasionally reported as a major constituent of the material, i.e., estimated at 20% or higher. Twenty-six of these samples contained mica, usually estimated as trace or less than 5% of the material. Portlandite was only noted in two samples at trace levels, including the one indoor sample analyzed.

1. Association of Asbestos and Synthetic Vitreous Fibers

Based upon the sampling results, it appears that SVF is likely to be found in settled surface dust whenever asbestos is detected in the settled surface dust. All of the six outdoor and five common areas that had asbestos in settled surface dust also had SVF in the settled surface dust (Table 9). Of the ten residences that contained asbestos in settled surface dust, a little more than half also contained SVF. However, this does not hold true in areas without asbestos, where the absence of asbestos does not indicate an absence of SVF. Of the eight outdoor areas without asbestos in the settled surface dust, three contained SVF. Similarly, SVF was found in approximately 25% of the common areas and in approximately 36% of the residences without asbestos in the dust. Although the presence of asbestos in the dust seems to correspond to SVF, the absence of asbestos does not predict or correspond to a presence or absence of SVF in settled surface

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dust, in either indoor or outdoor areas of lower Manhattan.

2. Association of Asbestos and Synthetic Vitreous Fiber Levels Outside of and Within a Building

Outdoor settled surface dust was collected at 14 buildings in lower Manhattan. One purpose for collecting outdoor dust was to determine if the contents of the outdoor dust at a location would reflect the type of indoor dust. In the case of fibers, there is little correlation in the indoor and outdoor dust composition. High levels of outdoor SVF are associated with both high and low indoor levels. The presence or absence of asbestos in settled surface dust shows a similar lack of correlation. The outdoor settled surface dust samples do not correspond with indoor dust composition for either group of fibers. This lack of association could, in part, be due to whether and how frequent interiors and exteriors had been cleaned.

In contrast, indoor levels of fibers in settled surface dust did seem to correspond within a building. Buildings with elevated SVF levels in the common area tended to have elevated levels in the residences. A similar pattern was seen between the two residences sampled in the same building. For example, SVF was often found in both residences sampled within the same building, or was absent in both residences. Within this limited data set, fiber levels in one area of a building seem to weakly correspond with fiber levels in other areas of the same building. However, none of these data represent total dust loading, only the relative amount of fibers within the dust.

3. Occurrence of Crystalline Minerals

Indoor areas that have elevated levels of quartz in settled surface dust appear to also have elevated levels of calcite, portlandite, and gypsum(see Figure 10). Additionally, these four minerals appear together in all outdoor samples with only minor exceptions. Although only 14 of the 30 buildings had samples taken of outdoor dust, there does seem to be a correlation between elevated outdoor and indoor levels of quartz, gypsum, and the other minerals. It is unknown if this would be seen in outdoor areas above 59th Street for comparison, as not enough outdoor dust was available for analysis.

Most elevated quartz and gypsum levels indoors were found in the first ten buildings sampled during the first 5 days of the project (with the exception of 14% quartz in the common area of building 22). Although many of these buildings were closer to the WTC site, location may not be the only factor contributing to higher mineral levels in the dust. Other buildings sampled in these areas later (e.g., 13, 14, and 28) did not have elevated levels of minerals. Many factors may contribute to this finding including whether the area was cleaned (indoors, outdoors), the cleaning method used, the time since the last cleaning, and the amount of dust that was initially in the area. It is not clear which factors contributed to variation in mineral levels by building.

Within a building, levels of quartz, calcite, and portlandite tended

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to be similar, and in some cases showed a similar profile in areas with elevated quartz (see Figures 13, 15, and 16). In general, where quartz was greater than 5%, calcite and portlandite were also present, but as smaller proportions of the dust. Gypsum, although often present with the other minerals, varied from being the most abundant to the least abundant in the dust.

4. Buildings Impacted by Asbestos, Synthetic Vitreous Fibers, and Crystalline Minerals

There was no clear pattern of which buildings were impacted by asbestos, SVF, and crystalline minerals. Figure 17 shows the approximate locations of the buildings and the level of contaminants in settled surface dust that were above or below the levels found in the comparison areas. The data are summarized and presented to indicate the indoor areas within a building with higher levels of a material in settled surface dust than was found in the comparison areas above 59th Street (Table 12). In this table, quartz was considered representative of the two other minerals associated with concrete, portlandite and calcite.

In 6 of the 29 buildings (approximately 21%) sampled in lower Manhattan, concentrations of these materials were not detected at levels higher than the levels in the comparison buildings above 59th Street. These six buildings tend to be among the buildings farthest from the World Trade Center and not located along what appear to be major streets or intersections. Map 17 shows the approximate locations of the buildings and the level of contaminants in settled surface dust that were above or below the levels found in the comparison areas.

Twenty-three buildings (approximately 79%) had levels of at least one of these materials in the dust at levels higher than the maximum found in the comparison buildings. Four of these buildings (buildings 4, 5, 6, and 9) contained all four materials above levels seen in the comparison areas above 59th Street in at least one indoor sample (Table 7). Seven of the 23 buildings were only impacted by SVF in indoor areas (buildings 13, 14, 17, 18, 25, 26, and 28). One building was only impacted by asbestos (building 11). The remaining 11 buildings were impacted by some combination of fibers and minerals. No clear pattern emerges in terms of which fibers or minerals occurred in the indoor dust of a building. Three of these building had only the two fiber types present (buildings 15, 24, and 27). One of these building had only the two minerals present (building 8).

The limited number of buildings sampled and the limited number of indoor locations that were sampled make it difficult to draw conclusions about the relationship of geographic location and the number of different materials found in the dust above the levels found in the comparison locations. However, buildings close to the World Trade Center tend to have a greater number of these materials found.

5. Significance of Minerals and Fibers in the Settled Surface Dust

The results previously discussed indicate minerals, asbestos, and

SVF are all found at higher percentages in the samples from lower Manhattan when compared to the sampled areas above 59th Street. These findings are based on comparing the percent of each mineral and fiber in the settled surface dust. However, to determine the total mineral and fiber content in a room, the amount of dust present would also need to be known. Because surface loading is not known, we cannot demonstrate that the total amount of mineral and fiber is increased in any given area. However, these data indicate the components and quality of the dust in lower Manhattan is different from that of the comparison areas above 59th Street.

The increased crystalline minerals and fibers in the settled surface dust indicate a potential for contact with these materials. The magnitude of this contact will vary with dust loading (which is unknown) and activity in the area. Residents may come into contact with the dust directly (i.e., skin, eyes). Additionally, the dust may also become re-suspended in the air through activities such as cleaning. In this way the settled surface dust may be a reservoir for material in the air. Therefore settled surface dust results are important both to evaluate direct contact, as well as to evaluate the potential for airborne/inhalation exposures.

6. Significance of Minerals and Fibers in Air

The settled surface dust samples suggest the potential for airborne particles and fibers. The air samples taken indicate that some of these materials are present in the air at measurable levels. Because the air samples were taken over several hours, they provide an understanding of average air levels over the course of the day. Some of these air samples were taken during normal daily activity outdoors in common areas and in residences. They represent the impact of vehicular traffic, walking, and normal activity in the area. As such they are a good measure of average exposure at that time and place. No samples were taken to assess high levels of activity, such as cleaning, which might generate short-term periods of higher levels of materials in the air. However, about 40% of the residences were aggressively sampled, which gives some indication of the impact of increased activity on airborne levels.

Although semiquantitative, the minerals detected in air provide important information. Quartz and mica, which have potential health effects on the lung, were found in the respirable fraction of the dust (PM4). This indicates that some portion of the quartz and mica found in the settled surface dust is of respirable size. Minerals found in the larger size air fractions, thoracic (PM10) and inhalable (PM100), indicate that larger particles may also be present that could irritate the upper areas of the respiratory tract. It should be noted that these larger fractions also include thoracic and respirable material.

The fiber analysis by PCM provides an upper bound of airborne fibers. Although fiber type is not identified in this analysis, there can be no more asbestos fibers than total fibers detected. Re-analysis of some of these samples shows that very few fibers of public health interest (SVF or asbestos) were present. However, care must be taken when interpreting these results because there

were samples taken which showed fibers by PCM, which were not re-analyzed. Any of these air samples, especially those taken in areas with asbestos or SVF in the dust, may have some of these fibers as part of the PCM fiber count. Generally, the levels of dust and air did not indicate a consistent pattern at different locations. It was not possible to conduct a more accurate correlation analysis between asbestos and SVF material in settled surface dust and fibers in air because the majority of air samples were not analyzed specifically for asbestos or SVF (i.e., TEM or SEM analysis). The limited data gathered during this investigation does not support nor refute the assumption that all the fibers in the air samples will be asbestos or SVF even when asbestos was found in dust.

B. Public Health Evaluation

The potential for health effects is possible after exposures to certain materials. An exposure to a material occurs when it comes into contact with or is taken into our bodies. The route of exposure is the method by which a material comes into contact with the body (e.g., dermal contact, inhalation, or ingestion). The nature of the health effect will depend on the material involved, how it comes into contact with the body, the amount of material (exposure level), the duration of the exposure, resultant dose, and the susceptibility of the individual (e.g., pre-existing health conditions may make an individual more sensitive to a contaminant).

Initially, screening values were established and listed in the project-sampling plan. These screening values were established to provide a guideline for evaluating the data as it was collected for any indication of a hazard requiring immediate attention, and to ensure the proper analytical detection limit to support a chronic health evaluation. These screening values were not used in this report because this public health evaluation is specific to the levels of materials found in the study area.

Because levels of asbestos, SVF, and some crystalline minerals are elevated in the settledsurface dust of some buildings in lower Manhattan, individuals may be exposed to those materials in their homes, out of doors, or at work either by direct contact or by inhalation when the dust is disturbed and suspended in the air. Depending on the environment, one or all of these materials may be present in the dust of an area.

1. Sensitive Populations

Sensitive populations are individuals who may experience greater responses when exposed to a material than normally predicted. This sensitivity may be due to life stage, pre-existing medical or exposure conditions, or genetic susceptibility.

Children are considered a sensitive population for several reasons. The first consideration is the potential for greater exposure than adults. With a lower body weight, and higher relative ventilation rate, children have higher doses than adults given exposure to the same levels of materials in air, food, or drinking water. For biopersistent materials, such as some of the minerals discussed

previously, childhood exposures present a greater lifetime risk due to longer residence time in the lung. This is demonstrated for asbestos where an exposure with onset at 1-year old presents a greater risk than an exposure at age 18 (10). Finally, because they are shorter than adults, children breathe air that is closer to the ground, and they may play in contaminated areas, creating situations where they are impacted more by materials in soil or dust.

Children and adults with pre-existing medical conditions may be more susceptible. Many of the materials found in the areas sampled have irritant effects on skin, mucous membranes, and the respiratory tract. Individuals with pre-existing allergic and cardiopulmonary diseases may be more sensitive to the effects of exposure to this dust. One of the most clinically important and frequent responses of the airways to dust and irritant exposures is bronchoconstriction. Therefore, individuals with pre-existing asthma are much more likely to develop bronchoconstriction in response to exposure to dust particles, fibers, and irritants.

Obstructive lung disease and other respiratory and cardiopulmonary disorders are factors for increased sensitivity. Any individuals in lower Manhattan who received a large dose of dust during or immediately following the WTC collapse may also be more sensitive. Anyone who has been experiencing respiratory symptoms since the collapse should consult their physician for proper treatment.

Individuals who smoke are at greater risk. Smoking can reduce lung function and may cause pulmonary disease that would make individuals more sensitive. Additionally, smoking has been shown to synergistically increase the risk of developing lung cancer from asbestos exposures. Smoking also increases the risk of developing lung cancer in workers exposed to crystalline silica (e.g., quartz).

Although possible skin, eye, and respiratory tract irritants, the soluble minerals gypsum, portlandite, and calcite do not pose any hazard for long-term health effects.

2. Soluble Minerals: Gypsum, Portlandite, and Calcite

The potential health effects of gypsum (hydrated calcium sulfate), portlandite (calcium hydroxide), and calcite (calcium carbonate) are similar as these minerals are similar chemically and physically. All three minerals are crystalline in form and soluble (11,12). Because these minerals are soluble in

body fluid, they are easily cleared from the respiratory tract and

lungs when inhaled (13,14,15). Therefore, no long-term respiratory effects have been observed, even at the very high exposures that occur during the mining and processing of these minerals (16,17).

Calcite, and portlandite increase the alkalinity of a fluid. Therefore, when these materials come into contact with tissue, they can cause irritation of skin and mucous membranes due to increased alkalinity. Any anhydrous gypsum in settled dust would be hygroscopic, which would be drying and irritating to the skin and eyes. Similarly, inhaled material may irritate or burn the respiratory tract (nose, throat, and lungs). The signs of an inflammatory response include redness, swelling, heat, and pain. Reaction to a skin irritant usually occurs at the point of contact between the skin and the substance. Eye irritants can cause redness, tearing, and itching of the eyes. Respiratory irritants can affect the nose, throat, and lungs. They may cause an itchy, watery nose, a scratchy or sore throat, coughing, chest tightness, wheezing, or difficulty breathing. All of these irritant effects are generally temporary and will begin to resolve once exposures cease.

Occupational exposure guidelines (NIOSH) and standards (OSHA) for these minerals were developed to prevent these irritant symptoms in most workers for a 40-hour workweek exposure (13,14,15). Although no guidelines or standards are available for skin contact or residential exposures, air exposure levels are established for both total and respirable minerals in air (see the following table). The airborne mineral levels measured in lower Manhattan are orders of magnitude below these occupational values. Although the occupational standards do not account for sensitive individuals or for extended periods of exposure, they provide a point of comparison. The levels of minerals seen in airborne dust of lower Manhattan are not at the levels known to be irritating to healthy adult workers. However, it is possible that sensitive individuals may feel some irritation. Additionally, direct contact with the dust—or shorter periods of higher air concentrations caused by disturbing the dust—may result in more irritation than would be predicted by the reported airborne mineral levels.

Mineral	NIOSH REL ($\mu g/m^3$)	OSHA PEL ($\mu g/m^3$)	Maximum Estimated Value in Lower Manhattan ($\mu g/m^3$)
Gypsum	10,000 (total) 5,000 (resp)	15,000 (total) 5,000 (resp)	14J (PM100) 15J (PM4)
Portlandite	5,000	15,000 (total) 5,000 (resp)	95J (PM100) 84J (PM4)
Calcite	10,000 (total) 5,000 (resp)	15,000 (total) 5,000 (resp)	14J (PM100) 10J (PM 4)

NIOSH = National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention

REL = recommended exposure level/limit

OSHA = Occupational Safety and Health Administration

PEL = permissible exposure limit.

$\mu g/m^3$ = microgram of mineral per cubic meter of air

total = all airborne particles (could include particles >100 micrometers)

resp = respirable fraction (PM4)

3. Mica

Mica is a group of water-insoluble silicate minerals (18). The mica detected in these dust and air samples of lower Manhattan was muscovite. Mica has been shown to cause pneumoconiosis in workers exposed to high levels during mining and processing operations (19,20). Although workers may have also been exposed to quartz in some of these studies, pneumoconiosis in workers with only mica exposures has been documented. (21,22)

Respirable mica particles that deposit in the deep lung may be cleared slowly due to the relative insolubility of the mineral. Over time, the presence of the mineral will irritate the lung tissue, generate immune response, and result in scarring or fibrosis (23,24). The magnitude of this response is believed to be a function of both the dose and duration of exposure. The current worker standard set at 3,000 $\mu g/m^3$ is a level at which mild

pneumoconiosis was seen in some workers only after extended exposure (18 years).

Mica and halite, although elevated in lower Manhattan relative to the comparison areas above 59th Street, are not likely to contribute to any adverse health effects.

The airborne levels of mica seen in lower Manhattan with an estimated maximum of 43 $\mu g/m^3$J in respirable dust are well below levels of mica that are associated with the development of pneumoconiosis in workers (25). Although disturbing settled surface dust might generate short-term exposures above the measured values, it is the cumulative exposure that is believed to predict health effects (23). Given the low airborne levels of mica seen in lower Manhattan and the low frequency of detection in both air and settled surface dust samples, no health effects are expected from mica exposure alone.

4. Halite

Halite is simply sodium chloride, or rock salt (18). This crystalline form of the salt will readily dissolve in the body and is not expected to have any adverse health effects. Although large changes in salinity can disrupt tissues, the trace amounts of halite and the low frequency of detection do not indicate any potential health concern.

5. Crystalline Silica (Quartz and Cristobalite)

Silica is chemically inert for the most part, so it is the physical form of silica that imparts its toxicity. Small crystals of silica may be deposited in lung tissue. Once deposited, the crystals remain and fibrogenic lesions may appear over time, damaging the lung tissue and reducing lung capacity (26). Silica has been demonstrated to be a pulmonary toxin linked both to silicosis (a fibrotic lung disease) and lung cancer (27,28,29,30). These findings are supported by both human and animal studies. Chronic silica exposure may contribute to lung cancer; emphysema; obstructive airway, etiology, immune, or connective tissue disease; and lymph node fibrosis (27,30,31,32,33).

a. Silicosis

Generally silicosis is seen after years of high-level occupational exposures, although it can result from short-term acute exposure (26,30). It is not known if chronic ambient environmental exposure contributes to silicosis (26). Because the lung damage is proportional to the total amount of silica deposited in the lung, current evaluations are based on a measure of cumulative exposure of air concentration over work-years of exposure (28,34,35).

Short-term exposures to quartz, even for a continuous year of exposure at the highest estimated air concentration, is not expected to result in any adverse health effects.

Assuming worst-case theoretical assumptions, the estimated quartz levels measured cannot rule out adverse health effects from chronic exposures (i.e., 30 years). For individuals who conduct frequent cleaning of their residences, as recommended in this report, or participate in the U.S. Environmental Protection Agency cleaning/sampling program, it is unlikely that their exposure would resemble these worst-case conditions.

Exposures of less than 1 milligram per cubic meter 1 (mg/m^3) of air work-year* of exposure are believed to not result in significant incidence of silicosis in workers (28,34,35). The peak respirable quartz level estimated in lower Manhattan of 19 $\mu g/m^3$ would be equivalent to 0.08 (mg/m^3)-work year.‡ Therefore, at this measurement even an entire year of exposure 24 hours a day 7 days a week would not be expected to result in silicosis when compared to work environments known to result in silicosis.‡

b. Lung Cancer

The International Agency for Research on Cancer (IARC) has determined that there is sufficient evidence that crystalline silica in the form of quartz or cristobalite is carcinogenic in humans (28). The IARC cites only limited evidence for the carcinogenic potential of tridymite from animal studies and inadequate evidence in either humans or animals to classify amorphous silica. Respirable crystalline silica is listed as a known human carcinogen in the National Toxicology Program's ninth report to Congress (27).

Although the exact mechanism for silica-induced lung cancer is

not known, it is believed cancer incidence is linked to the development of other silica-induced lung disease (34). It is possible the mechanisms involved in the development of silicosis are linked to the carcinogenic process through the production of reactive oxygen species and tissue responses to immune signals and fibrotic changes (36,37). Some researchers have developed dose cancer risk estimates from epidemiologic studies by building off risk estimates for silicosis (34,38,39). A risk assessment produced for both silicosis and lung cancer on the basis of crystalline silica exposures reviews major studies and proposes that lung cancer incidence may be expected to increase by 14% for each additional 1 (mg/m^3) work-year exposure above the baseline of 1 (mg/m^3) work-year exposure (36).*

The maximum estimated detection of quartz (crystalline silica) in air in lower Manhattan was 19 $\mu g/m^3$J. Using the above risk estimates, the cumulative exposure for 1-year continuous exposure 0.08 (mg/m^3) work-year poses negligible increased cancer risk. Although there are uncertainties in this evaluation, current scientific opinion would indicate short-term exposures to the measured quartz levels do not pose a health hazard.†

If the highest measured airborne levels are representative of long-term conditions, the cumulative exposure for a continuous 30-year residence would exceed the 1 (mg/m^3) work-year cumulative exposure which is believed to be the departure point for adverse effects for both silicosis and lung cancer. Therefore these data cannot rule out the potential for long-term risk. However, the highest airborne level measured during this study is not necessarily representative of long-term exposure. In addition, the XRD analysis for quartz in air is semiquantitative (i.e., an estimated value). This adds additional uncertainty to the risk estimation. As presented in the discussion section of this report, it is expected that the ongoing cleaning of lower Manhattan and natural dispersion should reduce these materials over time, thus reducing long-term risk. Therefore cleaning should be continued and levels of respirable crystalline silica monitored, until the data demonstrate that long-term risk of adverse health effects is minimal.

6. Synthetic Vitreous Fibers

The term synthetic vitreous fibers (SVF) refers to several types of manufactured vitreous fibers: glass wool, mineral wool, and refractory ceramic fibers (RCF) (41,42). Because RCF was not found during this investigation, its health effects are not discussed. The types of SVF found in settled surface dust, glass wool and mineral wool, are primarily skin and upper respiratory tract irritants. Although some data do indicate a potential for pulmonary effects, no adverse effects on the lung are expected from the levels measured in this investigation.

a. Irritant Effects

No long-term health effects are

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expected from the skin and eye irritation that may have occurred because of exposure to synthetic vitreous fibers.

No adverse pulmonary health effects are expected from the levels of airborne synthetic vitreous fibers measured in this investigation.

The primary short-term and acute health effects of SVF are skin, upper respiratory tract, and eye irritation (42). It is the physical shape and size of the SVF fibers that cause irritation, generally fibers more than 5 microns in diameter cause skin irritation (41,43,44). The affected area may itch and a rash may form. These symptoms subside as exposure is ended, as the fibers slowly work themselves out of the affected tissue. Upper respiratory tract irritation due to inhaled fibers has been reported when fiber concentrations were greater than 1 f/cc in air (41,42,45).

Generally this type of irritation has been observed in individuals who are manufacturing and installing SVF insulation materials. Although the settled surface dust results indicate SVF is present in many areas of lower Manhattan, total dust loading is not known. Because these irritant health effects would be due to the total amount of SVF contact exposure, dust loading as well as activity levels would influence whether a particular environment was irritating. Extremely low levels were detected in the air samples analyzed via SEM. In the PCM analysis, even if all of the fibers counted are assumed to be SVF, the detected maximum value of 0.003 f/cc is well below the documented level of irritation. These data indicate that SVF is present at elevated levels in settled surface dust and may be an irritant under certain conditions, or to sensitive individuals. No long-term health effects are expected from the skin, eye, or upper respiratory tract irritation related to the SVF exposure.

b. Pulmonary Effects

SVF less than 3 microns in diameter are respirable and available to enter and deposit in the pulmonary regions of the lung (41). Clearance of these fibers from the lung will be determined by fiber solubility and length (41,42). Fibers cleared from the lung have less potential to create long-term health effects.* Although some animal studies have demonstrated both fibrotic and carcinogenic potential for fibrous glass and mineral wools (41,42,46), more recent studies do not fully support this finding.† Epidemiologic studies on workers exposed to fibrous glass do not provide consistent evidence of pulmonary effects, although some effects were noted (42,47). Similarly, when assessing deaths due to lung cancer in workers exposed to glass wool, studies do not provide strong evidence for increased risk of cancer deaths attributable to glass wool fiber exposures.

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The carcinogenic potential of fiberglass has been reviewed by several agencies. The IARC originally classified both glass and mineral wool fibers as Group 2B carcinogens, possibly carcinogenic to humans, based on animal studies (50). Similarly these materials were classified as carcinogens by the National Toxicology program and the American Conference of Governmental Industrial Hygienists (41,49). However a review of the carcinogenic potential of these fibers by IARC in 2001, which takes into account updated human studies, animal inhalation studies, and mechanistic studies, recommends a change in this classification. The IARC has announced that the recent monograph designates both glass and mineral wool as Group 3, unclassifiable as to carcinogenicity in humans, because of inadequate evidence of carcinogenicity in humans and the relatively low biopersistence of the materials (50).

Although both glass wool and mineral wool have been found at elevated levels in the settled surface dust in lower Manhattan, airborne levels are extremely low, and well below a level associated with the worker exposures reviewed in this report. No adverse pulmonary health effects are expected from the airborne SVF levels measured in this investigation.

7. Asbestos

Asbestos refers to a group of natural fibrous silicate minerals of various structures (18). Used primarily for its fire resistant properties and as an insulation material during the 1900s, asbestos is now known to cause pulmonary damage, lung cancer, and mesothelioma. Asbestos fibers less than 2 microns in diameter and less than 5 microns in length with a 3:1 aspect ratio may enter and deposit in the alveolar and pleural regions of the lung (10). Material that is not cleared by the normal processes of the lung will remain, resulting in possible damaged tissue, fibrotic lesions, and cancer (10,52–54). Fibers may also migrate from the lung to the pleural lining, causing mesothelioma. This discussion will focus on the most studied health effects, asbestosis and cancer. It should be noted that the chrysotile asbestos found in settled surface dust during this investigation is believed to be cleared from lungs to a greater degree than other forms of asbestos (10). Therefore the following review, which considers all forms of asbestos, would be conservative for chrysotile asbestos exposures.

a. Asbestosis

Asbestosis is similar to other mineral pneumoconiosis of the lung. Fibers are deposited in the lung and remain due to their insoluble nature and the inability of lung macrophages to engulf and remove longer fibers (>5 microns in length) (10,54). These fibers can create localized tissue damage, stimulate the immune system, and create a scarring of the lung.

Asbestosis has been observed in workers exposed over several years to levels much higher than seen environmentally. It is believed the cumulative exposure to asbestos correlates to the development of asbestosis, and some cases of asbestosis have been reported with only a brief high exposure documented (55).

Because cumulative asbestos exposure is believed to be the appropriate metric for assessing asbestos health effects, it is possible long-term, continuous low-level exposures could contribute to asbestosis. Recent studies of a population exposed to tremolite asbestos in Libby, Montana, do indicate increased pleural anomalies, consistent with asbestosis, for individuals who were not exposed occupationally. Individuals who lived with plant workers or those who had contact with vermiculite piles containing tremolite had increased odds ratios for these anomalies (56).

Although asbestos is present in some settled surface dust in lower Manhattan, aggressive sampling produced a maximum level of 0.003 f/cc (PCM). This level is not high enough to result in asbestosis after short exposures. Although it is theoretically possible that lower level environmental exposures could contribute to disease over extended exposures, the data from this pilot study are too limited to support that finding.

Short-term exposures to asbestos, even for a continuous year of exposure at the highest estimated air concentration, are not expected to result in any adverse health effects.

Assuming worst-case theoretical assumptions, the highest fiber levels measured cannot rule out adverse health effects from chronic exposures (i.e., 30 years), but it is unlikely levels will remain elevated for that long. For individuals who conduct frequent cleaning of their residences, as recommended in this report, or participate in the U.S. Environmental Protection Agency cleaning/sampling program, it is unlikely that their exposure would resemble these worst-case conditions.

b. Lung Cancer and Mesothelioma

Asbestos exposure is known to increase lung cancer incidence, particularly for high-level occupational exposures over an extended period of time (e.g., decades) (10,48,52). Additionally, some studies have indicated increased lung cancer and mesothelioma due to high naturally occurring levels of asbestos or low dose environmental exposures (57–60). Longer asbestos fibers can penetrate into the deeper portions of the lung. Because asbestos is relatively insoluble, longer fibers cannot be physically removed by the body's immune systems and may remain in the lung and cause damage. Although the exact mechanism for lung cancer is not known, it is believed the localized immune response to the asbestos may contribute to cancer. Fibers may also migrate out of the lung and cause mesothelioma, a cancer specific to the lining around the lungs. In general, shorter fibers (less than 5 microns) are more efficiently cleared from the lung and therefore are less potent (10). Additionally, there is some indication that chrysotile asbestos is less potent than other forms of asbestos due to better clearance from the lungs.

EPA has established a cancer slope factor for asbestos to estimate risk in the general population due to chronic environmental exposures to asbestos (48).* Factors that influence excess cancer estimates are age at time of exposure, sex, and cigarette smoking (52).† EPA's Integrated Risk Information System (IRIS) is used to

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develop risk estimates for comparison, with the understanding that smokers will be at higher risk.

Air samples from several indoor areas with asbestos fibers detected in the settled surface dust did contain fibers as described by PCM analysis (0.001 f/cc to 0.003 f/cc).‡ Because none of these air samples were analyzed by TEM, it is not known if they were asbestos fibers. For this analysis of a worst-case exposure, it will be assumed they are asbestos. Four of these samples were taken in common areas during normal daily activity. All other air samples, including the highest, 0.003 f/cc, were taken in residences that were aggressively sampled. Using the IRIS slope factor, no appreciable increase in cancer risk is seen when considering a 1-year continuous exposure at the highest fiber level cited (1×10^{-5} excess cancer risk).

If the highest measured PCM levels are assumed to be all asbestos fibers (a worst-case assumption) and were representative of long-term conditions (another worst-case assumption), the cumulative exposure for a continuous 30-year residence would result in a greater risk estimate for lung cancer and mesothelioma. Therefore these data cannot rule out the potential for long-term risk. However, the highest airborne level measured during this study is not necessarily representative of long-term exposure nor is the highest level necessarily all asbestos fibers. As presented in the discussion section of this report, it is expected that the ongoing cleaning of lower Manhattan should reduce levels of these materials over time, thus reducing long-term risk. Therefore cleaning should be continued and levels of asbestos monitored, until the data demonstrate long-term risk of lung cancer and mesothelioma are minimal.

8. Multiple Material Exposures

Each of the materials discussed previously may exist singly or in combination with other materials found in lower Manhattan. The combinations of materials found in this investigation are described in the discussion of results. When exposures to multiple materials occur together, there is some potential that the agents may interact with respect to their adverse effects. Agents may be additive if they impact an organ system similarly. Synergistic and antagonistic effects may also be seen if the agents either potentiate or disrupt the effects of other agents.

a. Irritant Effects

The effects of the alkaline minerals are most likely additive, although it should be noted that not all of the materials are equally caustic. Therefore, cumulative effects on pH would be the best measure of irritant effects based on the caustic nature of the dust. There may also be potentially additive or synergistic effects with the irritant effects of the SVF. The ability of either caustic action or the mechanical action of the fibers or minerals to degrade the protective properties of skin and mucus membranes may make tissue more susceptible to irritant effects. Additionally, because both types of actions may trigger localized immune responses, these irritants may potentiate each other.

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b. Noncancer Pulmonary Effects

Several of the minerals detected contribute to fibrotic lung damage and may result in several diseases that reduce lung function including silicosis, asbestosis, other mineral fibroses, emphysema, and other respiratory disorders. The mechanisms and pathology of these conditions are similar, and the effects of these agents may be considered at least additive. However, each material has a different toxicity based on the mineral properties of that material. Less biopersistent materials, such as SVF, have the least long-term toxicity, and more biopersistent material, such as asbestos, have greater long-term toxicity. In general, the order of toxicity may be SVF < mica < silica < asbestos, based on solubility and availability for clearance. No factors currently exist to combine risk estimates for these different materials.

CONCLUSIONS

On the basis of the analytical results of samples taken between November 4 through December 11, 2001, and information collected during the sampling effort, the New York City Department of Health and Mental Hygiene and the U.S. Agency for Toxic Substances and Disease Registry make the following conclusions (not in order of importance).

· Total fiber counts of air samples taken in lower Manhattan were similar to the comparison areas above 59th Street sampled during this investigation. The six lower Manhattan areas that had elevated total fiber counts were re-examined by transmission electron microscopy (TEM) and scanning electron microscopy (SEM). The TEM and SEM results indicated that neither asbestos nor SVF contributed to the elevated fiber counts.

· Low levels of asbestos were found in some settled surface dust, primarily below Chambers Street. Many of the lower Manhattan locations sampled had been previously cleaned prior to this investigation. No asbestos was detected in the comparison indoor dust samples taken north of 59th Street. The City of New York has conducted follow-up activities at the locations where asbestos was detected in settled surface dust. Only two follow-up locations, outdoor areas, required professional asbestos abatement. Following-up activity at the other locations did not find any asbestos containing materials.

· When compared with the results obtained from the comparison sampling locations, the lower Manhattan residential areas sampled by this investigation tended to have a greater percentage of SVF (primarily fiberglass), mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum, mica, and halite) in settled surface dust. However, the frequency of detections and prevalence patterns of these minerals are similar in both residential areas.

· Exposure to significant amounts of synthetic vitreous fibers (SVF), mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum) may cause skin rashes, eye irritation, and upper respiratory irritation, all of which have been voiced as concerns by

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citizens and first responders. If the reported irritant effects are associated with World Trade Center related materials, these effects will subside once exposure to SVF, mineral components of concrete, and mineral components of building wallboard end. Some people with pre-existing heart or lung disease (e.g., asthma) or a previous history of very high levels of exposures (occupational) to SVF, mineral components of concrete, and mineral components may be more sensitive to the irritant effects of SVF, mineral components of concrete, and mineral components of building wallboard.

· Sometimes mineral components of concrete (calcite and portlandite) and mineral components of building wallboard (gypsum, mica, and halite) were detected in air samples at higher estimated levels in lower Manhattan residential areas than in samples taken at comparison residential areas above 59th Street. These detected mineral levels are orders of magnitude below occupational standards. Although the occupational standards do not account for sensitive individuals or extended periods of exposure, they provide a comparison to an established health guidance value. The levels of minerals seen in airborne dust do not pose potential health hazards even for a continuous year of exposure at the highest levels detected.

· Some settled surface dust could become airborne if disturbed. Therefore, people could potentially inhale the asbestos, SVF, mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum, mica, and halite) found in settled surface dust of some lower Manhattan residences. Because we did not determine the weight of dust present in the areas sampled, it is not possible to determine whether any particular residence had an elevated dust loading. Appropriate continued frequent cleaning should minimize exposures.

· Several worst-case assumptions were made in order to assess the potential long-term public health risks of airborne asbestos and quartz. Some of the assumptions were that no cleaning of indoor spaces has occurred or will occur, all fibers found in air were asbestos fibers, and the highest levels detected last fall in air represent long-term air levels. Using these worst-case assumptions, prolonged exposure (decades) to airborne asbestos and quartz *may* increase the long-term, theoretical risk of people developing lung cancer and other adverse lung health effects (more than 1 additional case in 10,000 people exposed). For individuals who conduct frequent cleaning of their residences, as recommended in this report, or participate in the U.S. Environmental Protection Agency cleaning/sampling program, it is unlikely that their exposure would resemble these worst-case conditions.

· A review of the building sampling results from this investigation indicates that there is not a consistent spatial distribution pattern of asbestos, SVF, mineral components of concrete, and mineral components of wallboard in air and settled surface dust. This indicates that the materials are heterogeneously distributed. There are many factors that may contribute to the heterogeneous distribution, including whether the area was cleaned (indoors and

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outdoors), cleaning method, date since last cleaning, and how much dust was initially in the area. It is not clear which factors contributed to this trend.

· Results from this investigation do not necessarily reflect conditions that would be found in other buildings, at other times just following the collapse, or after the sampling period. The measurements reflect conditions present at the time of the sampling (November 4–December 12, 2001) in the buildings and areas sampled. The limited number of results obtained from the comparison areas above 59th Street may or may not reflect the New York City-specific background levels of asbestos, SVF, mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum, mica, and halite).

RECOMMENDATIONS

On the basis of the conclusions of this investigation, the New York City Department of Health and Mental Hygiene and the U.S. Agency for Toxic Substances and Disease Registry make the following recommendations.

· Because more asbestos, synthetic vitreous fibers (e.g., fiberglass), mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum, mica, and halite) were found in settled surface dust in lower Manhattan residential areas when compared to comparison residential areas above 59th Street, the New York City Department of Health and Mental Hygiene and the U.S. Agency for Toxic Substances and Disease Registry are recommending that people continue to conduct frequent cleaning with HEPA vacuums and damp cloths/mops to reduce the potential for exposure.

· To ensure that the recommended frequent cleaning is effective and to ensure that the health of people of New York City is protected, the New York City Department of Health and Mental Hygiene and the U.S. Agency for Toxic Substances and Disease Registry are recommending additional monitoring of residential areas in lower Manhattan. In addition, an investigation should be conducted to better define background levels specific to the city of New York for asbestos, synthetic vitreous fibers, mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum, mica, and halite).

· Lower Manhattan residents concerned about possible World Trade Center-related dust in their residential areas can request cleaning and/or testing from the U.S. Environmental Protection Agency (EPA) by logging on to the agency's World Trade Center Web page at www.epa.gov/wtc or by calling the EPA hotline at 1-877-796-5471.

PUBLIC HEALTH ACTION PLAN

The Public Health Action Plan (PHAP) for the World Trade Center response contains a description of actions to be taken by the New

York City Department of Health and Mental Hygiene (NYC DOHMH), the U.S. Agency for Toxic Substances and Disease Registry (ATSDR), and/or other government agencies. The purpose of the PHAP is to ensure that this investigation not only identifies potential public health hazards, but also provides a plan of action designed to mitigate and prevent possible adverse human health effects resulting from exposure to hazardous substances in the environment.

A. Public Health Actions Taken

Shortly after the collapse of the World Trade Center towers, NYC DOHMH staff, along with other governmental and private organizations, provided respirators and fit checking for people participating in the recovery operations.

Beginning September 13, 2001, NYC DOHMH staff coordinated daily conference calls with the various governmental and private organizations that were conducting environmental sampling at and around the World Trade Center. These coordination calls ended in January 2002.

On September 15, 2001, the U.S. Department of Health and Human Services, the U.S. Environmental Protection Agency, and the U.S. Department of Labor formed the World Trade Center Environmental Assessment Working Group. The purpose of the group is to coordinate public health and occupational sampling and data review among the three federal agencies in support of the New York City Department of Health and Mental Hygiene and the New York State Department of Health. Other governmental (e.g., New York State Department of Health, New York State Department of Environmental Conservation, New York City Department of Health and Mental Hygiene, and the New York City Department of Environmental Protection) and private organizations (unions, research institutions, companies) participated on the Working Group.

Shortly after September 11, 2001, and through June of 2002, the U.S. Environmental Protection Agency (EPA), the Occupational Safety and Health Administration, the New York State Department of Environmental Conservation, the New York State Department of Health, and the New York City Department of Environmental Protection conducted frequent ambient environmental and occupational monitoring of many different types specifically for the World Trade Center response.

From September 18 through October 4, 2001, the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, conducted occupational sampling and evaluation of the conditions at the World Trade Center.

From November 4 through December 11, 2001, NYC DOHMH and ATSDR, with assistance from the U.S. Public Health Service Commissioned Corps, conducted limited sampling of residential areas in lower Manhattan.

On February 4, 2002, NYC DOHMH and ATSDR provided the public with the preliminary findings (asbestos air and dust and synthetic

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vitreous fibers dust sampling results) of the limited residential sampling investigation conducted in November and December of 2001. Various public meetings were conducted to provide the public with the most relevant information.

On February 13, 2002, EPA formed the Indoor Air Task Force to help address the remaining indoor air quality issues in lower Manhattan.

On March 8, 2002, New York City created the lower Manhattan Air Quality Task Force.

On May 8, 2002, EPA and its federal, state, and city partners announced a comprehensive plan to ensure that residences impacted by the collapse of the World Trade Center have been properly cleaned.

On June 1, 2002, lower Manhattan residents concerned about possible World Trade Center-related dust in their residential areas could begin to request cleaning and/or testing from EPA by logging on to the agency's World Trade Center Web page at www.epa.gov/wtc or by calling the EPA hotline at 1-877-796-5471.

B. Public Health Actions Planned

During the summer of 2002, EPA and its federal, state, and city partners will conduct additional sampling of settled surface dust and air of residential areas not impacted by the collapse of the World Trade Center towers. The purpose of this investigation is to better define the New York City-specific background levels of asbestos, synthetic vitreous fibers, and quartz. Mineral components of concrete (calcite and portlandite) and mineral components of building wallboard (gypsum, mica, and halite) will also be investigated.

During the summer of 2002, EPA and its federal, state, and city partners will conduct an investigation to determine the effectiveness of various cleaning methods to remove World Trade Center-related material.

In late summer/early fall 2002, EPA will begin to conduct cleaning and/or testing of residential areas requested by lower Manhattan residents.

The New York City Department of Health and Mental Hygiene and the U.S. Agency for Toxic Substances and Disease Registry will establish a unified World Trade Center Exposure Registry of people who may have been exposed to harmful substances resulting from the collapse of the World Trade Center towers.

The New York City Department of Health and Mental Hygiene and the U.S. Agency for Toxic Substances and Disease Registry will continue to work with other federal, state, and local agencies to provide information on the sampling results to the citizens of New York and to help interpret the possible health effects of contaminants found.

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World Trade Center Environmental Assessment Working Group

Formed on September 15, 2001, the World Trade Center Environmental Assessment Working Group is made up of representatives from the U.S. Department of Health and Human Services, the U.S. Environmental Protection Agency, and the U.S. Department of Labor. Other governmental (e.g., New York State Department of Health, New York State Department of Environmental Conservation, New York City Department of Health and Mental Hygiene and New York City Department of Environmental Protection) and private organizations (unions, research institutions, companies) participated on the Working Group. The purpose of the group is to coordinate public health and occupational sampling and data review among the three federal agencies in support of the New York City Department of Health and Mental Hygiene and the New York State Department of Health.

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* Cumulative exposure is expressed as a constant air concentration over a specified period of time. If a worker is exposed to a constant concentration of 1 mg/m^3 of quartz throughout the workday, for an entire year, that is equivalent to 1 (mg/m^3) work-year. (One milligram per cubic meter of air is 1 mg/m^3).

† In order to compare a continuous residential exposure to a workday exposure, the estimated air level was adjusted to be comparable to a shorter workday exposure across the entire year.

† It should be noted that children might be at slightly higher risk than adults in sensitive populations. However, the estimated 0.08 (mg/m^3) work-year exposure is significantly below the departure threshold of 1 mg/m^3 per work-year exposure, and therefore no adverse effects would be expected.

* This estimate was derived by looking at cancer incidence studies and by relating the incidence of lung cancer to silicosis risk estimates. Both methods provided similar risk estimates. However it should be noted other authors caution about directly linking silicosis and lung cancer risk estimates (39).

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† There are many uncertainties about whether this risk would be realized. The first is that even though the risk of cancer is not linear, the risk estimates treat it as linear (36). Therefore there may be an overestimate of risk at low exposures compared with the studied populations. The air levels of silica we are examining here are well below those studied in worker populations; therefore even this small increased risk may be overestimated. Conversely, the studied populations were adult workers. So risk estimates based on these studies may underestimate risks to children and to adults with respiratory disorders.

* Less soluble materials have a longer residence time in the lung and therefore have a greater potential to contribute to tissue damage or malignant disease. Within SVF types, glass fibers and slag wool are considered the most soluble, and therefore least toxic. Mineral wool is less soluble than glass wool. Fibers longer than approximately 15 microns, the diameter of a macrophage, are also cleared less efficiently, leading to a greater potential for adverse effects (26).

† Early studies often relied upon injection and implantation studies, which may not accurately predict a pulmonary response from inhalation exposures. A review of inhalation studies indicates that glass wool did not cause pulmonary fibrosis or lung cancer in these animal studies (47). A recent study by Hesterberg indicates no increase in pulmonary fibrosis or lung cancer even at doses of 222 f/cc, although cancer incidence in control animals was considered high (51).

* This slope factor is based on epidemiologic studies and assumes a linear dose response for cancer, even at very low environmental doses (0.23 excess cancers per million people exposed for each f/cc of asbestos.) This type of cancer risk estimate may over predict risk and does not take into account any lower threshold for effect, which may exist. Additionally, the EPA slope factor was designed to apply equally to all types of asbestos, and all fibers greater than 5 microns in length (IRIS).

† Variability in these factors is not accounted for in the EPA slope factor because it does not include synergistic effects with the effects of smoking (48).

† However, because asbestos as a percentage of settled surface dust was elevated, an area with significant dust may be capable of generating higher airborne levels of asbestos, especially during high activity.

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