WORLD TRADE CENTER RESIDENTIAL DUST CLEANUP PROGRAM

Final Report

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Note:
This interim final report is a working document that will be subject to further Agency and third-party review. EPA intends to excerpt, and possibly expand, portions of this report for inclusion in manuscripts that will be submitted to scientific journals for review and consideration for publishing.

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GLOSSARY

Average residence dust lead (dioxin) loading: The arithmetic mean of the results from multiple (typically three) dust wipe samples that were collected from each residence before (i.e., pre-cleanup dust lead/dioxin loading) and after (i.e., post-cleanup dust lead/dioxin loading) cleaning.

Centrographic statistics: The two dimensional counterparts to the traditional univariate statistics that are used to describe the location (e.g., mean, median) and dispersion (e.g., standard deviation) of a single variable. Centrographic statistics are used to describe the geographic center of a collection of objects, their distribution in space, and the orientation of the distribution; e.g., buildings with PCMe exceedances.

***Clean and test* buildings:** Buildings that contain one or more residences or common areas that were cleaned and then tested for airborne asbestos; a subset of these residences were also tested for metals and dust dioxin loading (mass/unit area). Many *clean and test* buildings also contain residences that were tested but not cleaned, at the request of the residents.

***Clean and test* data:** Consists of the results of samples collected from residences and common areas that were cleaned and then tested for airborne asbestos; a selected subset of the residences was also tested for dust lead loading and dust dioxin loading.

Common areas: Areas of residential buildings that are accessible to all building occupants; e.g., hallways, laundry rooms, stairwells.

Count data: A type of categorical data that represent the number of times something occurs within an interval of time, space or volume; e.g., the number of PCMe exceedance within the potentially effected area surrounding the WTC site.

CSR: Complete spatial randomness

Dust dioxin loading: Nanograms of dioxin per square meter of sampled surface (ng/m^2).

Dust dioxin loading exceedance: Dust dioxin loadings that exceed the health-based benchmark of 2 ng/m^2.

Dust lead loading: Micrograms of lead per square foot of sampled surface ($\mu g/ft^2$).

Dust lead loading exceedance: Dust lead loadings that exceed the HUD screening level of 25 $\mu g/ft^2$.

Dust wipe samples: Samples of residential dust that were collected from residences and common areas. Samples were typically collected from three different surfaces within an apartment (e.g., walls, floors, counter tops).

Nearest neighbor distance (NNd): Used in the point pattern analysis to assess the spatial distribution of PCMe exceedance. The NNd is the average distance between a PCMe exceedance and the closest other PCMe exceedance. The NNd is compared against the distance that is expected if the PCMe exceedances are randomly distributed in space. Values less than the expected distance indicate spatial clustering, values greater than the expected distance indicate dispersion.

PCMe: Asbestos phase contrast microscopy equivalent (PCMe) concentrations measured by TEM. Phase Contrast Microscopy equivalence (PCMe) is a process to identify asbestos fibers by TEM analysis that would also be visible by PCM.

PCMe exceedance: PCMe results that exceeded the health-based benchmark of 0.0009 fibers per cubic centimeter (f/cc) of air.

Point pattern analysis: A statistical analysis in which the emphasis is on the *location* of events (e.g., PCMe exceedance), rather than the magnitude of the data (e.g., PCMe concentration). The focus of point pattern analysis is often to test the null hypothesis of complete spatial randomness (CSR) (i.e., the distribution of events follow a homogeneous spatial Poisson process). The nonparametric hypothesis of *spatial randomness* is also tested in this report, using computer simulation methods.

Poisson distribution (Poisson model): Used to describe the occurrence of rare events. The Poisson distribution is used throughout this report to describe the distribution of PCMe exceedances. The Poisson distribution is typically used to model the occurrence of an event during a fixed period of time or within a fixed region of space.

Positive spatial autocorrelation: The tendency for samples collected near each other to have similar values.

Ripley's K function: Used in the point pattern analysis to assess the spatial distribution of PCMe exceedance. Ripley's K function counts the number of other events that occur within a certain distance of an event. The count is repeated for each event. Ripley's K function equals the sum of the counts. Typically, Ripley's K function is calculated for several distance intervals and the values are plotted versus the distance intervals. Values greater than zero indicate spatial clustering, values less than zero indicate dispersion.

Spatial autoregression: A type of statistical regression analysis that considers, explicitly, the spatial autocorrelation exhibited by the data, if any.

Spatial clustering: The tendency for PCMe exceedance to be spaced closer together than is likely if the exceedances were randomly distributed in space (i.e., randomly distributed among the sampled buildings).

Spatial dispersion: The tendency for PCMe exceedance to be spaced further apart on average than is likely if the exceedances were randomly distributed in space (i.e., randomly distributed among the sampled buildings). A square grid is an example of a spatial dispersion.

Spatial resolution: Refers to the coarseness of geographic aggregation. In this report, PCMe data are analyzed at two levels of spatial resolution: at the building level and at the statistical summary area (SSA) level.

Spatial scale: Refers to the geographic extent over which an analysis is performed. In this report, the spatial scale is Lower Manhattan, south of Canal Street.

TEM: Transmission electron microscopy; an analytical method to identify and count the number of asbestos fibers present in a sample.

***Test only* buildings:** Buildings that contain one or more residences that were tested for one or more of the following: airborne asbestos, dust lead loading, dust dioxin loading, but were not cleaned, at the request of the residents. Most *test only* buildings also contain residences or common areas that were cleaned and tested.

***Test only* data:** Results of samples collected from residences that were tested for one or more of the following: airborne asbestos, dust lead loading, dust dioxin loading, but were not cleaned, at the request of the residents.

Unique *test only* buildings: Buildings that contain one or more residences that were tested for one or more of the following: airborne asbestos, dust lead loading, dust dioxin loading, but were not cleaned, at the request of the residents. Unique *test only* buildings do ***not*** contain residences or common areas that were cleaned and tested.

ACRONYMS

PCMe	phase contrast microscopy equivalent
TEM	transmission electron microscopy
CV	coefficient of variation
TEQ	toxicity equivalent quotient
SSAs	statistical summary areas
iid	independent and identically distributed
NNd	nearest neighbor distance
NNI	nearest neighbor index
N	total number of events
A	area of the site
CSR	complete spatial randomness
CI	confidence interval
S-W statistic	Shapiro-Wilk statistic
f/cc	fibers/cubic centimeter
$\mu g/ft^2$	micrograms per square foot
ng/m^2	nanograms per square meter

EXECUTIVE SUMMARY

Introduction and Background

This report presents and summarizes the results of EPA's World Trade Center Dust Cleanup and Testing. Under the authority of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act), EPA formed an Indoor Air Task Force in February 2002. In April 2002, the Mayor of the City of New York requested that EPA serve as the lead agency for addressing potential effects of WTC dust on residences in lower Manhattan. EPA subsequently developed and implemented a comprehensive program, with broad interagency input at federal, state and local levels, to ensure that lower Manhattan residents were protected from potential exposures to WTC-related dust and debris.

The WTC dust cleanup and testing program allowed residents living south of Canal Street in lower Manhattan to have their homes professionally cleaned and tested or just tested free of charge. In addition to offering this service to residents, EPA conducted three supporting projects, also funded by FEMA under the Stafford Act. The projects were:

- A Contaminants of Potential Concern (COPC) Report established health-based benchmarks for contaminants in support of cleanup efforts.
- A Confirmation Cleaning Building Study evaluated the effectiveness of various cleaning techniques on WTC-related dust.
- A Background Study provided data on contaminants in indoor air and settled dust in residences North of 78th Street.

Overview of WTC Dust Cleanup and Testing Program

All residents of lower Manhattan living below Canal Street were given a choice of services. Residents could chose to have their residence professionally cleaned, followed by confirmatory testing, or they could choose to just have their homes tested. Certified professional contractors cleaned and tested the homes, under the direction of EPA. Owners and managers of residential buildings and coop boards could also have their building's common areas cleaned and HVAC system evaluated and cleaned, if necessary. The cleaning and monitoring contractors cleaned and tested common areas such as the building lobby, hallways, stairways and elevator interiors. The contractors evaluated other common areas, including laundry rooms, utility rooms, compactor rooms, and elevator shafts and cleaned as needed.

Residences were cleaned using standard asbestos cleanup methods – using HEPA-filtered vacuums and wet wiping all horizontal hard surfaces (i.e. floors, ceilings, ledges, trims, furnishings, appliances, equipment, etc.). Vertical and soft surfaces were HEPA vacuumed two times. EPA did not require workers to wear personal protection equipment during these routine cleanups because OSHA determined that such equipment was not necessary. As an added precaution, contractors isolated the areas containing visible dust and wore personal protection equipment.

Depending upon the size of the residence, from three to five air samples were collected and analyzed for asbestos using transmission electron microscopy (TEM) and phase contrast microscopy (PCM). In a subset of the residences, pre- and post-cleanup dust wipe samples were collected (e.g., from floors, walls, and furniture) and analyzed for dioxin, mercury, lead, and 21 other metals. The results of this sampling, along with interpretation through a comparison with health-based benchmarks, were shared with occupants of the residences. Residences that did not meet the health-based benchmark of 0.0009 fibers per cubic centimeter for asbestos in one or more samples were encouraged to have their residences re-cleaned and tested until they met the benchmark. In a few cases, residents chose not to have their residences recleaned. There were a number of outcomes that resulted in inconclusive results. Filter overload was the most common. Filter overload occurs when too many dust particles are captured on the filter. The filter becomes obscured so technicians examining it under a microscope cannot separate out individual fibers. This causes an inconclusive result, which is discarded. Other causes of inconclusive results are blown or damaged filters. Residents with more than one inconclusive result were encouraged to have their apartments re-cleaned and re-tested. A total of 28,702 valid sample results was analyzed, 22,497 from residential units and 6,205 from common areas within residential buildings (e.g., hallways, laundry rooms).

<u>Results</u>

Asbestos

The number of samples that exceeded the health-based benchmarks for airborne asbestos was very small – about 0.4% of the asbestos samples taken. In those cases where the benchmark was exceeded in both residences and in common spaces, the cleanup program was successful in achieving the health-based benchmark for asbestos after the first cleaning approximately 99% of the time.

Wipe Samples

Contractors collected wipe samples from 263 apartments in 156 buildings. Approximately 14% of the pre-cleanup samples exceeded the U.S. Housing and Urban Development (HUD) screening level of 25 $\mu g/ft^2$, while only about 3% of the post-cleanup samples exceeded the screening level. This showed that the cleanup methods were effective in reducing lead. The percent of apartments that exceeded the lead health-based benchmark was greater than the percentages of apartments that had exceedances for other metals, mercury and dioxin. The level was consistent, however, with data from the HUD on housing stock in the Northeast United States. This factor makes it difficult to distinguish between lead from World Trade Center dust and other sources, especially in older buildings.

There were very few exceedances of the health-based screening values measured for any of the other 22 metals. The screening value of 627 $\mu g/m^2$ for antimony was exceeded in 2 pre-cleanup samples (0.1% of all samples); the maximum measured value was 1,180 $\mu g/m^2$. The screening value of 157 $\mu g/m^2$ for mercury was exceeded in 5 pre-cleanup samples (0.4% of all samples).

Reductions in dust dioxin loadings were modest due to the low pre-cleanup levels. Only 8 of the 1,535 (approximately 0.5%) of the combined samples (i.e., *test only* and *clean and test*) exceeded the health-based benchmark for residential dust dioxin loading of 2 ng/ m^2.

An analysis of the location of asbestos exceedances does not demonstrate a special pattern of exceedances relative to WTC proximity. Apparent groups of asbestos exceedances could be explained by the location of the sampled buildings and the variability in the number of samples that were collected from each building.

1.0 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) supported federal, state, and New York City efforts to recover from the federally declared disaster resulting from the September 11, 2001 attack on the World Trade Center (WTC). These actions were taken under the authority of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) and in accordance with the applicable procedures and policies of the National Oil and Hazardous Substance Pollution Contingency Plan, 40 C.F.R. Part 300 (the NCP) (EPA, 1990). This report provides a summary of the actions taken by EPA to cleanup the indoor environment in Lower Manhattan.

The cleanup of the WTC site and surrounding ambient (i.e., outdoor) environment proceeded through the winter of 2001-2002. Early investigations indicated that an indeterminate number of residences located in the vicinity of the WTC complex were contaminated with dust and debris following the WTC attack; and there was growing concern in the re-occupied residential communities of Lower Manhattan regarding potential long-term health problems associated with residual WTC-related indoor dust *(Figure 1-1)*. EPA formed an Indoor Air Task Force in February, 2002 and by request of the Mayor of the City of New York, EPA was designated the lead governmental agency for addressing the indoor environment in April, 2002. EPA's focus in this regard was to address indoor air concerns through an indoor dust cleanup and air sampling program for residential spaces in Lower Manhattan. This comprehensive program was implemented to ensure that Lower Manhattan residents were protected from potential exposures to harmful dust and debris residuals. EPA developed this program with broad interagency input at federal, state and local levels. EPA utilized all the tools available, including appropriate aspects of the NCP, to achieve this goal as expeditiously as possible.

EPA implemented three programs related to indoor air in Lower Manhattan residences. These programs were funded by FEMA under the Stafford Act, specifically Sections 403 (Essential Assistance) and 407 (Debris Removal) *(Figure 1-2)*. First, EPA directed a Confirmation Cleaning Building Study (EPA, 2003a) by collecting samples in a building that had only minimal cleaning after the attack, employing and evaluating various cleaning techniques on WTC-related dust. Second, EPA directed a Background Study (EPA, 2003b) to provide monitoring data on indoor air contaminants in residences north of 78th Street, which were minimally affected by the collapse of the WTC, so that such data could be compared with data obtained in residences in Lower Manhattan. Third, EPA, along with the New York City Department of Environmental Protection (NYCDEP), provided for the monitoring and cleaning of Lower Manhattan residences through the Indoor Air Residential Assistance Program-WTC Dust Cleanup.

Figure 1-1. Site location map

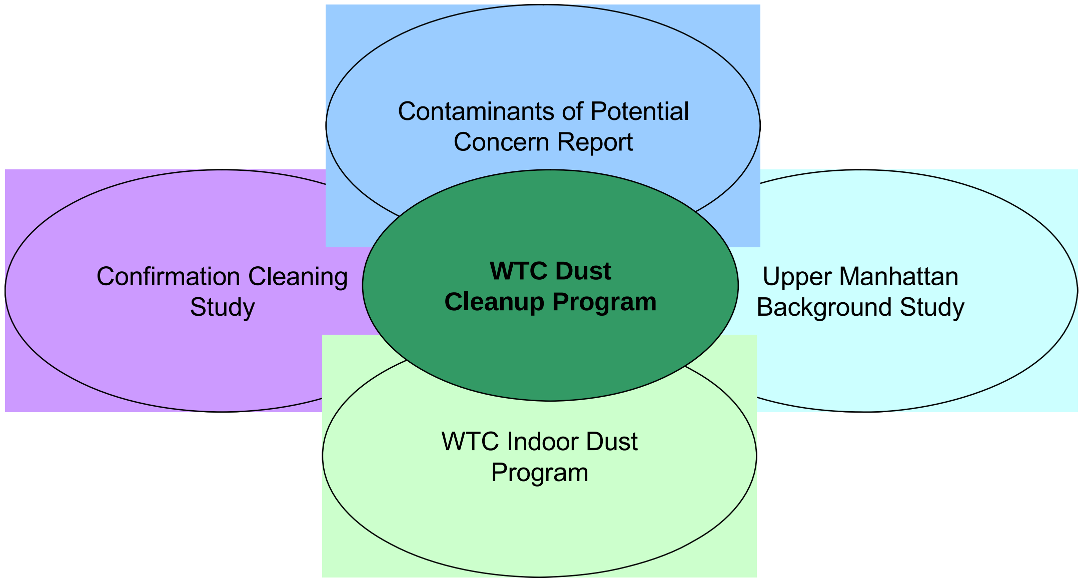

Figure 1-2. Illustration of the four components that comprised the WTC Dust Cleanup Program.

Under this program residents were given the option of requesting either cleaning followed by sampling, or sampling alone. Pursuant to interagency agreements under the Stafford Act, FEMA provided funds to the city, which used its emergency contracting authority to enter into contracts for a hotline contractor to register residents for the indoor dust cleaning program, and with certified asbestos cleanup contractors to professionally clean apartments, as well as with Project Monitors to oversee the cleaning contractors and conduct air monitoring. The actual cleaning and monitoring was carried out by NYCDEP contractors, under the direction and oversight of EPA, in coordination with the city. The samples collected by the NYCDEP contractors were analyzed by EPA contractors.

EPA evaluated the information and data that were gathered in the Confirmation Study (EPA, 2003a) and the Background Study (EPA, 2003b), as well as the results of a peer review of a draft technical document on World Trade Center Contaminants of Potential Concern (EPA, 2003c), as the residential cleaning and monitoring activities proceeded. This document provided the health-based benchmarks for indoor air and settled dust. The data from the Confirmation and Background studies, and the COPC benchmarks, were used to determine whether any program adjustments or modifications were needed. This approach of conducting studies and cleanups in parallel was necessary because of the scientific complexities of dealing with indoor environments and the need for timely response to the potential threat to public health and welfare. For the indoor environment in NYC, EPA had limited indoor sampling protocols, health benchmarks, background data for urban areas (especially Manhattan), correlations of dust to air exposures, etc. This degree of scientific uncertainty made defining a cleanup program very difficult. Cleanup methods that are effective for asbestos and fibrous materials cleanup were employed; these methods were expected to be effective for any other WTC particulate matter that might pose health concerns. Sampling was performed for airborne asbestos in every residence EPA was asked to clean or test, and samples for metals and dioxin were collected from a subset of residences. This provided additional information on the contaminants of potential concern. If the results from the studies indicated the need to modify the cleanup approach, EPA did so. Again, the cleanup efforts and study efforts were performed concurrently by EPA to complete the cleanup of residential spaces as soon as possible. EPA believed this was appropriate given the urgency and scope of the actions needed to help restore Lower Manhattan to pre-9/ll conditions. In developing the Indoor Air Residential Assistance Program-WTC Dust Cleanup, EPA relied on the existing data, the intergovernmental collaboration process, and discussions with scientific, technical, and medical professionals and concerned community members.

The Indoor Air Residential Assistance Program- WTC Dust Cleanup responded to a disaster involving a release that was most certainly not typical, not only because of the terrorist act that led to the release but also because of the unique challenges posed by the presence and potential presence of WTC dust in thousands of Lower Manhattan apartments. When the WTC collapse occurred, there was a release of asbestos, a hazardous substance, to the environment. The debris and pulverized dust from the collapse affected many structures in Lower Manhattan to varying degrees. This release was documented by bulk dust sampling done by EPA; approximately 35% of bulk dust samples outdoors contained greater than 1% asbestos, which is a regulatory definition of asbestos-containing material (ACM) under federal, state and local statutes.

Limited investigation of residential indoor environments was conducted in the weeks and months after the WTC collapsed. Two notable studies were the Agency for Toxic Substances and Disease Registry (ATSDR)/ New York City Department of Health and Mental Hygiene (NYCDOHMH) Study, "Final Report of the Public Health Investigation to Assess Potential Exposures to Airborne and Settled Surface Dust in Residential Areas of Lower Manhattan" (ATSDR/NYCDOHMH, 2002) and the Ground Zero Taskforce Report, "Characterization of Particulate Found In Apartments After Destruction of the World Trade Center" (Ground Zero Taskforce, 2001). The ATSDR/NYCDOHMH Study (2002) was larger (30 study buildings and 4 background [i.e., comparison] buildings) and included both re-occupied and unoccupied apartments. Sampling took place from November 4 through December 11, 2001. The report was released in September 2002; after the EPA indoor air cleanup program was underway. This study showed that 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 synthetic vitreous fibers (SVF) contributed to the elevated fiber counts. However, 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 Ground Zero Taskforce Report (2001) was limited to three apartments that were still undisturbed when sampled on 9/18/01. Samples demonstrated significantly elevated levels of asbestos in the settled dust.

The ACM was deposited in a very variable manner, that is, samples of bulk dust/debris, taken virtually adjacent to each other, had differing levels of asbestos. EPA believes that the dust materials that reached the interiors of structures were likewise variable in its deposition. In addition, some of the material may have contained asbestos at levels of concern for long-term risk, even though it may not have exceeded 1% ACM. Given that there are over 20,000 residential units in Lower Manhattan, specifically identifying which of them were affected by amounts of dust potentially causing long-term health effects would have been time- and resource-intensive. In addition, making risk or exposure assessments in indoor environments is very complex. The age, building materials, house keeping practices, past and current usage of the space may all impact exposure. The variability of the WTC debris/dust material and the manner in which it affected building interiors adds another layer of complication.

In deciding upon a cleanup program for Lower Manhattan residences EPA considered the following:

- The complexity of sampling dust material for quantities of hazardous substances and the lack of scientific consensus on how to do so;
- The absence of standards that have broad scientific support which relate airborne exposure routes to dust containing hazardous substances; and
- The absence of health- or risk-based standards for dust.

In addition, EPA had to consider how to gauge the residual impacts of cleanups already undertaken by residents who returned to their homes. All of the above have substantial uncertainty or controversy surrounding them.

Federal, state, and city health and medical professionals supported a program that addressed the need for cleanup assurances without the time, expense, and uncertainties associated with a location-specific sampling and risk assessment approach. EPA also consulted with environmental health and science experts in the academic and research sector on the cleanup approach described above. Though there were many questions and a desire for more data collection, they generally acknowledged that a broad-based cleanup program was an appropriate response.

For these reasons, and in consultation with FEMA, New York City, and New York State, EPA determined that rather than taking a risk-based approach to each residential unit or building, cleanup would be performed in any Lower Manhattan apartment based on residents' request.

The attack on and collapse of the WTC was a truly unprecedented event, far different from every other federally declared disaster. As such, EPA believe it warranted a unique response that supplemented FEMA relocation and cleanup assistance programs, was biased towards immediate action to protect the health and safety of the residents of Lower Manhattan, was consistent with federal disaster plan guidelines, and adhered to the applicable and appropriate provisions of the NCP.

Therefore, in response to the WTC collapse, EPA set in motion a program that moved its components (which might otherwise be implemented sequentially) along parallel tracks for the purpose of initiating residential cleanups as soon as possible. These components included: development of health-based benchmarks for indoor air and settled dust (EPA, 2003c); a site-specific characterization of background (EPA, 2003b); and, a study to assess the effectiveness of cleaning methods (EPA, 2003a). Each of these components informed the most important part of the program - the timely cleanup of residential dwellings. In developing the WTC Dust Cleanup Program EPA relied on existing data, the intergovernmental collaboration process, and discussions with scientific, technical and medical professionals and concerned community members. The concurrent program components, which are schematically illustrated in *Figure 1-2* were designed in such a way that adjustments and modifications to the Indoor Dust Program could be implemented based on information, as it became available, from these other initiatives. The material that follows provides a summary of efforts to develop health-based benchmarks, characterize background, and assess the efficacy of cleaning methods, (detailed reports on these efforts have already been issued and are available on the EPA website http://www.epa.gov/wtc/); and a detailed analysis of the results of the WTC Dust Cleanup Program.

2.0 WTC DUST CLEANUP PROGRAM COMPONENTS

As noted in the Introduction of this report, a number of initiatives were undertaken concurrently to expedite the cleanup of residences in Lower Manhattan; they are described below.

Contaminants of Potential Concern Report (COPC)

The first component was an evaluation, conducted by a multi-agency task force headed by EPA, to evaluate indoor environments for the presence of contaminants that might pose long-term health risks to local residents (EPA, 2003c). As part of this evaluation, a task force sub-committee was established (COPC Committee) to identify contaminants of potential concern (COPC) that are likely associated with the WTC disaster and establish health-based benchmarks for those contaminants in support of planned residential cleanup efforts in Lower Manhattan. A systematic risk-based approach was used to select COPC. The goal was to identify those contaminants most likely to be present within indoor environments at levels of health concern. The following chemicals were identified as COPC: Dioxin, PAHs, Lead, Asbestos, Fibrous Glass, and Crystalline Silica.

Health-based benchmarks were developed to be protective of long-term habitability of residential dwellings. A hierarchical approach was employed for developing benchmark values, including relevant and appropriate environmental standards/regulations (HUD standard for lead in indoor dust); calculation of health-based benchmarks employing conventional environmental risk assessment paradigms and guidance (for asbestos, dioxin and PAHs); and adaptation of occupational standards with additional safety factors (fibrous glass and crystalline silica).

Confirmation Cleaning Study

The second component was an effort to confirm that the cleaning methods recommended to the public were effective in reducing contaminants from dust generated from the WTC collapse and recovery efforts (EPA, 2003a). EPA, with support from FEMA and New York City, studied cleaning methods in a heavily contaminated building on Liberty Street, just south of the WTC site. The cleaning confirmation study examined various cleaning and vacuuming methods that were likely to be used by or were recommended to residents and professional cleaning companies to clean dust and debris from residential living areas in the aftermath of the attacks.

EPA contractors cleaned homes and a few commercial spaces in the building that contained a complex mixture of contaminants, including construction debris and fire-related compounds.

Eleven cleaning methods were selected and assigned to the residential units within the building according to the levels of observed dust. Each cleaning method was tested in units with significant and minimal levels of dust. The following cleaning methods were used:

- Residential quality upright vacuums and shop vacuums
- Residential quality upright vacuums with the addition of an air filtration device (AFD)
- HEPA-filtered upright and shop vacuums
- HEPA-filtered upright and shop vacuums with the addition of an AFD
- Industrial quality HEPA-filtered vacuums
- Industrial quality HEPA-filtered vacuums with the addition of an AFD
- Wet wiping of all horizontal and/or vertical surfaces with soap and water
- Carpet cleaning
- Standard cleaning procedures used by professional duct cleaning companies for the cleaning of air conditioning (A/C) systems, ducts and related equipment
- Use of water only for wet wipe of horizontal and/or vertical surfaces
- Scope A cleaning procedures developed by EPA and New York City for the cleaning of residential units in Lower Manhattan (EPA, 2003a)

Results were compared to health-based benchmarks for COPCs identified above to determine if the cleaning was successful. A summary of the significant conclusions of the study is provided below. These include observations about the extent of WTC-related contamination within the building and the effectiveness of the cleaning methods tested in the study.

- The observation of WTC dust is a reasonable indicator that WTC contaminants may be present and that the amount of WTC dust correlates with the level of contamination.

- Concentrations of some contaminants in the WTC dust were elevated above health-based benchmarks.

- The use of a standard cleaning method of vacuuming and wet wiping significantly reduced levels of WTC-related contamination with each cleaning event and was successful in reducing concentrations to levels below health based benchmarks.

- In some cases, multiple cleaning sessions (2 or 3) were necessary to reduce contamination. The methods were highly effective in reducing all COPC below health-based benchmarks.

- Asbestos in air is a reasonable indicator of whether additional cleaning is needed. Based on the compounds and testing methods chosen, the data suggests that using asbestos air samples as an indicator for additional cleaning is the most sensitive of the testing methods, as it resulted in the largest percentage of additional cleanings.

- Standard HVAC cleaning methods reduced the concentrations of WTC contaminants in HVAC systems.

WTC USEPA Background Study

The third component of the USEPA's WTC response was a background study (EPA, 2003b) to determine concentrations of building-related materials and combustion byproducts in residential dwelling. A background study was initiated because limited information was available in the literature for the analytes that were identified in WTC-related dust. Characterization and evaluation of the degree of impact to the indoor environments required knowledge regarding pre-attack concentrations of the potential indoor contaminants. Although the COPC identified in WTC-related dust have been used extensively in building construction or studied as environmental contaminants, there is limited information available that reports background concentrations of these compounds in urban residential indoor environments.

The objective of the background study was to determine the indoor concentrations of building-related materials and materials found in fire-related combustion byproducts, including asbestos, synthetic vitreous fiber (SVF), fibrous glass, crystalline silica (as alpha-quartz), calcite, gypsum, dioxin, and polycyclic aromatic hydrocarbons (PAHs). The results from the background study were to provide a basis upon which to make risk management decisions if the health-based benchmarks could not be realistically achieved. The estimated background values that were derived from the background study were not used because the health-based benchmarks were consistently achieved.

Volunteers residing in Upper Manhattan locations that were minimally impacted by the WTC collapse were recruited for the study. The outer boundary of the affected area was determined from a preliminary dispersal and dilution model using meteorological data on September 11, 2001 (EPA, 2001) and shortly thereafter. Computer modeling results showed that Upper Manhattan locations north of 78th Street, approximately eight kilometers or five miles from the WTC site, would be minimally affected by WTC fallout dust. The computer model predicted that the concentration of fallout particulate matter for areas north of 78th Street would be from 1,000 – 10,000 times less than that at the WTC site (*Figures 2-1* and *2-2*). Air and settled dust samples were collected from 25 residential units and 9 common areas within 14 buildings. The sampled buildings were approximately 8 – 19 kilometers (5 – 12 miles) northeast of the WTC site. When possible, samples were collected from two residential units and from one common area, such as the lobby, hallway, stairwell, or shared laundry facility in each building. The comparison of the results from the background study to the data from the WTC site did not include formal tests to determine if the concentrations were statistically significant due to the disparity in the number of samples that were collected from each building, and the large number of samples that were collected in each study with results below detection limits (i.e., high rate of *non-detects*).

Evaluation of the data collected from the WTC USEPA Background Study was able to: provide estimates of baseline levels or background concentrations of compounds that were identified as COPCs related to the World Trade Center collapse; show that the estimated background concentrations were consistent with other background studies and historical data, when comparison data were available; and, provide a source of data to help address data gaps in the scientific literature on background concentrations of building-related materials.

Overview of the WTC Dust Cleanup Program

Registration for the WTC Dust Cleanup Program was open from June 05 through December 28, 2002. EPA conducted a public outreach initiative to inform residents about the Program. Components of this initiative included: distribution of pamphlets at residential buildings, subway stations and local businesses; meetings with community groups; operation of a registration hotline; establishment of a website for on-line registration; mailings; and, newspaper advertisements.

The WTC Dust Cleanup Program was open to all residents living below Canal Street. Upon signing up, residents had a choice of receiving a cleaning with confirmatory testing, or, in the event the residence was already professionally cleaned and/or not significantly impacted by the WTC collapse, testing only. A brief description of the protocols that were followed is provided below. The protocols are provided in *Appendices B-D*.

Cleanup work was conducted by contractors and workers (the Cleanup Contractor) certified by New York State and New York City. Separate, third-party contractors, also licensed by New York State, oversaw the cleanup work and conducted all testing (the Project Monitor). Further direct oversight was provided by EPA personnel. All personnel involved in this program carried appropriate photo identification.

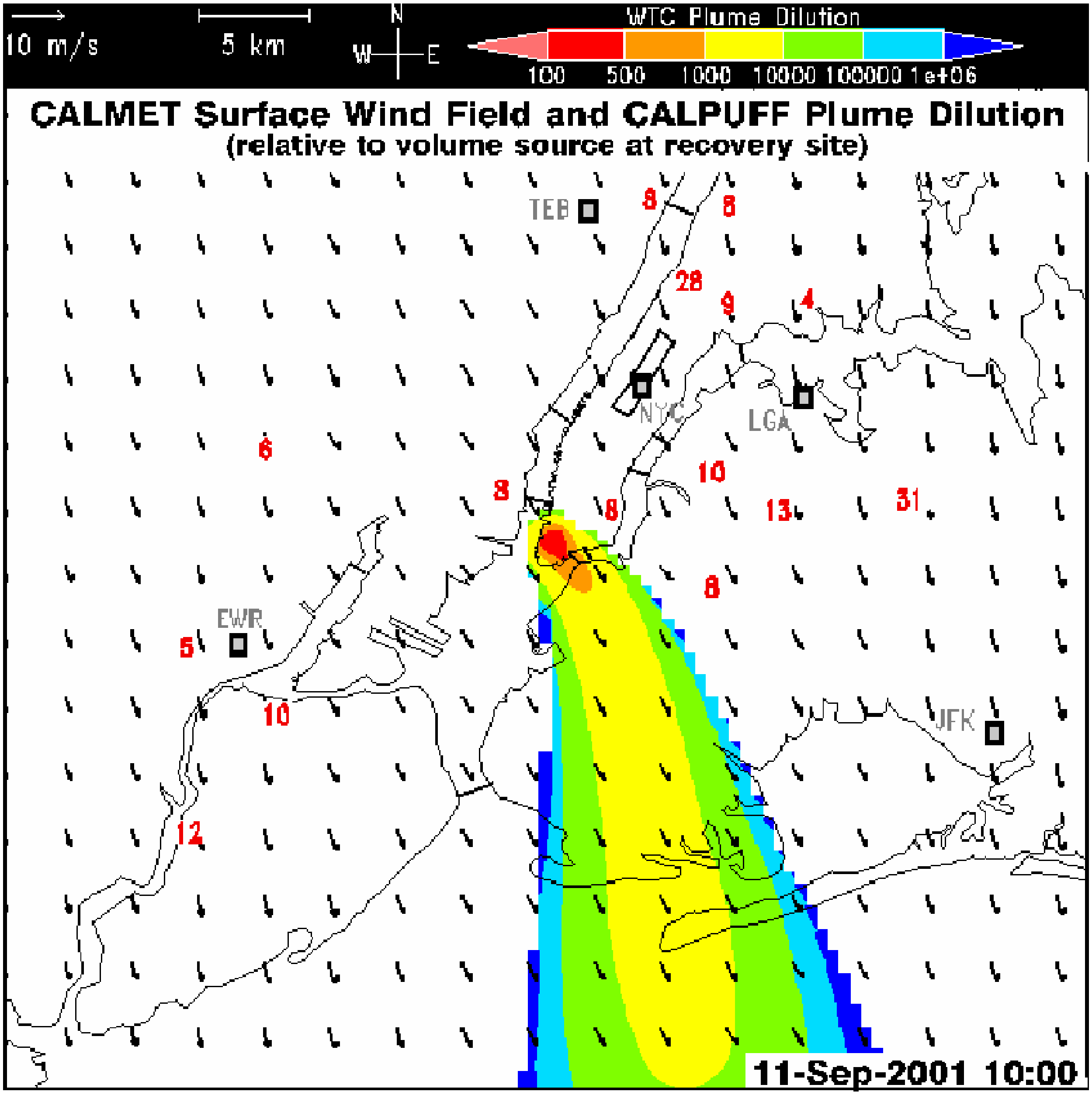

Figure 2-1. Simulation of WTC plume on the morning of the attack. National Oceanic and Atmospheric Administration meteorological stations are indicated as: Newark (EWR), Teterboro (TEB), LaGuardia Airport (LGA), Central Park (NYC) and John F. Kennedy Airport (JFK). Numbers in red are the hourly average concentration of particulate matter ≤ 2.5 μm in size in μg/m^3. Plume direction is towards the south-southeast and dilution of the plume varies from less than 500 to approximately 1,000,000.

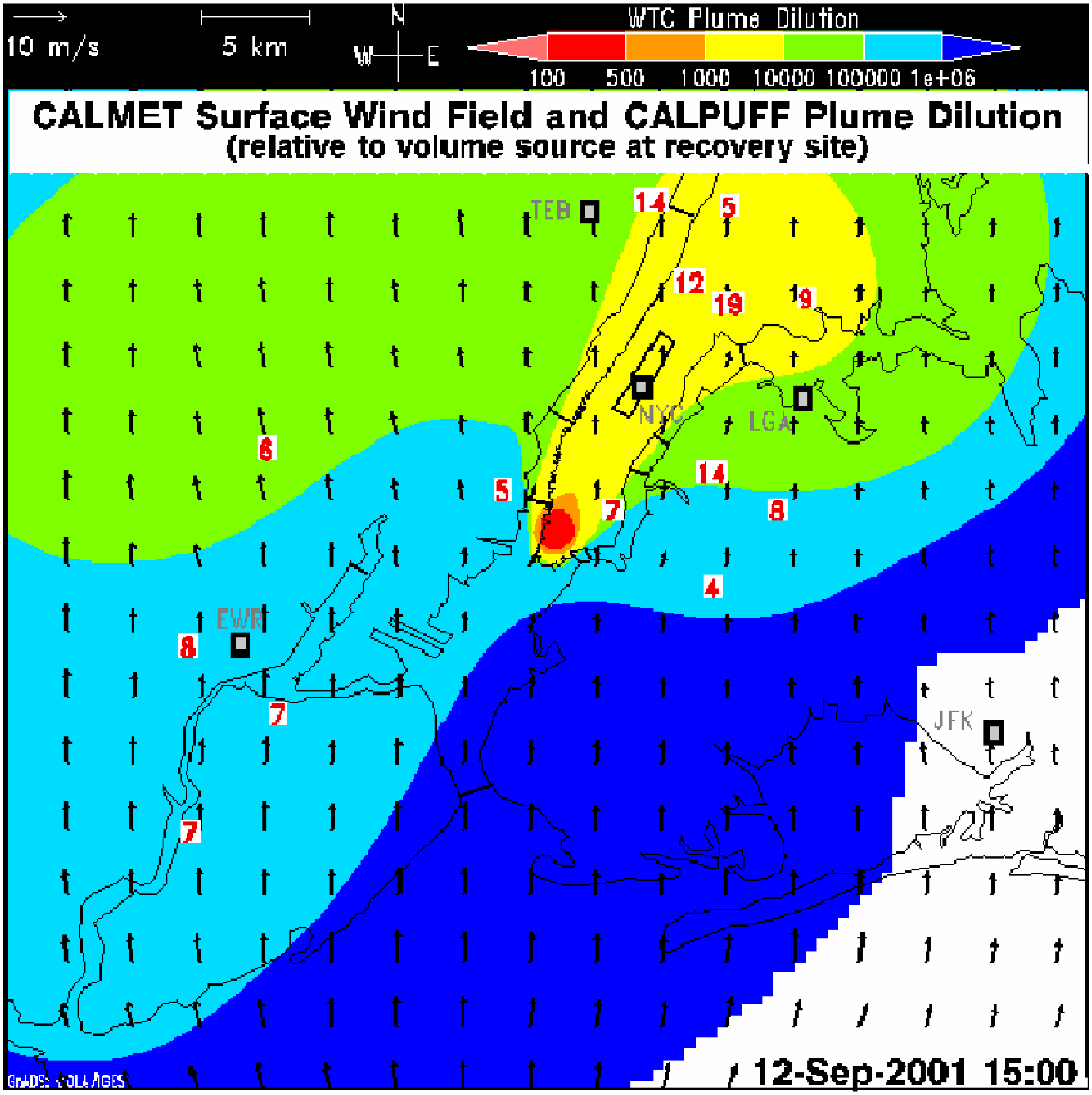

Figure 2-2. Simulation of WTC plume in the afternoon the day after the attack. National Oceanic and Atmospheric Administration meteorological stations are indicated as: Newark (EWR), Teterboro (TEB), LaGuardia Airport (LGA), Central Park (NYC) and John F. Kennedy Airport (JFK). Numbers in red are the hourly average concentration of particulate matter ≤ 2.5 µm in size in µg/m^3. Plume direction is primarily towards the northeast.

The Project Monitor contacted residents requesting assistance to confirm and schedule cleanup and testing. The Project Monitor had access to a translation service to assist with the process for those whose primary language is not English. There were three phases to the actual work: 1) Pre-cleaning inspection; 2) Cleaning; and 3) Testing.

Owners and managers of residential buildings and coop boards could request to have their building's common areas cleaned and HVAC system evaluated and cleaned, if necessary. After receiving the request, common areas such as the building lobby, hallways, stairways and elevator interiors would be cleaned. Other common areas, including laundry rooms, utility rooms, compactor rooms, and elevator shafts were evaluated and cleaned as needed.

During a pre-cleaning inspection for an individual residence, the Project Monitor met with the occupant(s) to assess conditions, discuss procedures and testing options, determine any special concerns or needs, and answer questions. The Project Monitor obtained written access and authorization, and scheduled the cleaning work. Residents were given information about preparing for cleaning including the handling of valuable personal items, the presence of pets, etc. The Project Monitor discussed the level of cleanup required (see below) and resident's options for post-cleanup testing.

Damage to a building as a result of the WTC collapse may have resulted in the growth of mold in apartments. As part of the Cleaning Program, the Project Monitor contacted the NYCDOHMH if mold was observed in a residence or residential building. The NYCDOHMH then contacted the building owner to provide recommendations on how to address the affected areas. Further information regarding mold can be found in the NYCDOHMH fact sheet entitled "Facts About Mold" (NYCDOHMH, 1994). (http://www.ci.nyc.ny.us/html/doh/html/epi/epimold.html)

If the Project Monitor identified the presence of potential friable asbestos type insulation in areas requested to be cleaned, it was reported to NYCDEP for evaluation and appropriate follow up action. Likewise, if the Project Monitor identified potential peeling, flaking or chalking paint, the NYCDOHMH was notified for evaluation and appropriate follow up action.

Cleaning Scope

Following the assessment, the Project Monitor determined the appropriate cleanup approach. Most residences were addressed under EPA's "Scope A" cleanup. Residences (typically unoccupied) where there was still significant amounts of WTC dust and/or debris were dealt with under EPA's "Scope B" cleanup which adds precautions to require further worker protection and techniques to minimize spreading of possible contamination while removing the dust/debris. Areas where localized accumulations of WTC dust were found in a residence which otherwise had minimal dust (i.e., between windows, inside air conditioners), were addressed under a Scope B cleanup, wherein the areas containing the dust were isolated from the remainder of the residence prior to removal. Residents (or their representatives) may have been present (but did not have to be) during Scope A cleanings. Residents were not allowed to be present during Scope B cleanings, unless the Scope B cleanup applied to only parts of the residence. In most cases, cleaning operations took no more than two days.

In a Scope A cleanup, all horizontal hard surfaces, including floors, ceilings, ledges, trims, furnishings, appliances, equipment, etc., were HEPA vacuumed and wet wiped. Vertical and soft surfaces were HEPA vacuumed two times. Dry sweeping was prohibited. A detailed description of the minimum cleaning requirements is listed below (field experience may have resulted in the modification of these procedures):

- Terraces, balconies, exterior window sills, window wells and window guards that are accessible from the interior of the dwelling, will be cleaned.

- Interior windows, screens, window sills and window guards will be cleaned.

- Vacuuming will begin with the ceiling, continue down the walls and include the floor.

- Impermeable walls and floors will be wet wiped using disposable wipes, after consultation with and approval by owner. Wet wiping will not be conducted if it is determined that it would cause damage to the surface.

- Curtains, fabric window treatments, upholstery and other materials that cannot be cleaned by wet wiping shall be HEPA vacuumed two times. Fabric covered furniture will be vacuumed using a stiff brush attachment.

- Carpets will be cleaned with a water extraction cleaner equipped with a motorized agitator brush. Water extraction cleaning will not be conducted if it is determined that it would cause damage to the carpet.

- Paperwork and books will be HEPA vacuumed.

- Electrical outlets will be vacuumed.

- Window air conditioners will be vacuumed then removed from their position and vacuumed internally. Filters will be HEPA vacuumed and reinstalled. Air conditioners will be reinstalled after cleaning.

- Intake/discharge registers of HVAC systems (if present) will be removed/cleaned. The first foot of duct work will also be vacuumed, then the register will be reinstalled and covered with plastic.

- Appliances such as refrigerators and stoves will be cleaned and moved. The floor footprint of the appliances will be cleaned and the appliance will be reinstalled in its original position.
- Refrigerator cooling tubes will be brushed and vacuumed.
- Stove exhaust fan filters will be cleaned.
- The first foot of all exhaust duct work (including stove, dryer and bathroom vents) will be vacuumed. Exhaust fans will be vacuumed and wiped.
- Closet floors will be vacuumed.
- Solid objects (electrical equipment, exercise equipment, etc.) will be wet wiped, moved to allow cleaning of the underlying surface and will be returned to their original location.
- Dishwasher toe plates will be removed and the floor beneath the appliance will be cleaned.
- Baseboard heaters will be cleaned. Protective covers on finned radiant heaters and baseboard heaters will be removed to expose heat elements. Fins are to be brushed and vacuumed to remove dust.
- All cleaning equipment will be vacuumed and/or wet wiped for use on the residence.

In a Scope B cleanup, the areas containing dust and/or debris were sealed off and exhaust fans equipped with HEPA filters were used to lower the air pressure within the sealed off area so that no dust escaped. Dust and debris were bagged and sealed for removal. Workers wore protective gear and residents were not allowed within the sealed off area. Scope B work could be applied to an entire residence or to portions of a residence where remnants of bulk dust were discovered.

Testing Protocol

Sampling was conducted no later than 24 hours after clean-up was completed. For *test only* apartments sampling was conducted in the absence of a cleaning event. Air samples, that were analyzed for both asbestos (separate counts for long, i.e., >5 um length, versus total fibers) and non-asbestos fibers, were obtained from all residences. Generally, one sample was obtained from each room in an apartment or from contiguous areas in common spaces. A subset of *clean and test* (approximately 200) and "test only" (approximately 50) apartments received wipe sampling for 23 metals plus dioxin. A description of the testing (sampling and analysis) protocol is summarized below.

When cleaning was completed, the Project Monitor did a visual inspection. If dust was observed, the residence was re-cleaned as necessary. Once the visual inspection found the residence to be dust free, final air sampling was authorized.

This final testing phase took approximately eight hours and was completed within one day (24 hours) of the completion of cleanup work. Residents had a choice between two forms of airborne asbestos testing, modified-aggressive and aggressive. Modified-aggressive testing simulates the normal air movement in a room where a fan or air conditioner is running. In aggressive testing, a one-horsepower leaf blower was used to blast air into all corners of the residence before testing was begun. From that point on, the two tests are identical. Any air conditioners were turned on and 20-inch fans (one per 10,000 cubic feet of room space) were run at low speeds for the duration of the test. Depending on the number of rooms in a residence, from three to five air samplers were located in the residence and run for approximately eight hours. These samplers draw in a measured volume of room air and collect dust from the air on a filter. The collected dust is then examined in a laboratory for asbestos using transmission electron microscopy (TEM). Additional analysis by phase contrast microscopy (PCM) was conducted to obtain a count of non-asbestos fibrous material.

Residents may have occupied their home during modified-aggressive testing but were cautioned to be prepared for noise and disruption. Occupants with known allergies, asthma or other health concerns were advised to consider contacting their health care provider to determine whether it was advisable to be present while cleaning and/or testing was underway. Residents were required to relocate during, and for 48 hours after, aggressive testing. The Red Cross agreed to provide financial assistance to defray costs for relocation expenses. Information from the Red Cross was provided as needed. Occupants were required to remove or secure objects, including pictures and artwork that could be blown over or otherwise damaged.

The Project Monitor conducted a post-cleaning inspection of the apartment with the resident at the completion of modified-aggressive sampling, or upon re-entry after aggressive sampling. During this inspection the project monitor and the resident determined whether cleaning/monitoring activities were completed and whether any property damage or loss had occurred. The resident then signed a Project Completion Form.

At a limited number of “clean and test” residences (approximately 200), the Project Monitor conducted pre- and post-cleanup wipe sampling for dioxin, mercury and metals. Approximately 50 *test only* residences received a single round of wipe sampling for dioxin, mercury and metals. Generally, wipe samples were obtained from three discrete surfaces within an apartment. Results of this sampling, along with interpretation through a comparison with health-based benchmarks, were shared with occupants of the residences.

EPA notified residents and owners of the results of the post-cleanup airborne asbestos testing. Notification letters included an interpretation of the TEM results for long (>5 um) asbestos fibers through comparison with EPA's cleanup criteria (see below). Additional information was provided on the results of total asbestos fibers (>0.5 um) by TEM and total non-asbestos fibers by PCM analysis. Residence-specific test results were not made public. Residences were re-cleaned and re-tested if any post-cleanup samples registered levels of asbestos in excess of EPA's cleanup criteria. For *test only* apartments, residents were eligible for cleaning if any airborne asbestos samples exceeded EPA's cleanup criteria. A technical discussion of asbestos air sampling and metals/dioxin wipe sampling can be accessed at www.epa.gov/wtc (See EPA's WTC Residential Confirmation Cleaning Study; EPA, 2003a).

Interpretation of test results

Clearance criteria were developed for evaluating airborne asbestos sampling results. A health-based value of 0.0009 f/cc was established based on TEM analysis of phase contrast microscopy equivalent (PCMe) fibers. The TEM analysis protocol was adapted from the Asbestos Hazard Emergency Response act (AHERA) and modified to count only asbestos fibers greater than 5 microns in length, with an aspect ratio greater than 5:1, and no minimum width requirement. The basis for the clearance criteria of 0.0009 f/cc (PCMe) is detailed in the COPC Report.

As previously stated, residences were re-cleaned and re-tested if the post-cleanup testing found levels of asbestos in excess of the cleanup criteria of 0.0009 f/cc (PCMe). There were a number of outcomes that resulted in inconclusive results. Filter overload (defined as dust deposition obscuring more than 10–25% of the filter), which compromises the ability to accurately count asbestos fibers, was the most common cause of inconclusive results. Other causes of inconclusive results included blown and/or damaged filters. Apartments with overloaded and/or blown/damaged filters were re-cleaned and re-tested. In addition, sampling results for total asbestos fibers greater than 0.5 microns in length (as per AHERA counting rules), and total non-asbestos fibers by PCM analysis were evaluated on a case-by-case basis.

Wipe Sampling

The wipe samples taken as part of the Dust Cleanup Program supplemented the findings of the WTC Confirmation Cleaning Study by providing additional information obtained under actual field conditions. While this single sampling event, conducted approximately 18 months after the release, could not reconstruct the collective exposure incurred since 9/11, it could serve to put into context the existing contaminant levels in settled dust by comparing the results of the sampling to health-based benchmarks (see EPA, 2003a, *Appendix Z*, *Table Z.3*) developed for the WTC Clean-up Program.

Wipe samples were collected and analyzed in accordance with the procedures and methods presented in the Quality Assurance Project Plan (QAPP). Procedures for the collection of wipe samples are detailed in *Appendix F* of the QAPP (EPA, 2003a). Samples were collected and analyzed for 22 metals, mercury and dioxin (EPA, 2003a, *Appendix Z, Table Z.3*). Of these, dioxin and lead were identified as COPCs that are likely associated with the WTC disaster. A summary of the wipe sample results is presented in *Appendix Z*. Detailed results for lead and dioxin are provided in *Section 3.0*.

3.0 WTC DUST CLEANUP PROGRAM

Data analyzed in this report were extracted from the Residential database on September 10, 2003. A copy of the data set, with data necessary to protect the privacy of individual participants in the program redacted, is available from the EPA Region 2 Records Center. *Appendix E* contains a detailed discussion of the results presented in this section. *Appendix F* contains additional information on other fiber analyses that were conducted.

Overall, the data indicate a low rate of exceedance of the health-based benchmarks that were established for the WTC cleanup effort. The exceedance rates for airborne asbestos, and the exceedances rates for dust loading for the 21 metals other than lead, were less than 0.5% on a sample-basis. The exceedance rate for dust lead loading decreased from approximately 14% before cleanup, to 3% after cleanup, on a sample-basis. The exceedance rate for dust dioxin loading was less than 1% before and after cleanup.

3.1 DATA SUMMARY

3.1.1 Summary of TEM (PCMe) data

Table 3-1 summarizes the sample results for asbestos. The data described in this section and *Section 3.1.2* are results for asbestos phase contrast microscopy equivalent (PCMe) concentrations measured by transmission electron microscopy (TEM). A total of 28,702 sample results were available for asbestos by PCMe; 22,497 from residential units, and 6,205 from common areas within residential buildings (e.g., hallways, laundry rooms). Samples for PCMe analysis were collected from residential units that were tested only, as well as from residential units and common areas that were cleaned and tested. Results by PCMe were compared to the health-based benchmark of 0.0009 f/cc (fibers/cubic centimeter) to determine the status of the residential units/common areas.

The asbestos clearance criteria for the WTC Indoor Air Clean-up Program were based on long (i.e., ≥ 5 μm) fiber counts. The use of a minimum fiber length of 5 μm for carcinogenic activity represents current scientific consensus and reflects the criteria in EPA's Integrated Risk Information System (IRIS) toxicity data base for attributing carcinogenic potency.

Table 3-1. Summary of Available Asbestos PCMe Results		
Summary of residential airborne asbestos data. The data represent phase contrast microscopy equivalent (PCMe) concentrations measured by transmission electron microscopy (TEM). The health-based benchmark of 0.0009 fibers/cubic centimeter was exceeded in a very small fraction of the samples. Occupants of residences with one or more exceedance for PCMe were offered recleaning.		
Sample Type	**Residential Samples**	**Common Area Samples**
Samples collected	22,497	6,205
Number of samples >0.0009[a] (exceeds)	102	21
Percent exceeds	0.45%	0.34%
Maximum concentration	0.0204	0.0042
Minimum concentration	Not Detected[b]	Not Detected

[a]The health-based benchmark for asbestos is 0.0009 fibers/cubic centimeters.
[b]Detection limit ranged from 0.0004 to 0.0005 fibers/cubic centimeters.

Phase Contrast Microscopy equivalence is a process to identify asbestos fibers by TEM analysis that would also be visible by PCM. The optical resolution of the phase contrast microscope is approximately 5 microns in length and 0.25 microns in width for fiber analysis. Historically, most of the occupational studies available (and reviewed by IRIS) to estimate the cancer potency of asbestos, employed PCM analysis. Therefore, in cases where TEM is used for asbestos analysis, fiber counts need to be adjusted to PCMe.

The asbestos counting rules employed for the WTC Indoor Cleanup Program were designed to record PCMe fibers. Thus, TEM analyses were performed and fibers were then counted following AHERA (Asbestos Hazard Emergency Response Act) counting rules. Fibers ≥ 5 µm (AHERA also stipulates a minimum 5:1 aspect ratio) were distinguished from total (i.e., >0.5 µm) fiber counts, although total fiber counts were also recorded. To maximize analytical capacity for a large sampling event, no minimum width requirement was employed. This may have resulted in a modest over counting bias by not eliminating extremely thin fibers (i.e., <0.25 µm) from the count. However, the potential bias attributed to this counting procedure would be protective of human health. Modification was made to AHERA (by obtaining larger samples volumes) in order to achieve the lower detection limits required by the use of a risk-based clearance criteria.

3.1.2 Summary of TEM data

Table 3-2 lists the types of asbestos that were detected by TEM in the airborne asbestos samples from residences and common areas. Asbestos was detected in approximately 4% of the available TEM samples. Chrysotile asbestos was detected in approximately 92% of the samples included in this subset of the data; amosite was detected in approximately 3%. Other forms of asbestos that were detected included actinolite, anthophyllite, tremolite, and crocidolite.

3.1.3 Summary of Dust Wipe data

Summary of Dust Lead Wipe Data

The database contained 1,540 wipe samples for dust lead loading that were collected from 263 residences, located in 157 buildings. Summary statistics for the data are provided in *Table 3-3*. Samples that were below the detection limit of 1.86 $\mu g/ft^2$ were set equal to the detection limit. Review of existing environmental standards/regulations identified an applicable and relevant standard to set a health-based benchmark for lead in interior dust. The Residential Lead-Based Paint Hazard Reduction Act (Title X) Final Rule (40 CFR, Part 745, 1/5/01) established uniform national standards for lead in interior dust.

Table 3-2. Number of Samples of Residential Airborne Asbestos Analyzed by Transmission Electron Microscopy (TEM) and By Asbestos Type Detected

For samples where asbestos was detected; Chrysotile was encountered in approximately 92% of the residential samples, and in 91% of the samples collected from common areas. The next most frequently identified type of asbestos was Amosite (3% in residential, 4% in common areas).

Asbestos Type	Residential Samples	Common Area Samples
Not detected	21,543	5,926
Actinolite	9	1
Amosite	31	10
Amosite/Chrysotile	3	2
Amosite/Chrysotile/Crocidolite	1	0
Amphibole	1	3
Anthophyllite	6	3
Anthophyllite/Chrysotile	3	1
Chrysotile	878	255
Chrysotile/Actinolite	6	0
Chrysotile Amphibole	0	2
Chrysotile/Tremolite	3	0
Crocidolite	1	0
Gypsum fibers present[a]	7	0
Tremolite	5	2
Total	**22,497**	**6,205**

[a]Non asbestos fibers.

Table 3-3. Statistics for All Lead Wipe Data Combined ($\mu g/ft^2$)	
This table provides summary statistics for residential dust lead loading data that was collected from residences that were cleaned and tested (both before and after cleanup), and tested only.	
Apartments sampled[a]	263
Buildings sampled	157
Number of samples	1540
Nondetects	264 (17.1%)
Exceedances @ 25 $\mu g/ft^2$ [a]	136 (8.8%)
Exceedances @ 40 $\mu g/ft^2$ [b]	95 (6.2%)

[a]The database contains matching data (i.e., pre- and post-cleanup data) for 214 apartments, and unmatched data (i.e, only pre-cleanup or only post-cleanup) for 49 apartments, for a total of 263 apartments..
[b]Exceedance: lead wipe samples that exceeded the health-based benchmark of 25 $\mu g/ft^2$

Thus, both EPA and the United States Department of Housing and Urban Development (HUD) have set a dust standard for lead of 40 $\mu g/ft^2$ for floors (including carpeted floors), and 250 $\mu g/ft^2$ for interior window sills. To support the development of a dust standard, EPA performed an analysis of the Rochester Lead-in-Dust Study (HUD, 1995). At 40 $\mu g/ft^2$, a multimedia analysis shows a 5.3% probability that a child's blood lead level would exceed 10 µg/dL. Thus, this standard meets the criteria established by EPA (i.e., 95% probability to be below 10 µg/dL) (EPA, 1994) for managing environmental lead hazards. However, an additional increment of protectiveness was added by setting the health-based benchmark for lead in settled dust at the more stringent HUD screening level of 25 $\mu g/ft^2$. Approximately 9% of all lead wipe samples (i.e., *test only* and *clean and test*) were above the HUD screening level of 25 $\mu g/ft^2$ *(Table 3-3)*; approximately 14% of the pre-cleanup samples exceeded the HUD screening level , while approximately 3% of the post-cleanup samples exceeded the screening level (*Tables 3-4* and *3-5*). Approximately 6% of the samples were above the HUD benchmark of 40 $\mu g/ft^2$m (*Table 3-3)*.

Summary of Dust Dioxin Wipe Data

The database contained 1,535 wipe samples for dust dioxin loading that were collected from 263 residences, located in 157 buildings. Basic statistics for the data are provided in *Table 3-6*. The dioxin results were modified using a toxicity equivalency quotient (TEQ), which takes into account the toxicity differences between 17 congener groups**.** The results are reported in 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) equivalents. The TEQ value reported in the table represents the estimated maximum potential concentration (EMPC). The TEQ EMPC value used data that indicated the presence of a congener above zero ng/m^2 even if all of the QA/QC reporting level criteria were met for that sample. This value represents the highest potential concentration of dioxin that may have been present. At least one of the 17 congeners was detected in 1,136 of the samples; the remaining 399 samples were reported as below the detection limit for each congener. Only 8 of the 1,535 (approximately 0.5%) of the combined samples (i.e., *test only* and *clean and test*; *Table 3-6*) exceeded the health-based benchmark for residential dust dioxin loading of 2 ng/m2 *(Table 3-6)*.

Summary of Dust Wipe Data for Other Metals

Data for 21 metals, in addition to lead, were collected. Statistics for the 21 metals (plus lead and dioxin), and the reduction in the average dust loading rates for each, are provided in *Table 3-7*. The data are grouped into three categories in *Table 3-7*: samples collected from residences and common areas that were cleaned and tested (*clean and test samples*), samples that were collected from residences that were tested only (*test only samples*), and the combination of these two categories (*all samples*).

Table 3-4. Statistics for Lead Wipe *Clean and Test* Data

The *clean and test* subset of the data exhibit very high positive skewness and high variability. The raw data and log-transformed pre- and post-cleanup data fail the S-W test for normality (log-transformed data [pre-/post-]: S-W statistic=0.89/0.85, p<0.0001/p<0.0001). This table includes two observations that have been treated as outliers in subsequent analyses (see *Section 3.4.1* for details). Statistics for the data set, after removal of the two outliers, are provided in *Tables 3-7* and *A-1a*.

Statistic	**Pre-cleanup**	**Post-cleanup**
Apartments sampled	214	214
Buildings sampled	145	145
Number of samples	680	674
Nondetects	101 (14.8%)	140 (20.8%)
Exceedances @ 25 µg/ft^2 [a]	93 (13.7%)	21 (3.1%)
Exceedances @ 40 µg/ft^2 [b]	67 (9.9%)	12 (1.8%)
Minimum	1.86	1.86
Median	7.32	6.38
Mean	35.46	19.03
Maximum	6790	7250
Standard deviation	286.03	279.64
Skewness	20.56	25.77
CV[c]	8.07	14.70
S-W Statistic[d]	0.07	0.03
Prob Normal[e]	<0.0001	<0.0001

[a]Exceedance: lead wipe samples that exceeded the health-based screening level of 25 µg/ft^2
[b]Exceedance: lead wipe samples that exceeded the HUD health-based benchmark of 40 µg/ft^2
[c]CV=coefficient of variation=standard deviation/mean
[d]S-W Statistic: Shapiro-Wilk statistic
[e]Prob Normal: probability the data are from a normal distribution

Table 3-5. Statistics for Lead Wipe *Clean and Test* Data with Outliers Removed

The *clean and test* subset of the data exhibit very high positive skewness and high variability. The raw data and log-transformed pre- and post-cleanup data fail the S-W test for normality (log-transformed data [pre-/post-]: S-W statistic0.90/0.89, p<0.0001/p<0.0001). This table excludes two observations that have been treated as outliers (see *Section 3.4.1* for details).

Statistic	**Pre-cleanup**	**Post-cleanup**
Apartments sampled	214	214
Buildings sampled	145	145
Number of samples	679	673
Nondetects	101 (14.9)	140 (20.8)
Exceedances @ 25 $\mu g/ft^2$ [a]	92 (13.5)	20 (3.0)
Exceedances @ 40 $\mu g/ft^2$ [b]	66 (9.7%)	11 (1.6%)
Minimum	1.86	1.86
Median	7.32	6.37
Mean	25.52	8.28
Maximum	2530	394
Standard deviation	121.00	19.79
Skewness	15.24	13.89
CV[c]	4.74	2.39
S-W Statistic[d]	0.15	0.21
Prob Normal[e]	<0.0001	<0.0001

[a]Exceedance: lead wipe samples that exceeded the health-based screening level of 25 $\mu g/ft^2$
[b]Exceedance: lead wipe samples that exceeded the HUD health-based benchmark of 40 $\mu g/ft^2$
[c]CV=coefficient of variation=standard deviation/mean
[d]S-W Statistic: Shapiro-Wilk statistic
[e]Prob Normal: probability the data are from a normal distribution

Table 3-6. Statistics for All Dioxin (TEQ) Wipe Data (ng/m^2)

This table provides summary statistics for residential dust dioxin loading data that was collected from residences that were cleaned and tested (both before and after cleanup), and tested only.

Apartments sampled[a]	263
Buildings sampled	157
Number of samples	1535
Nondetects	399 (26.0%)
Exceedances[b]	8 (0.52%)

[a]The database contains matching data (i.e., pre- and post-cleanup data) for 214 apartments, and unmatched data (i.e, only pre-cleanup or only post-cleanup) for 49 apartments, for a total of 263 apartments.
[b]Exceedance: dioxin wipe samples that exceeded the health-based benchmark of 2 ng/m^2 TEQ EMPC (ND = ½).

Table 3-7. Dust Wipe Sample Data

Total Samples			Matched Pre- and Post-Cleaning Samples			Test Only Samples		
Aluminum	Number	Percentages	Aluminum	Number	Percentages	Aluminum	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	1536	99.5%	Detects	1329	99.5%	Detects	102	99.0%
Nondetects	8	0.5%	Nondetects	7	0.5%	Nondetects	1	1.0%
Nondetects @ 200	7	87.5%	Nondetects @ 200	7	100.0%	Nondetects @ 200	0	0.0%
Nondetects @ 1000	1	12.5%	Nondetects @ 1000	0	0.0%	Nondetects @ 1000	1	100.0%
Max	319000		Max	296000		Max	45500	
Min	ND @ 200		Min	ND @ 200		Min	ND @ 248	
Exceedances	0	0.0%	Exceedances	0	0.0%	Exceedances	0	0.0%
			Avg Pre-Means	3258.97				
			Avg Post-Means	1093.05				
			Avg % Reduction	35.44				
Antimony	Number	Percentages	Antimony	Number	Percentages	Antimony	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	13	0.8%	Detects	7	0.5%	Detects	4	3.9%
Nondetects	1531	99.2%	Nondetects	1329	99.5%	Nondetects	99	96.1%
Nondetects @ 80	1526	99.7%	Nondetects @ 80	1329	100.0%	Nondetects @ 80	94	94.9%
Nondetects @ 400	5	0.3%	Nondetects @ 400	0	0.0%	Nondetects @ 400	5	5.1%
Max	1180		Max	1180		Max	404	
Min	ND @ 80		Min	ND @ 80		Min	ND @ 80	
Exceedances	2	0.1%	Exceedances	2	0.1%	Exceedances	0	0.0%
			Avg Pre-Means	84.38				
			Avg Post-Means	80.01				
			Avg % Reduction	1.47				
Arsenic	Number	Percentages	Arsenic	Number	Percentages	Arsenic	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	34	2.2%	Detects	30	2.2%	Detects	1	1.0%
Nondetects	1510	97.8%	Nondetects	1306	97.8%	Nondetects	102	99.0%
Nondetects @ 20	1505	99.7%	Nondetects @ 20	1306	100.0%	Nondetects @ 20	97	95.1%
Nondetects @ 100	5	0.3%	Nondetects @ 100	0	0.0%	Nondetects @ 100	5	4.9%
Max	286		Max	268		Max	100	
Min	ND @ 20		Min	ND @ 20		Min	ND @ 20	
Exceedances	0	0.0%	Exceedances	0	0.0%	Exceedances	0	0.0%
			Avg Pre-Means	21.21				
			Avg Post-Means	20.06				
			Avg % Reduction	2.09				

Notes: The 'Total' sample numbers do not equal the sum of the '*Clean and Test*' and '*Test Only*' sample numbers because the 'Matched Pre- and Post-Cleaning Samples' include only the matched pre- and post-cleanup samples collected from the same location.. Similarly, the lead and dioxin sample numbers do not match the sample numbers shown in *Tables B-7, B-7a* or *B-13* because *Tables B-7, B-7a* and *B-13* inlcude all pre-and post-cleanup samples (i.e., residences with only pre- or post-cleanup samples are not excluded from *Tables B-7*, *B-7a* and *B-13*).

Table 3-7. Dust Wipe Sample Data

Total Samples			Matched Pre- and Post-Cleaning Samples			Test Only Samples		
Barium	Number	Percentages	Barium	Number	Percentages	Barium	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	245	15.9%	Detects	210	15.7%	Detects	17	16.5%
Nondetects	1299	84.1%	Nondetects	1126	84.3%	Nondetects	86	83.5%
Nondetects @ 200	1294	99.6%	Nondetects @ 200	1126	100.0%	Nondetects @ 200	81	94.2%
Nondetects @ 1000	5	0.4%	Nondetects @ 1000	0	0.0%	Nondetects @ 1000	5	5.8%
Max	23400		Max	23400		Max	5510	
Min	ND @ 200		Min	ND @ 200		Min	ND @ 200	
Exceedances	0	0.0%	Exceedances	0	0.0%	Exceedances	0	0.0%
			Avg Pre-Means:	367.84				
			Avg Post-Means:	215.12				
			Avg % Reduction:	13.92				
Beryllium	Number	Percentages	Beryllium	Number	Percentages	Beryllium	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	0	0.0%	Detects	0	0.0%	Detects	0	0.0%
Nondetects	1544	100.0%	Nondetects	1336	100.0%	Nondetects	103	100.0%
Nondetects @ 20	1539	99.7%	Nondetects @ 20	1336	100.0%	Nondetects @ 20	98	95.1%
Nondetects @ 100	5	0.3%	Nondetects @ 100	0	0.0%	Nondetects @ 100	5	4.9%
Max	ND @ 100		Max	ND @ 20		Max	ND @ 100	
Min	ND @ 20		Min	ND @ 20		Min	ND @ 20	
Exceedances	0	0.0%	Exceedances	0	0.0%	Exceedances	0	0.0%
			Avg Pre-Means	20.00				
			Avg Post-Means	20.00				
			Avg % Reduction	0.00				
Cadmium	Number	Percentages	Cadmium	Number	Percentages	Cadmium	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	68	4.4%	Detects	50	3.7%	Detects	12	11.7%
Nondetects	1476	95.6%	Nondetects	1286	96.3%	Nondetects	91	88.3%
Nondetects @ 20	1471	99.7%	Nondetects @ 20	1286	100.0%	Nondetects @ 20	86	94.5%
Nondetects @ 100	5	0.3%	Nondetects @ 100	0	0.0%	Nondetects @ 100	5	5.5%
Max	1180		Max	906		Max	1180	
Min	ND @ 20		Min	ND @ 20		Min	ND @ 20	
Exceedances	0	0.0%	Exceedances	0	0.0%	Exceedances	0	0.0%
			Avg Pre-Means	22.34				
			Avg Post-Means	20.28				
			Avg % Reduction	3.13				

Notes: The 'Total' sample numbers do not equal the sum of the '*Clean and Test*' and '*Test Only*' sample numbers because the 'Matched Pre- and Post-Cleaning Samples' include only the matched pre- and post-cleanup samples collected from the same location. Similarly, the lead and dioxin sample numbers do not match the sample numbers shown *in Tables B-7, B-7a or B-13* because *Tables B-7, B-7a* and *B-13* inlcude all pre-and post-cleanup samples (i.e., residences with only pre- or post-cleanup samples are not excluded from *Tables B-7, B-7a* and *B-13*).

Table 3-7. Dust Wipe Sample Data

Total Samples			Matched Pre- and Post-Cleaning Samples			Test Only Samples		
Calcium	Number	Percentages	Calcium	Number	Percentages	Calcium	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	1544	100.0%	Detects	1336	100.0%	Detects	103	100.0%
Nondetects	0	0.0%	Nondetects	0	0.0%	Nondetects	0	0.0%
Max	4050000		Max	4050000		Max	474000	
Min	1440		Min	1680		Min	1440	
Exceedances	0	0.0%	Exceedances	0	0.0%	Exceedances	0	0.0%
			Avg Pre-Means	43239.15				
			Avg Post-Means	24571.60				
			Avg % Reduction	28.95				
Chromium	Number	Percentages	Chromium	Number	Percentages	Chromium	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	855	55.4%	Detects	723	54.2%	Detects	63	61.2%
Nondetects	689	44.6%	Nondetects	613	45.8%	Nondetects	40	38.8%
Nondetects @ 20	684	99.3%	Nondetects @ 20	613	100.0%	Nondetects @ 20	35	87.5%
Nondetects @ 100	5	0.7%	Nondetects @ 100	0	0.0%	Nondetects @ 100	5	12.5%
Max	1900		Max	1050		Max	1900	
Min	ND @ 20		Min	ND @ 20		Min	ND @ 20	
Exceedances	0	0.0%	Exceedances	0	0.0%	Exceedances	0	0.0%
			Avg Pre-Means	48.01				
			Avg Post-Means	28.23				
			Avg % Reduction	21.45				
Cobalt	Number	Percentages	Cobalt	Number	Percentages	Cobalt	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	4	0.3%	Detects	2	0.1%	Detects	1	1.0%
Nondetects	1540	99.7%	Nondetects	1334	99.9%	Nondetects	102	99.0%
Nondetects @ 200	1535	99.7%	Nondetects @ 200	1334	100.0%	Nondetects @ 200	97	95.1%
Nondetects @ 1000	5	0.3%	Nondetects @ 1000	0	0.0%	Nondetects @ 1000	5	4.9%
Max	1000		Max	654		Max	1000	
Min	ND @ 200		Min	ND @ 200		Min	ND @ 200	
Exceedances	0	0.0%	Exceedances	0	0.0%	Exceedances	0	0.0%
			Avg Pre-Means	200.92				
			Avg Post-Means	200.00				
			Avg % Reduction	0.29				

Notes: The 'Total' sample numbers do not equal the sum of the '*Clean and Test*' and '*Test Only'* sample numbers because the 'Matched Pre- and Post-Cleaning Samples' include only the matched pre- and post-cleanup samples collected from the same location. Similarly, the lead and dioxin sample numbers do not match the sample numbers shown in *Tables B-7, B-7a* or *B-13* because *Tables B-7, B-7a* and *B-13* inlcude all pre-and post-cleanup samples (i.e., residences with only pre- or post-cleanup samples are not excluded from *Tables B-7, B-7a* and *B-13*).

Table 3-7. Dust Wipe Sample Data

Total Samples				Matched Pre- and Post-Cleaning Samples				Test Only Samples		
Copper	Number	Percentages		Copper	Number	Percentages		Copper	Number	Percentages
Samples	1544			Samples	1336			Samples	103	
Detects	1544	100.0%		Detects	1336	100.0%		Detects	103	100.0%
Nondetects	0	0.0%		Nondetects	0	0.0%		Nondetects	0	0.0%
Max	14500			Max	14500			Max	3700	
Min	36			Min	36			Min	108	
Exceedances	0	0.0%		Exceedances	0	0.0%		Exceedances	0	0.0%
				Avg Pre-Means	387.98					
				Avg Post-Means	226.82					
				Avg % Reduction	18.73					
Iron	Number	Percentages		Iron	Number	Percentages		Iron	Number	Percentages
Samples	1544			Samples	1336			Samples	103	
Detects	1544	100.0%		Detects	1336	100.0%		Detects	103	100.0%
Nondetects	0	0.0%		Nondetects	0	0.0%		Nondetects	0	0.0%
Max	228000			Max	212000			Max	168000	
Min	207			Min	462			Min	207	
Exceedances	0	0.0%		Exceedances	0	0.0%		Exceedances	0	0.0%
				Avg Pre-Means	5438.09					
				Avg Post-Means	1689.07					
				Avg % Reduction	34.77					
Lead	Number	Percentages		Lead	Number	Percentages		Lead	Number	Percentages
Samples	1544			Samples	1336			Samples	103	
Detects	1280	82.9%		Detects	1090	81.6%		Detects	89	86.4%
Nondetects	264	17.1%		Nondetects	246	18.4%		Nondetects	14	13.6%
Nondetects @ 1.86	260	98.5%		Nondetects @ 1.86	246	100.0%		Nondetects @ 1.86	10	71.4%
Nondetects @ 9.29	4	1.5%		Nondetects @ 9.29	0	0.0%		Nondetects @ 9.29	4	28.6%
Max	7250			Max	7250			Max	1380	
Min	ND @ 1.86			Min	ND @ 1.86			Min	ND @ 1.86	
Exceedances	136	8.8%		Exceedances	112	8.4%		Exceedances	12	11.7%
				Avg Pre-Means	24.40					
				Avg Post-Means	16.21					
				Avg % Reduction	8.19					

Notes: The 'Total' sample numbers do not equal the sum of the '*Clean and Test*' and '*Test Only'*sample numbers because the 'Matched Pre- and Post-Cleaning Samples' include only the matched pre- and post-cleanup samples collected from the same location. Similarly, the lead and dioxin sample numbers do not match the sample numbers shown in *Tables B-7, B-7a* or *B-13* because *Tables B-7, B-7a* and *B-13* inlcude all pre-and post-cleanup samples (i.e., residences with only pre- or post-cleanup samples are not excluded from *Tables B-7, B-7a* and *B-13*).

Table 3-7. Dust Wipe Sample Data

Total Samples			Matched Pre- and Post-Cleaning Samples			Test Only Samples		
Magnesium	Number	Percentages	Magnesium	Number	Percentages	Magnesium	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	1544	100.0%	Detects	1336	100.0%	Detects	103	100.0%
Nondetects	0	0.0%	Nondetects	0	0.0%	Nondetects	0	0.0%
Max	1550000		Max	1550000		Max	83400	
Min	2920		Min	4650		Min	3560	
Exceedances	0	0.0%	Exceedances	0	0.0%	Exceedances	0	0.0%
			Avg Pre-Means	15852.43				
			Avg Post-Means	11540.41				
			Avg % Reduction	12.46				
Manganese	Number	Percentages	Manganese	Number	Percentages	Manganese	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	1455	94.2%	Detects	1263	94.5%	Detects	95	92.2%
Nondetects	89	5.8%	Nondetects	73	5.5%	Nondetects	8	7.8%
Nondetects @ 20	85	95.5%	Nondetects @ 20	73	100.0%	Nondetects @ 20	4	50.0%
Nondetects @ 100	4	4.5%	Nondetects @ 100	0	0.0%	Nondetects @ 100	4	50.0%
Max	4410		Max	4410		Max	2390	
Min	ND @ 20		Min	ND @ 20		Min	ND @ 20	
Exceedances	0	0.0%	Exceedances	0	0.0%	Exceedances	0	0.0%
			Avg Pre-Means	117.82				
			Avg Post-Means	51.19				
			Avg % Reduction	30.18				
Mercury	Number	Percentages	Mercury	Number	Percentages	Mercury	Number	Percentages
Samples	1517		Samples	1298		Samples	100	
Detects	593	39.1%	Detects	469	36.1%	Detects	64	64.0%
Nondetects	924	60.9%	Nondetects	829	63.9%	Nondetects	36	36.0%
Nondetects @ 0.4	885	95.8%	Nondetects @ 0.4	793	95.7%	Nondetects @ 0.4	36	100.0%
Nondetects @ 1.6	8	0.9%	Nondetects @ 1.6	7	0.8%	Nondetects @ 1.6	0	0.0%
Nondetects @ 40	2	0.2%	Nondetects @ 40	2	0.2%	Nondetects @ 40	0	0.0%
Nondetects @ 2	20	2.2%	Nondetects @ 2	19	2.3%	Nondetects @ 2	0	0.0%
Nondetects @ 4	9	1.0%	Nondetects @ 4	8	1.0%	Nondetects @ 4	0	
Max	248		Max	248		Max	15.8	
Min	ND @ 0.4		Min	ND @ 0.4		Min	ND @ 0.4	
Exceedances	6	0.4%	Exceedances	5	0.4%	Exceedances	0	0.0%
			Avg Pre-Means	4.71				
			Avg Post-Means	2.24				
			Avg % Reduction	0.84				

Notes: The 'Total' sample numbers do not equal the sum of the '*Clean and Test*' and '*Test Only*'sample numbers because the 'Matched Pre- and Post-Cleaning Samples' include only the matched pre- and post-cleanup samples collected from the same location. Similarly, the lead and dioxin sample numbers do not match the sample numbers shown in *Tables B-7, B-7a or B-13* because *Tables B-7, B-7a* and *B-13* inlcude all pre-and post-cleanup samples (i.e., residences with only pre- or post-cleanup samples are not excluded from *Tables B-7, B-7a and B-13*).

Table 3-7. Dust Wipe Sample Data

Total Samples				Matched Pre- and Post-Cleaning Samples				Test Only Samples		
Nickel	Number	Percentages		Nickel	Number	Percentages		Nickel	Number	Percentages
Samples	1544			Samples	1336			Samples	103	
Detects	613	39.7%		Detects	523	39.2%		Detects	57	55.3%
Nondetects	931	60.3%		Nondetects	813	60.8%		Nondetects	46	44.7%
Nondetects @ 20	928	99.7%		Nondetects @ 20	813	100.0%		Nondetects @ 20	43	93.5%
Nondetects @ 100	3	0.3%		Nondetects @ 100	0	0.0%		Nondetects @ 100	3	6.5%
Max	3160			Max	3160			Max	492	
Min	ND @ 20			Min	ND @ 20			Min	ND @ 20	
Exceedances	0	0.0%		Exceedances	0	0.0%		Exceedances	0	0.0%
				Avg Pre-Means	62.56					
				Avg Post-Means	27.13					
				Avg % Reduction	23.15					
Potassium	Number	Percentages		Postassium	Number	Percentages		Postassium	Number	Percentages
Samples	1544			Samples	1336			Samples	103	
Detects	1544	100.0%		Detects	1336	100.0%		Detects	103	100.0%
Nondetects	0	0.0%		Nondetects	0	0.0%		Nondetects	0	0.0%
Max	239000			Max	239000			Max	100000	
Min	1350			Min	1350			Min	8140	
Exceedances	0	0.0%		Exceedances	0	0.0%		Exceedances	0	0.0%
				Avg Pre-Means	24749.34					
				Avg Post-Means	20235.38					
				Avg % Reduction	10.67					
Selenium	Number	Percentages		Selenium	Number	Percentages		Selenium	Number	Percentages
Samples	1544			Samples	1319			Samples	103	
Detects	1204	78.0%		Detects	984	74.7%		Detects	102	99.0%
Nondetects	340	22.0%		Nondetects	334	25.3%		Nondetects	1	1.0%
Nondetects @ 20	280	82.4%		Nondetects @ 20	277	82.9%		Nondetects @ 20	1	100.0%
Nondetects @ 40	60	17.6%		Nondetects @ 40	57	17.1%		Nondetects @ 40	0	0.0%
Max	590			Max	590			Max	559	
Min	ND @ 20			Min	ND @ 20			Min	ND @ 20	
Exceedances	0	0.0%		Exceedances	0	0.0%		Exceedances	0	0.0%
				Avg Pre-Means	137.85					
				Avg Post-Means	240.49					
				Avg % Reduction	-38.53					

Notes: The 'Total' sample numbers do not equal the sum of the '*Clean and Tes*t' and '*Test Only'*sample numbers because the 'Matched Pre- and Post-Cleaning Samples' include only the matched pre- and post-cleanup samples collected from the same location. Similarly, the lead and dioxin sample numbers do not match the sample numbers shown in *Tables B-7, B-7a* or *B-13* because *Tables B-7, B-7a* and *B-13* inlcude all pre-and post-cleanup samples (i.e., residences with only pre- or post-cleanup samples are not excluded from *Tables B-7, B-7a* and *B-13*).

Table 3-7. Dust Wipe Sample Data

Total Samples			Matched Pre- and Post-Cleaning Samples			Test Only Samples		
Silver	Number	Percentages	Silver	Number	Percentages	Silver	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	26	1.7%	Detects	24	1.8%	Detects	1	1.0%
Nondetects	1518	98.3%	Nondetects	1312	98.2%	Nondetects	102	99.0%
Nondetects @ 20	1512	99.6%	Nondetects @ 20	1311	99.9%	Nondetects @ 20	97	95.1%
Nondetects @ 100	5	0.3%	Nondetects @ 100	0	0.0%	Nondetects @ 100	5	4.9%
Nondetects @ 200	1	0.1%	Nondetects @ 200	1	0.1%	Nondetects @ 200	0	0.0%
Max	1400		Max	1400		Max	268	
Min	ND @ 20		Min	ND @ 20		Min	ND @ 20	
Exceedances	0	0.0%	Exceedances	0	0.0%	Exceedances	0	0.0%
			Avg Pre-Means	22.49				
			Avg Post-Means	650.77				
			Avg % Reduction	-3151.96				
Sodium	Number	Percentages	Sodium	Number	Percentages	Sodium	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	1538	99.6%	Detects	1333	99.8%	Detects	101	98.1%
Nondetects	6	0.4%	Nondetects	3	0.2%	Nondetects	2	1.9%
Nondetects @ 400	2	33.3%	Nondetects @ 400	1	33.3%	Nondetects @ 400	1	50.0%
Nondetects @ 4000	2	33.3%	Nondetects @ 4000	1	33.3%	Nondetects @ 4000	1	50.0%
Max	2	33.3%	Max	1	33.3%	Max	0	0.0%
Min	557000		Min	557000		Min	222000	
Exceedances	ND @ 400		Exceedances	ND @ 400		Exceedances	ND @ 400	
			Avg Pre-Means	63441.36				
			Avg Post-Means	51980.14				
			Avg % Reduction	11.33				
Dioxin (TEQ ND=1/2)	Number	Percentages	Dioxin (TEQ ND=1/2)	Number	Percentages	Dioxin (TEQ ND=1/2)	Number	Percentages
Samples	1538		Samples	1322		Samples	103	
Detects	1136	73.9%	Detects	938	71.0%	Detects	96	93.2%
Nondetects	402	26.1%	Nondetects	384	29.0%	Nondetects	7	6.8%
Max	75.3		Max	2.29		Max	3.01	
Min	0.265		Min	0.265		Min	0.349	
Exceedances	8	0.5%	Exceedances	3	0.2%	Exceedances	1	1.0%
			Avg Pre-Means	0.65				
			Avg Post-Means	0.64				
			Avg % Reduction	0.01				

Notes: The 'Total' sample numbers do not equal the sum of the '*Clean and Test*' and '*Test Only*'sample numbers because the 'Matched Pre- and Post-Cleaning Samples' include only the matched pre- and post-cleanup samples collected from the same location. Similarly, the lead and dioxin sample numbers do not match the sample numbers shown in *Tables B-7, B-7a* or *B-13* because *Tables B-7, B-7a* and *B-13* inlcude all pre-and post-cleanup samples (i.e., residences with only pre- or post-cleanup samples are not excluded from *Tables B-7, B-7a* and *B-13*).

Table 3-7. Dust Wipe Sample Data

Total Samples			Matched Pre- and Post-Cleaning Samples			Test Only Samples		
Thallium	Number	Percentages	Thallium	Number	Percentages	Thallium	Number	Percentages
Samples	1544		Samples	938		Samples	103	
Detects	0	0.0%	Detects	0	0.0%	Detects	0	0.0%
Nondetects	1544	100.0%	Nondetects	938	100.0%	Nondetects	103	100.0%
Nondetects @ 200	1539	99.7%	Nondetects @ 200	938	100.0%	Nondetects @ 200	98	95.1%
Nondetects @ 1000	5	0.3%	Nondetects @ 1000	0	0.0%	Nondetects @ 1000	5	4.9%
Max	ND @ 1000		Max	ND @ 200		Max	ND @ 1000	
Min	ND @ 200		Min	ND @ 200		Min	ND @ 200	
Exceedances	0	0.0%	Exceedances	0	0.0%	Exceedances	0	0.0%
			Avg Pre-Means	235.80				
			Avg Post-Means	195.51				
			Avg % Reduction	3.85				
Vanadium	Number	Percentages	Vanadium	Number	Percentages	Vanadium	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	7	0.5%	Detects	3	0.2%	Detects	1	1.0%
Nondetects	1537	99.5%	Nondetects	1333	99.8%	Nondetects	102	99.0%
Nondetects @ 200	1532	99.7%	Nondetects @ 200	1333	100.0%	Nondetects @ 200	97	95.1%
Nondetects @ 1000	5	0.3%	Nondetects @ 1000	0	0.0%	Nondetects @ 1000	5	4.9%
Max	1000		Max	539		Max	1000	
Min	ND @ 200		Min	ND @ 200		Min	ND @ 200	
Exceedances	0	0.0%	Exceedances	0	0.0%	Exceedances	0	0.0%
			Avg Pre-Means	236.67				
			Avg Post-Means	641.60				
			Avg % Reduction	-218.87				
Zinc	Number	Percentages	Zinc	Number	Percentages	Zinc	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	1544	100.0%	Detects	1336	100.0%	Detects	103	100.0%
Nondetects	0	0.0%	Nondetects	0	0.0%	Nondetects	0	0.0%
Max	78900		Max	78900		Max	67400	
Min	372		Min	539		Min	380	
Exceedances	0	0.0%	Exceedances	0	0.0%	Exceedances	0	0.0%
			Avg Pre-Means	2196.83				
			Avg Post-Means	1419.72				
			Avg % Reduction	16.89				

Notes: The 'Total' sample numbers do not equal the sum of the '*Clean and Test*' and '*Test Only*'sample numbers because the 'Matched Pre- and Post-Cleaning Samples' include only the matched pre- and post-cleanup samples collected from the same location. Similarly, the lead and dioxin sample numbers do not match the sample numbers shown in *Tables B-7, B-7a* or *B-13* because *Tables B-7, B-7a* and *B-13* inlcude all pre-and post-cleanup samples (i.e., residences with only pre- or post-cleanup samples are not excluded from *Tables B-7, B-7a* and *B-13*).

The database contained 1,517 results for mercury, and 1,544 results for all of the other metals. The rate of detection (based on all samples) varied widely from 0 for beryllium and thallium, to 100% for calcium, copper, iron, magnesium, potassium and zinc. Eight of the 21 metals had detection rates of less than or equal to 5%; 4 had detection rates between 6 and 60%. Results for each metal were compared against risk-based screening levels *(Table 3-8)*. Very few exceedances of the risk-based screening values were measured for any of the metals. The screening value of 627 $\mu g/m^2$ for antimony was exceeded in 2 pre-cleanup samples (0.1% of all samples); the maximum measured value was 1,180 $\mu g/m^2$. The screening value of 157 $\mu g/m^2$ for mercury was exceeded in 5 pre-cleanup samples (0.4% of all samples). No residence had an average antimony dust loading or mercury dust loading greater than their respective health-based benchmarks.

3.2 EFFICACY OF THE DUST CLEANUP PROGRAM

3.2.1 Reductions in the Rate of PCMe Exceedance

The efficacy of the asbestos cleanup effort was assessed using PCMe exceedances for *clean and test* data. One measure of effectiveness is the overall rate of exceedances, which equals the number of exceedances divided by the total number of samples that were collected. The overall exceedance rate on sample-basis for the WTC Cleanup Program was approximately 0.00418, or 0.42%.

An alternative measure of efficacy is the number of times a residence or a common area within a building (e.g., hallway, stairwell, laundry) had to be recleaned to achieve the clearance criteria of 0.0009 f/cc. Residences were recleaned if one or more samples exceeded the health-based benchmark for asbestos, or one or more samples could not be analyzed in the laboratory due to excessive dust on the air filter (i.e., *overloads*). The cleanup effort was effective in achieving the clearance criteria for PCMe approximately 99% of the time in residential units and common areas. The PCMe clearance criterion was not achieved in 35 out of 3,387 (1.03%) residences and in 11 out of 785 common areas (1.40%) after the first cleaning. The probability of achieving the clearance on the second attempt in residential units that did not achieve clearance after the first cleaning was approximately 1 (>0.999; 2 out of the 25 residences that were recleaned did not achieve clearance after the second cleaning - 10 residents elected not to have their residences recleaned, or were unresponsive). These results suggest that the cleaning methods used were effective in reducing asbestos concentrations in residential air.

Table 3-8. Health-based Benchmarks and Screening Values for Chemicals of Potential Concern (COPCs) in Settled Dust	
Chemical of Potential Concern	**Health-based Benchmark/ Screening Value**
Aluminum	1567888
Antimony	627
Arsenic	387
Barium	109752
Beryllium	3136
Cadmium	1557
Chromium	4704
Cobalt	31358
Copper	62716
Iron	940733
Lead[a]	25
Manganese	31358
Mercury	157
Nickel	31358
Selenium	7839
Silver	7839
Thallium	110
Vanadium	10975
Zinc	470366
Dioxin[a]	2

Table is based on in EPA, May 2003 COPC report. All benchmarks are $\mu g/m^2$, except for lead, which is in $\mu g/ft^2$, and dioxin, which is ng/m^2.

[a]The health-based benchmark for lead is 40 $\mu g/ft^2$; however, the more stringent screening HUD screening value of 25 $\mu g/ft^2$ was used (see *Section 3.5.1* for details).

[b]Health-based benchmark is for toxicity equivalent (TEQ), which is a weighted summation of 17 types (congeners) of dioxin, where the weights represent the relative toxicity for each specific congener.

A *modified aggressive* sampling procedure was used in most of the apartments (EPA, 2003a). The modified-aggressive sampling procedure was adapted from the aggressive sampling procedure described in AHERA. The aggressive sampling procedure had a tendency to overload the sampling filter with dust, preventing the samples from being analyzed by the laboratory (EPA, 2003a). The modified aggressive sampling is thought to be more representative of typical household activity patterns (EPA, 2003a). The rate of exceedance varied between the two sampling procedures. On a sample basis, the exceedances rates in *test only* residences were 0.50 and 0.49% for the aggressive and modified aggressive sampling procedures, respectively; the exceedances rates for the *clean and test* residences were 3.4 and 0.20% for the aggressive and modified aggressive sampling procedures, respectively. The test only exceedances rates were not significantly different by Fisher's exact test ($p>0.99$); the *clean and test* exceedances rates were statistically significant by Fisher's exact test ($p<0.01$). On a residence-basis (i.e., one or more sample result from the residence equal or exceeded the benchmark for asbestos), the exceedances rates in *test only* residences were 3.0 and 1.1% for the aggressive and modified aggressive sampling procedures, respectively; the exceedances rates for the *clean and test* residences were 6.4 and 0.64% for the aggressive and modified aggressive sampling procedures, respectively. The *test only* exceedances rates were not significantly different by Fisher's exact test ($p>0.34$); the *clean and test* exceedances rates were statistically significant by Fisher's exact test ($p<0.01$).

3.2.2 Reduction in Dust Lead Loading

The methods used were effective in reducing levels of lead as measured by wipe samples. The indoor environment is considered to be a complex and dynamic system that is influenced by many interacting factors (physical, chemical, thermodynamic conditions, human activity, building design, building materials, HVAC system, etc.). Therefore, it is not uncommon to find variability in the amount of contaminants in settled dust within a building, and certainly from one building to the next. In addition to WTC proximity, high variability is also likely due to the wide range of diversity in the housing stock, contents of the residences and common areas, and preexisting conditions, or previous activity, at these sites.

To assess the effectiveness of the cleanup program, the wipe data were divided into two groups: samples that were collected before the apartments were cleaned (*pre-cleanup)*, and samples that were collected after the apartments were cleaned (*post-cleanup)*. Pre-cleanup lead wipe samples and post cleanup samples were collected from 214 apartments, located in 145 buildings.

The cleanup program reduced the average dust lead loading in residential units by approximately 16 $\mu g/ft^2$ (20%) (*Section E.4.1*).

Thirty-six residences had pre-cleanup average dust lead loadings greater than the HUD screening of 25 $\mu g/ft^2$. Average post-cleanup dust lead loading in residences with average pre-cleanup loadings above the HUD screening level of 25 $\mu g/ft^2$ were approximately 85 $\mu g/ft^2$ lower than pre-cleanup loadings. The cleanup program was successful in reducing the average dust lead loading in 31 of the 36 residences to below the 25 $\mu g/ft^2$ screening level, a success rate of approximately 86% *(Section E.4.2)*.

Twenty-three residences had pre-cleanup average dust lead loadings greater than the HUD benchmark of 40 µg/ft^2. Average post-cleanup dust lead loading in residences with average pre-cleanup loadings above the HUD benchmark of 40 µg/ft^2 were approximately 120 µg/ft^2 lower than average pre-cleanup loadings. The cleanup program reduced the average dust lead leading in 21 out of the 23 residences, a success rate of approximately 91%.

Residences located on the third floor or lower tended to have higher pre-cleanup average loadings (39.52 µg/ft^2) than residences located on floors 4-10 (21.08 µg/ft^2) and floors higher than 10 (14.18 µg/ft^2). Reduction in average dust lead loading also varied by building floor level. On average, dust lead loadings were reduced by 33.1 µg/ft^2 (43.5%) for residences on floors 3 and lower, by 11.1 µg/ft^2 (23.1%) for residences on floors 4–10, and by 6.9 (8.6%) for residences located on floors 11 and higher *(Section E.4.3)*.

The number of exceedances of dust lead loading on a *sample-basis* is shown in *Figure 3-1*. Two sets of bars are also shown for dust lead loading exceedances, corresponding to two different benchmarks for dust lead loading. The first set of bars corresponds to the WTC screening level of 25 µg/ft^2; the second set corresponds to the HUD health-based benchmark of 40 µg/ft^2. Regardless of the benchmark that is used, the reduction in the number of exceedances (on a sample-basis) is approximately 85%.

3.2.3 Reduction in Dust Dioxin Loading

The measurable effect of the cleanup program on dust dioxin loadings was less than it was for lead due primarily to low pre-cleanup dust dioxin loadings, which limits the usefulness of the dioxin data to assess the efficacy of the dust cleanup program. Pre-cleanup and post cleanup dust wipe samples for dioxin were collected from 212 apartments, located in 145 buildings. Reductions in dust dioxin loadings were modest due to the low pre-cleanup levels. The mean of the average pre-cleanup dust dioxin loading in each residence was 0.65 ng/m^2; all residential average dust dioxin loadings were less than the health-based benchmark of 2 ng/m^2. The cleanup program reduced the residential average dust dioxin loading by approximately 0.01 ng/m^2 *(Section E.4.4)*.

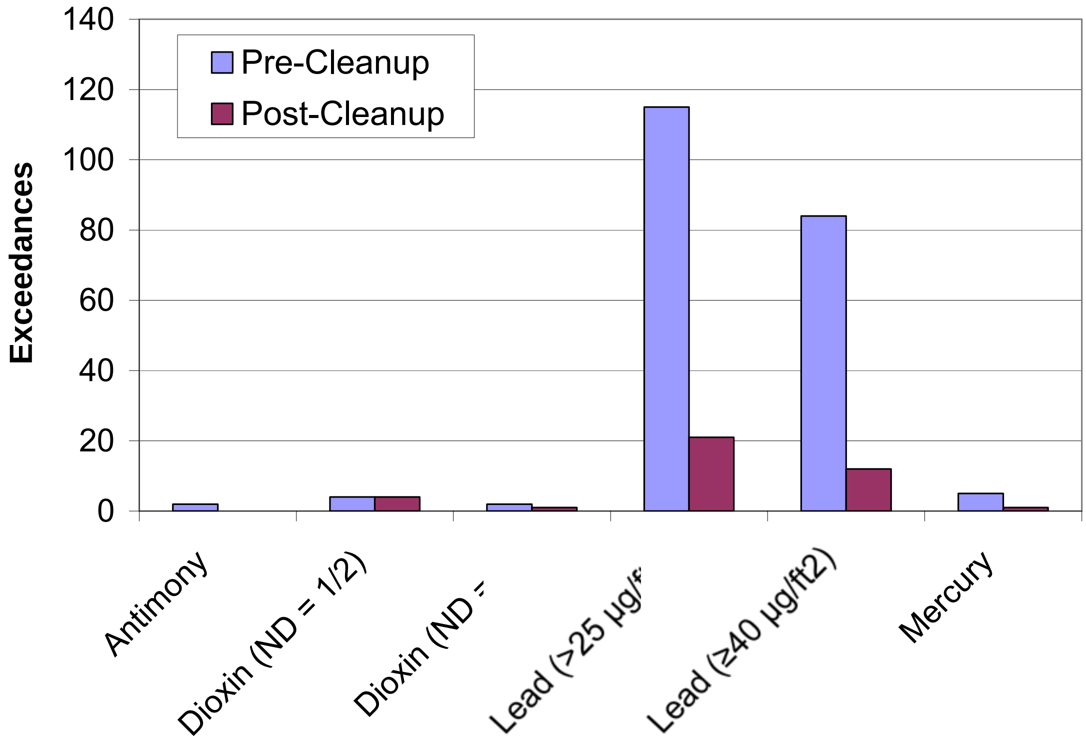

Figure 3-1. The number of *samples* (i.e., not residences) that exceeded health-based benchmarks, for contaminants that had at least one exceedance of their respective health-based benchmark. Two sets of bars are shown for dioxin, corresponding to two methods for treating the dioxin sample results that were reported as below detection limit (*nondetects*) by the laboratory. The first set of numbers (i.e., ND=1/2) corresponds to the method that was used in this report (nondetects were set equal to ½ of the detection limit); the second set of numbers corresponds to an alternative method of treating nondetects (setting nondetects equal to 0 ng/m^2). The number of exceedances is low regardless of the method that is used to treat the nondetects. Two sets of bars are also shown for dust lead loading exceedances, corresponding to two different benchmarks for dust lead loading. The first set of bars corresponds to the WTC screening level of 25 µg/ft^2; the second set corresponds to the HUD health-based benchmark of 40 µg/ft^2. The reductions in the number of exceedances (pre-cleanup, post-cleanup) are as follows: antimony (2, 0); dioxin (ND=1/2) (4, 4); dioxin (ND=0) (2, 1); lead (>25 µg/ft^2) (115, 21); lead (≥ 40 µg/ft^2) (84, 12); mercury (5, 1).

The number of exceedances of dust dioxin loading on a *sample-basis* is shown in *Figure 3-1*. Two sets of bars are shown for dioxin, corresponding to two methods for treating the dioxin sample results that were reported as below detection limit (*nondetects*) by the laboratory. The first set of numbers (i.e., ND=1/2) corresponds to the method that was used in this report (nondetects were set equal to ½ of the detection limit); the second set of numbers corresponds to an alternative method of treating nondetects (setting nondetects equal to 0 ng/m^2). The number of exceedances is low regardless of the method that is used to treat the nondetects.

3.2.4 Reduction in Dust Antimony Loading and Dust Mercury Loading

A comparison of the number of exceedances in pre-cleanup *samples* (*not* residences) to the number of exceedances in post-cleanup samples for antimony and mercury is provided in *Figure 3-1*. The number of dust antimony exceedances was reduced from 2 in the pre-cleanup samples to 0 in the post-cleanup samples; the number of dust mercury exceedances was reduced from 5 in the pre-cleanup samples to 1 in the post-cleanup samples.

3.3 SUMMARY OF THE SPATIAL ANALYSIS OF PCMe EXCEEDANCES

One hundred twenty two of the 28702 samples collected had exceedances of the health based standard (PCMe > 0.0009 f/cc) for asbestos. The comparison of the rates of PCMe exceedances between SSAs was restricted to a subset of the SSAs that had a sample size of 30 or more. Sample sizes less than 30 were considered to small to yield reliable results. The existence of a spatial pattern in the PCMe exceedances is not supported by the spatial analyses:

1. Analysis of the site-level (global) pattern of PCMe exceedances indicates that the geographic centers of the exceedance events for the *test only* and *clean and test* buildings tended to be located south of the geographic center of the sampled buildings, and east of the WTC site. Except for one location, the *test only* exceedance locations occurred along an east-west line located south of the WTC site. There is no obvious pattern to the *clean and test* exceedances. Interpretation of the exceedance locations is complicated by the variability in the number of samples that were collected in buildings *(Section E.3.2.1)*.

2. The analysis of PCMe exceedances at the statistical summary area (SSA) level indicated that the rate of PCMe exceedances varied over the sampled area:

    a. SSAs with similar PCMe exceedance rates tended to be located near each other (i.e., the rates exhibit positive spatial autocorrelation) *(Section E.3.2.2)*.

    b. Comparison of the rates of PCMe exceedances across the SSAs indicated that SSAs with exceedance rates that were significantly greater than the other SSAs were located east (*test only* data), and north and east (*clean and test* data) of the WTC site *(Section E.2.2.2)*.

3. Analysis of the building-level (local) pattern of PCMe exceedances, using nearest neighbor methods, suggests the pattern is consistent with a spatially random process *(Section E.3.2.3)*.

4. Analysis of the building-level (local) pattern of PCMe exceedances, using Ripley's K function, also failed to reject the hypothesis that the PCMe exceedances were generated by a spatially random process *(Section E.3.2.3)*.

5. Analysis of the site-level vertical distribution of PCMe exceedances, on a residence-basis, did not find any statistically significant pattern for residences that were tested (i.e., *test only* residences) or residences that were cleaned and tested (i.e., *clean and test* residences) *(Section E.3.2.4)*.

6. Analysis of the site-level vertical distribution of PCMe exceedances, on a sample-basis, indicates samples collected from *clean and test* residences and common areas that were located on lower floors (i.e., ≤ 3rd floor) were approximately 2 times more likely to exceed the health-based benchmark for airborne asbestos than were samples collected from *clean and test* residences and common areas located on upper floors (floors 10 and higher). No significant differences were found between *clean and test* samples collected on middle floors (floors 4–9) and upper floors. The rate of PCMe exceedances was found to differ between floor groups for the *test only* samples, although comparisons between the floor groups were not statistically significant *(Section E.3.2.4)*.

3.4 Comparison of WTC Indoor Dust Program and EPA Background Study

As described earlier, a background study was conducted in Upper Manhattan to determine indoor concentrations of selected analytes that were identified in WTC-related dust. Several of the analytes, specifically asbestos, lead, and dioxin, that were measured in Upper Manhattan were also measured in the WTC Indoor Dust Program. An evaluation was conducted with these three analytes to determine if the concentrations detected in Lower Manhattan one to two years after the collapse of the WTC were similar to those measured in Upper Manhattan. The evaluation consists of comparing the frequency of detection, the range of values reported (i.e., minimum and maximum), and the percentage of samples that were above the health-based benchmark for each analyte *(Table 3-9)*.

The most appropriate measurements for comparison are the frequency of detection and the percentage of samples that exceeded the health-based benchmark. The minimum and maximum values are not the most reliable method for comparing the two studies due to the variability in the detection limits and the substantial difference in sample size between the two studies. As sample size increases there is a tendency for the range of values detected to increase, which limits the reliability of comparing maximum values from the two studies.

In addition to comparing the two studies with each other, the results from the studies were compared to values obtained from the literature. Studies were identified that reported concentrations from indoor environments for these three analytes using similar sampling and analytical methodologies. The minimum, maximum, mean, median, and 90th percentile values from the literature were compared with the values reported from the EPA studies. The literature values were reported using censored data. In order to make the comparison the EPA data compatible with the literature values, the EPA data sets for each analyte were censored using the same method as reported in the literature. This was done for comparison purposes only and the censoring method employed does not provide any additional insight into what the actual values from the EPA studies may have been. The censoring method used, as well as detailed information from each literature study that was chosen for comparison, are presented in the discussion of each analyte.

Asbestos - The frequency of detection from samples collected in the two distinctly different geographic locations were similar, with a detection rate of 2% in Lower Manhattan and 5% in Upper Manhattan. The minimum concentrations from both areas were identical, while the maximum detected concentration in Lower Manhattan was higher than the maximum detected concentration in Upper Manhattan. Although the maximum detected concentrations were not similar between the two areas, the percentage of samples that exceeded the health-based criterion was similar, with 0.5% in Lower Manhattan and 0.0% in Upper Manhattan.

Table 3-9. Comparison of Descriptive Statistics from the USEPA WTC Indoor Dust Program and the USEPA Upper Manhattan Background Study

Comparison of airborne asbestos, dust lead loading and dust dioxin loading measured in Lower Manhattan to concentrations measured in in Upper Manhattan ('background'). The most appropriate measurements for comparison are the frequency of detection and the percentage of samples that exceeded the health-based benchmark. Comparison of the minimum values is confounded by the variability in the detection limits. Comparison of the maximum values is confounded by the variability in sample sizes; as sample size increases there is a tendency for the maximum value to increase.

Analyte	USEPA WTC Indoor Dust Program					USEPA Upper Manhattan Background Study				
	n	% det.[a]	min	max	% above[b]	n	% det.[a]	min	max	% above[b]
Asbestos (s/cc)[c]	20,887	2%	<0.0004	0.0204	0.5%	62	5%	<0.0004	0.0004	0.0%
Lead (μg/ft^2)	1812	78%	<1.86	2530	7.6%	114	50%	<0.5	49	0.9%
Dioxin (ng/m^2)[d]	1549	74%	0.292	5.14	0.5%	114	77%	0.475	1.66	0%

s/cc: structures per cubic centimeters; μg/ft^2 = micrograms of lead per square foot of surface; ng/m^2 = nanograms of dioxin per square meter of surface
[a]% det.: percent of samples that contained the contaminant at levels above the detection limit
[b]% above: percent of sample measurements that were greater than the health-based benchmark (health-based benchmarks: asbestos: 0.0009 f/cc; lead: 25 μg/ft^2; dioxin 2 ng/m^2:).
[c] Phase contrast microscopy equivalent (PCMe) results; see glossary for definition
[d] International toxicity equivalent quotient (TEQ) see glossary for definition; all congeners that were not detected were set equal to ½ their detection limit.

A summary paper by the Health Effects Institute presented asbestos results for several different types of buildings, including schools, residences, and public/commercial spaces (HEI-AR, 1991). The asbestos measurements were made using TEM analysis, and counted fibers that were ≤ 5 μm, which is the same method that was utilized in the EPA studies. The values reported in the summary paper were left-censored; a value of zero was substituted for samples that were reported as being below the detection limit. Values reported for residential spaces, and for all buildings combined (i.e., minimum, mean, median, and 90th percentile) in this summary paper were plotted beside the same values from the EPA studies *(Figure 3-2)*. The horizontal axis reports the results from the test-only data set from Lower Manhattan (LM-Pre), the clean and test data set from Lower Manhattan (LM-Post), the Upper Manhattan data set (UM), the residential data set (Residence) and the data set from all buildings (All) from the HEI summary paper. The results of this comparison indicate that all of the values that were plotted fall below the health-based benchmark that was established for the WTC Indoor Dust Cleanup program. The only exception is the maximum values that were reported for the Lower Manhattan data set, which were above the health-based benchmark. The maximum values from the literature were not reported, so a comparison cannot be made. The mean values from the literature are higher than those reported in the EPA studies (after replacing non-detects with 0). This may be in part due to the high number of non-detect samples that were present in the EPA studies. If the detection limit were substituted for the EPA non-detect samples, the means from the EPA studies would be near 0.0005 s/cc. It is likely that the true mean asbestos concentration in Manhattan, based on data from the EPA studies, lies somewhere between 0 and 0.0005 s/cc. The middle of the range, which is 0.00025 s/cc, is quite similar to the mean reported in the HEI summary paper.

Lead - The frequency of detection, the maximum detected concentration, and the percentage of samples that exceeded the health-based criteria were higher in Lower Manhattan when compared to the results from Upper Manhattan[1]. If only the post-cleaning samples from the clean and test apartments are used for the comparison, the percentage above the health-based criterion falls from 7.6% to 2.5%, which is more similar to the Upper Manhattan rate (0.9%).

[1] Two data points were removed from the Lower Manhattan data set for this analysis, as they were identified as outliers in the lead data set.

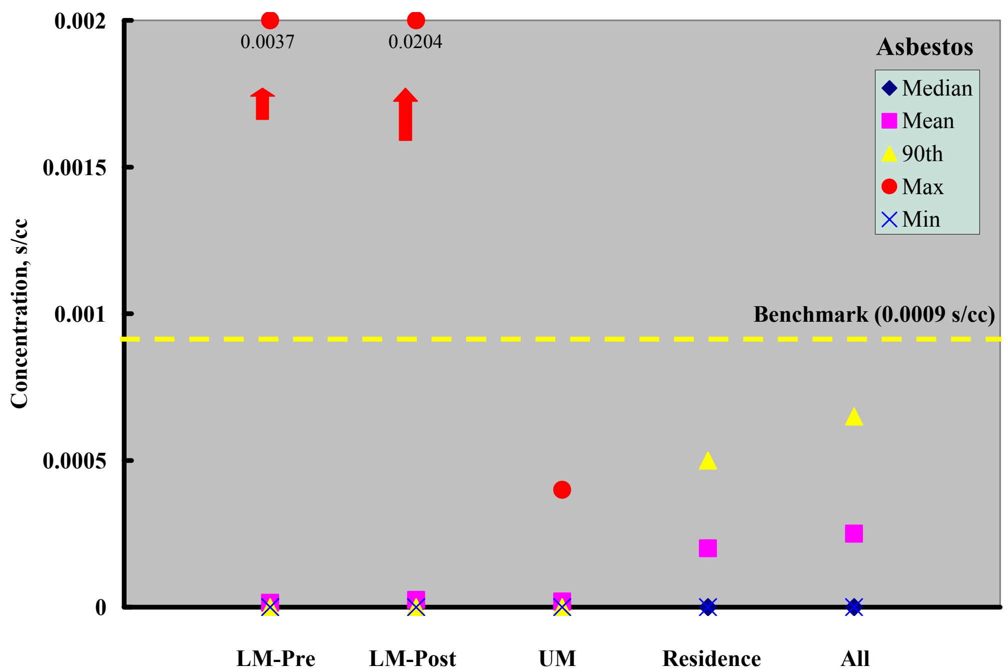

Figure 3-2. Comparison of airborne asbestos concentrations from WTC Dust Cleanup Program and Background Study to concentrations reported by the Health Effects Institute (HEI, 1991). The table includes data from the test-only data (LM-Pre), and clean and test data (LM-Post) from the Lower Manhattan Dust Cleanup Program; Upper Manhattan data (i.e., background) (UM) from the WTC Background Study (EPA, 2003b); and, the residential data (Residence) and the data from all buildings (All) from the HEI summary paper (HEI, 1991). The results of this comparison indicate that all of the values fall below the health-based benchmark that was established for the WTC Indoor Dust Cleanup program. The only exception is the maximum values that were reported for the Lower Manhattan data set, which were above the health-based benchmark. The maximum values from the literature were not reported, so a comparison cannot be made. The mean values from the literature are higher than those reported in the USEPA studies (after replacing non-detects with 0). This may be in part due to the high number of non-detect samples that were present in the USEPA studies. If the detection limit were substituted for the USEPA non-detect samples, the means from the USEPA studies would be near 0.0005 s/cc. Its likely that the true mean asbestos concentration in Manhattan, based on data from the USEPA studies, lies somewhere between 0 and 0.0005 s/cc An estimate that is in the middle of the that range, e.g., 0.00025 s/cc, is quite similar to the mean reported in the HEI summary paper.

The best comparison data set that was identified for lead was the 2001 Housing and Urban Development database for lead and allergens in U.S. housing (HUD, 2001). This database provides data on lead in settled dust from urban residences in four regions of the United States (i.e., Northeast, Midwest, South, and West), by building age. Information on the distribution of lead loadings for carpeted and uncarpeted floors in housing stock ranging in age from pre-1939 to 1998 for the Northeast was queried from the HUD database and descriptive statistics were generated. Values for samples that were identified as being below the detection limit were substituted with ½ of the detection limit. The minimum, maximum, median, mean, and 90th percentile values were plotted beside the same values from the USEPA studies *(Figure 3-3)*. The horizontal axis reports the results from the test-only data set from Lower Manhattan

(LM-Pre), the clean and test data set from Lower Manhattan (LM-Post), the Upper Manhattan data set (UM), and the HUD data set. The maximum values detected in the LM-Pre and HUD data sets were similar, although the LM-Pre value was higher. The means from the four data sets were all below the health-based benchmark. The LM-Pre mean was just under the benchmark, the LM-Post and HUD means were similar, and the UM mean was the lowest. The comparison indicates that the maximum detected concentrations varied between studies, the means, medians, and 90th percentile values for the LM-Post, UM, and HUD were below the benchmark, and all but the 90th percentile for the LM-Pre data set were below the benchmark.

Dioxin - The frequency of detection in the two areas were similar with a rate of 74% in Lower Manhattan and 77% in Upper Manhattan. The minimum detected concentrations were also similar, and the maximum detected concentration from Lower Manhattan was slightly higher than Upper Manhattan[2]. The percentage of samples that were above the health-based criterion was similar between the two areas with a rate of 0.5% in Lower Manhattan and 0.0% in Upper Manhattan.

There was limited information in the literature for dioxin wipe samples that could be used for comparison. The New York State Department of Health (NYSDOH) reported on post-occupancy environmental sampling from an office building that was impacted by a fire that released polychlorinated biphenyls and dioxin (NYSDOH, 2002). This report presented data (Binghamton data) for wipe samples that were collected and analyzed for dioxin using similar methods as those used in the EPA studies. The data represents the seventh round of post-occupancy sampling, which occurred in 1999, 18 years after the building fire. This was the last round of sampling because the dioxin concentrations were very low throughout the building. The values presented in the paper were reported in Toxicity Equivalents Quotients (TEQs) where congeners that were below the detection limit were set to ½ of the detection limit. The minimum, maximum, median, mean, and 90th percentile values from this study were plotted beside the same values from the EPA studies *(Figure 3-4)*. The minimum, median, and mean values from the three studies were very similar. There was a slightly higher value for the 90th percentile from the NYSDOH data set (NYSDOH, 2002). The minimum, median, mean, and 90th percentile values were all below the health-based benchmark. The maximum detected concentrations from the Lower Manhattan data sets (LM-Pre and LM-Post) were marginally higher than the Upper Manhattan (UM) and Binghamton data sets. With the exception of the UM data set, all of the maximum values were above the

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[2] One data point was removed from the Lower Manhattan data set for this analysis, as it was identified as outliers in the dioxin data set.

health-based benchmark. This indicates that the dioxin concentrations observed in the WTC Indoor Dust Program were similar to background, and similar to values reported in the literature.

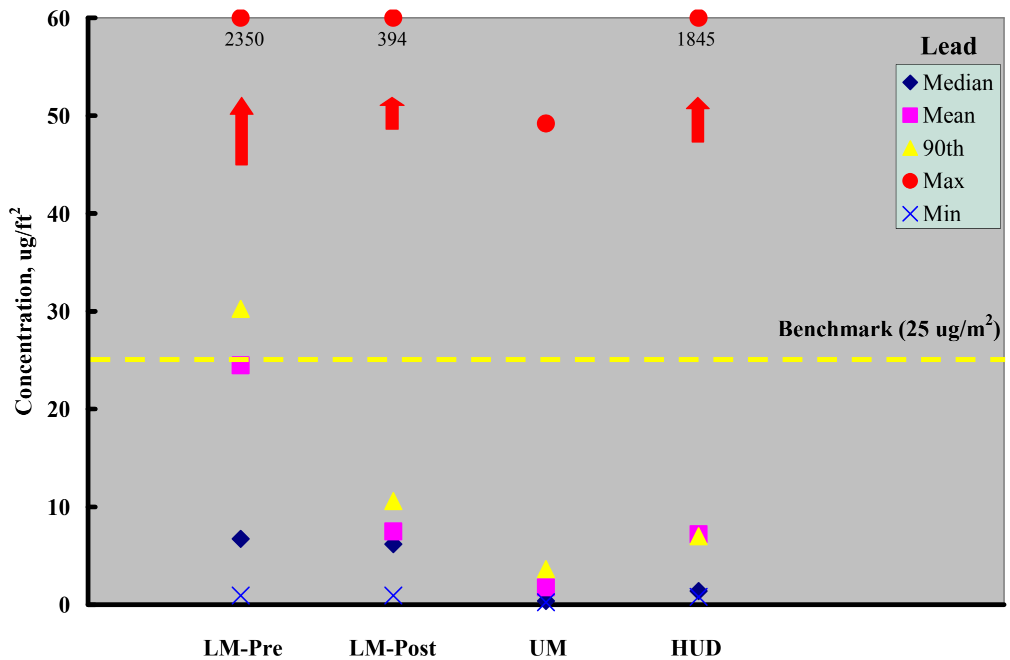

Figure 3-3. Comparison of dust lead loading levels from WTC Dust Cleanup Program and Background Study to loadings reported in the HUD Survey of Lead and Allergens in U.S. Housing database (HUD, 2001). Data for carpeted and uncarpeted buildings in the Northeast constructed from pre-1939 to 1998 were used in this analysis. The figure includes data from the test-only data (LM-Pre), and clean and test data (LM-Post) from the Lower Manhattan Dust Cleanup Program; Upper Manhattan data (i.e., background) (UM) from the WTC Background Study (EPA, 2003b); and, the data from the HUD database (HUD, 2001). Values for samples that were identified as being below the detection limit were substituted with ½ of the detection limit. The maximum values detected in the LM-Pre and HUD data sets were similar, although the LM-Pre value was higher. The means from the four data sets were all below the health-based benchmark. The LM-Pre mean was just under the benchmark, the LM-Post and HUD means were similar, and the UM mean was the lowest. The comparison indicates that the maximum detected concentrations varied between studies, the means, medians, and 90th percentile values for the LM-Post, UM, and HUD were below the benchmark, and all but the 90th percentile for the LM-Pre data set were below the benchmark.

In summary, a comparison between analytical results from Lower Manhattan and Upper Manhattan show that the number of samples that exceed health-based criteria for three analytes one to two years after the collapse of the WTC are similar. Additionally, values reported in the literature for these analytes indicate that the mean, median, and 90th percentile values are similar to those reported in the EPA studies, with the exception of maximum detected concentrations which were generally higher than those reported in the literature.

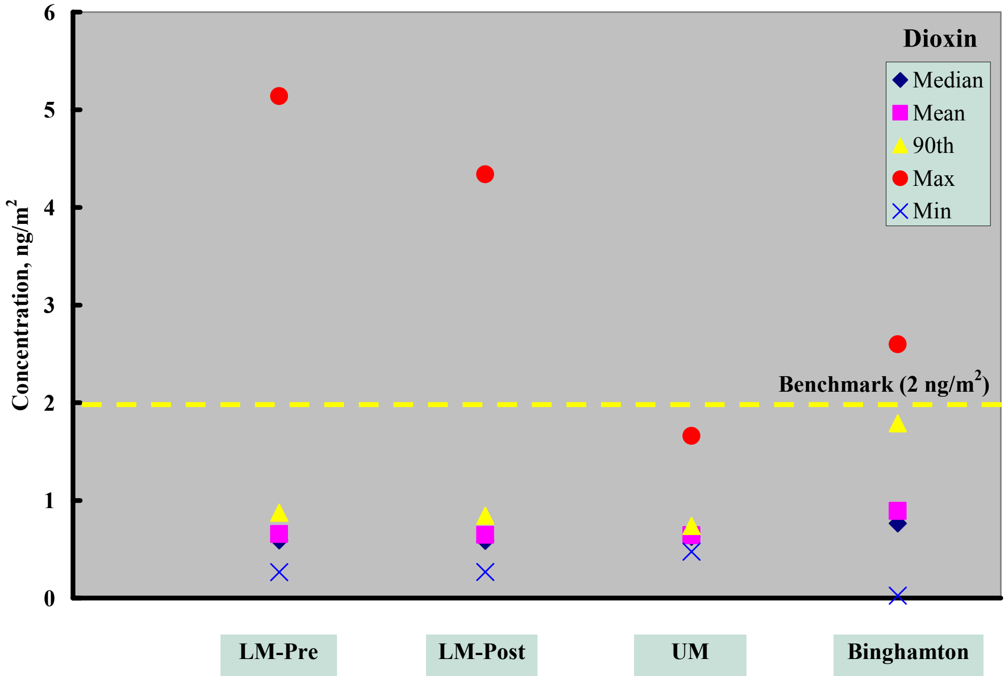

Figure 3-4. Comparison of dust dioxin loading levels from WTC Dust Cleanup Program and Background Study to loadings measured in an office building in Binghamton, NY by the New York State Department of Health (NYSDOH, 2002). The figure includes data from the test-only data (LM-Pre), and clean and test data (LM-Post) from the Lower Manhattan Dust Cleanup Program; Upper Manhattan data (i.e., background) (UM) from the WTC Background Study (EPA, 2003b); and, data from (NYSDOH, 2002). The minimum, median, and mean values from the three studies were very similar. There was a slightly higher value for the 90^{th} percentile from the NYSDOH data set (NYSDOH, 2002). The minimum, median, mean, and 90^{th} percentile values were all below the health-based benchmark. The maximum detected concentrations from the Lower Manhattan data sets (LM-Pre and LM-Post) were marginally higher than the Upper Manhattan (UM) and Binghamton data sets. With the exception of the UM data set, all of the maximum values were above the health-based benchmark. This indicates that the dioxin concentrations observed in the WTC Indoor Dust Program were similar to background, and similar to values reported in the literature.

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APPENDIX A.

Additional Statistics

Table A-1. Statistics for Lead Wipe *Clean and Test* Data

The *clean and test* subset of the data exhibit very high positive skewness and high variability. The raw data and log-transformed pre- and post-cleanup data fail the S-W test for normality (log-transformed data [pre-/post-]: S-W statistic=0.89/0.85, p<0.0001/p<0.0001). This table includes two observations that have been treated as outliers in subsequent analyses (see *Section E.2.2* for details). Statistics for the data set after removal of the two outliers are provided in *Table A-1a*.

	Pre-Cleanup	Post-Cleanup
apartments sampled	214	214
buildings sampled	145	145
number of samples	680	674
nondetects	101(14.8%)	140 (20.8%)
exceedances[a]	93 (13.7%)	21 (3.1%)
mean	35.46	19.03
standard deviation	286.03	279.64
skewness	20.56	25.77
CV[b]	8.07	14.70
variance	81812.09	78199.03
maximum	6790	7250
99^{th} percentile	470	83.2
95^{th} percentile	76.30	16.00
90^{th} percentile	37.30	11.00
75^{th} percentile	12.50	8.40
median	7.32	6.38
25^{th} percentile	3.23	2.47
10^{th} percentile	1.86	1.86
5^{th} percentile	1.86	1.86
1^{st} percentile	1.86	1.86
minimum	1.86	1.86
S-W Statistic[c]	0.07	0.03
Prob Normal[d]	<0.0001	<0.0001

[a]Exceedance: lead wipe (µg/ft^2) samples that exceeded the HUD screening level of 25 µg/ft^2
[b]CV=coefficient of variation=standard deviation/mean
[c]SW-Statistic: Shapiro-Wilk statistic
[d]Prob Normal: probability the data are from a normal distribution according to S-W test

Table A-1a. Statistics for Lead Wipe *Clean and Test* Data – Outliers Removed

The *clean and test* subset of the data exhibit very high positive skewness and high variability. The raw data and log-transformed pre- and post-cleanup data fail the S-W test for normality (log-transformed data [pre-/post-]: S-W statistic=0.90/0.89, p<0.0001/p<0.0001). This table excludes two observations that have been treated as outliers (see *Section E.2.2* for details).

	Pre-Cleanup	Post-Cleanup
apartments sampled	214	214
buildings sampled	145	145
number of samples	679	673
nondetects	101 (14.9)	140 (0.21)
exceedances[a]	92 (13.5)	20 (3.0)
mean	25.52	8.28
standard deviation	121.00	19.79
skewness	15.24	13.89
CV[b]	4.74	2.39
variance	14641.04	391.80
maximum	2530	394
99^{th} percentile	366.00	83.20
95^{th} percentile	73.00	15.50
90^{th} percentile	37.25	10.90
75^{th} percentile	12.50	8.40
median	7.32	6.37
25^{th} percentile	3.22	2.47
10^{th} percentile	1.86	1.86
5^{th} percentile	1.86	1.86
1^{st} percentile	1.86	1.86
minimum	1.86	1.86
S-W Statistic[c]	0.15	0.21
Prob Normal[d]	<0.0001	<0.0001

[a]Exceedance: lead wipe ($\mu g/ft^2$) samples that exceeded the HUD screening level of 25 $\mu g/ft^2$
[b]CV=coefficient of variation=standard deviation/mean
[c]SW-Statistic: Shapiro-Wilk statistic
[d]Prob Normal: probability the data are from a normal distribution according to S-W test

Table A-2. Statistics on the Reduction in Average Lead Wipe Loadings (Pre- and Post-cleanup)

Statistics for average pre-cleanup and post-cleanup residential dust lead loading ($\mu g/ft^2$) measured by wipe samples are shown, and statistics for the reduction in the average dust lead loading. The statistics describe the distribution of pre-cleanup and post-cleanup average lead loadings ($\mu g/ft^2$) that were measured in each residence. The average dust lead loadings and the reduction in the averages, continue to display substantial departures from normality; a log-transformation of the data fails to improve the fit of a normal distribution to the data (S-W statistic for reductions=0.37 0, p<0.0001; pre-cleanup averages: S-W statistic 0.95, p; post-cleanup averages: S-W statistic= 0.92, p<0.0001). Outliers were removed from the dataset (see *Section E.2.2* for details).

Statistic	Reduction in Average Lead Wipe Loading	Average Pre-Cleanup Lead Wipe Loading	Average Post-Cleanup Lead Wipe Loading
n	214	214	214
mean	16.21	24.40	8.19
standard deviation	65.16	66.34	17.10
skewness	7.23	7.73	12.17
CV[a]	4.02	2.727	2.096
variance	4245.98	4401.40	292.29
maximum	708.21	748.95	241.67
99th percentile	289.03	294.33	39.25
95th percentile	81.65	92.44	16.08
90th percentile	31.37	44.73	11.77
75th percentile	9.50	18.44	8.44
median	1.77	8.66	6.79
25th percentile	0.00	4.94	3.01
10th percentile	-1.31	2.34	1.86
5th percentile	-3.35	1.86	1.86
1st percentile	-21.50	1.86	1.86
minimum	-163.27	1.86	1.86
S-W Statistic[b]	0.33	0.15	0.22
Prob Normal[c]	<0.0001	<0.0001	<0.0001

[a]CV=coefficient of variation=standard deviation/mean
[b]S-W Statistic: Shapiro-Wilk statistic
[c]Prob Normal: probability the data are from a normal distribution according to S-W test

Table A-3. Statistics on Reduction in Average Lead Wipe Loadings (Pre- and Post-Cleanup) in Residences With Pre-cleanup Averages Greater Than the HUD Screening Level of 25 µg/ft^2

The statistics describe the distribution of pre-cleanup and post-cleanup average lead loadings (µg/ft^2) that were measured in each residence. The average dust lead loadings and the reduction in the averages show less variation and are less skewed than the complete distribution of average residential dust lead loadings. A log-transformation of the data improves the fit of a normal distribution to the data (S-W statistic for reductions=0.71, p<0.0001; pre-cleanup averages: S-W statistic=0.89, p<0.0001; post-cleanup averages: S-W statistic=0.88, p<0.0001); however, significant departures from the normal distribution model remain. Outliers were removed from the dataset (see *Section E.2.2* for details).

Statistic	**Reduction in Average Lead Wipe Loading**	**Average Pre-Cleanup Lead Wipe Loading**	**Average Post-Cleanup Lead Wipe Loading**
n	36	36	36
mean	84.84	102.12	17.28
standard deviation	140.85	138.37	39.62
skewness	2.90	3.47	5.49
CV[a]	166.01	135.50	229.28
variance	19838.34	19147.47	1569.75
maximum	708.21	748.95	241.67
99th percentile	708.21	748.95	241.67
95th percentile	408.96	413.87	40.74
90th percentile	199.74	209.36	31.73
75th percentile	88.03	101.78	11.56
median	38.82	48.52	8.08
25th percentile	25.26	34.74	6.39
10th percentile	19.92	26.86	3.78
5th percentile	10.35	25.98	2.08
1st percentile	-163.27	25.86	1.86
minimum	-163.27	25.86	1.86
S-W Statistic[b]	0.64	0.56	0.32
Prob Normal[c]	< 0.0001	< 0.0001	< 0.0001

[a]CV=coefficient of variation=standard deviation/mean
[b]S-W Statistic: Shapiro-Wilk statistic
[c]Prob Normal: probability the data are from a normal distribution according to S-W test

Table A-4. Statistics for Pre-cleanup Residential Average Dust Lead Loading by Floor Group

Average dust lead loadings (µg/ft^2) tend to decrease with increasing floor level, and variance tends to increase with increasing average dust lead loading. When grouped by floor level, the average pre-cleanup dust lead loadings show less variation and are less skewed than the complete distribution of average residential dust lead loadings. A log-transformation of the averages substantially improves the fit of a normal distribution to the data (S-W statistic for lower floor group=0.95, p=0.0149; middle: S-W statistic=0.96, p=0.0127; upper: S-W statistic=0.90, p=0.0002). Outliers were removed from the dataset (see *Section E.2.2* for details).

Statistic	Floor group[a]		
	Lower	Middle	Upper
n	61	93	60
mean	39.52	21.08	14.18
standard deviation	102.71	46.41	37.98
skewness	5.84	6.97	7.06
CV[b]	2.60	2.20	2.68
variance	10549.74	2154.14	1442.33
maximum	748.95	413.87	294.33
99th percentile	748.95	413.87	294.33
95th percentile	175.15	78.40	39.48
90th percentile	73.45	38.62	21.90
75th percentile	27.23	18.44	9.54
median	9.20	10.03	7.25
25th percentile	5.46	5.27	3.80
10th percentile	2.17	2.32	2.56
5th percentile	1.86	1.96	1.98
1st percentile	1.86	1.86	1.86
minimum	1.86	1.86	1.86
S-W Statistic[c]	0.36	0.34	0.25
Prob Normal[d]	<0.0001	<0.0001	<0.0001

[a]Floor groups were defined as follows; lower: ≤ floor 3; middle: floors 4 – 10 inclusive; upper: > floor 10
[b]CV=coefficient of variation=standard deviation/mean
[c]S-W Statistic: Shapiro-Wilk statistic
[d]Prob Normal: probability the data are from a normal distribution according to S-W test

Table A-5. Statistics for Dioxin Wipe *Clean and Test* Data

The data summarized in this table are dioxin toxicity equivalency quotients (TEQs) (ng/m^2), which are the sum of 17 different chemical forms (congeners) of dioxin. The *clean and test* subset of the data exhibit high positive skewness but low variance. Very few exceedances were observed for dioxin. The raw data and log-transformed pre- and post-cleanup data fail the S-W test for normality (log-transformed data [pre-/post-]: S-W statistic=0.71/0.89, p<0.0001/p<0.0001). This table excludes one observation that has been treated as an outlier in the analysis of the dioxin wipe data (see *Section E.2.3* for details). Statistics for the data set after removal of the outlier are provided in *Table A-5a*.

	Pre-Cleanup	Post-Cleanup
apartments sampled	212	212
buildings sampled	145	145
number of samples[a]	674	668
nondetects	0	0
exceedances	3 (0.4%)	4 (0.6%)
mean	0.81	0.65
standard deviation	3.95	0.28
skewness	25.75	5.27
CV[b]	0.49	0.42
variance	15.62	0.08
maximum	75.4	4.34
99th percentile	1.85	1.76
95th percentile	1.11	1.17
90th percentile	0.90	0.90
75th percentile	0.68	0.68
median	0.60	0.59
25th percentile	0.56	0.54
10th percentile	0.47	0.46
5th percentile	0.43	0.43
1st percentile	0.34	0.34
minimum	0.27	0.27
S-W Statistic[c]	0.03	0.62
Prob Normal[d]	<0.0001	<0.0001

[a]Exceedance: lead wipe samples that exceeded the HUD screening level of 25 $\mu g/ft^2$
[b]CV=coefficient of variation=standard deviation/mean
[c]S-W-Statistic: Shapiro-Wilk statistic
[d]Prob Normal: probability the data are from a normal distribution according to S-W test

Table A-5a. Statistics for Dioxin Wipe *Clean and Test* Data-One Outlier Removed

The data summarized in this table are dioxin toxicity equivalency quotients (TEQs) (ng/m^2), which are the sum of 17 different chemical forms (congeners) of dioxin. The *clean and test* subset of the data exhibit high positive skewness but low variance. Very few exceedances were observed for dioxin. The raw data and log-transformed pre- and post-cleanup data fail the S-W test for normality (log-transformed data [pre-/post-]: S-W statistic=0.88/0.89, p<0.0001/p<0.0001). One pre-cleanup observation with a value of 75.3 ng/m^2 was removed as an outlier (see *Section E.2.3* for details).

	Pre-Cleanup	**Post-Cleanup**
apartments sampled	212	212
buildings sampled	145	145
number of samples[a]	673	668
nondetects	0	0
exceedances	2	4
mean	0.66	0.65
standard deviation	0.29	0.28
skewness	6.79	5.27
CV[b]	0.44	0.42
variance	0.09	0.08
maximum	5.14	4.34
99^{th} percentile	1.81	1.76
95^{th} percentile	1.10	1.17
90^{th} percentile	0.90	0.90
75^{th} percentile	0.68	0.68
median	0.60	0.59
25^{th} percentile	0.56	0.54
10^{th} percentile	0.47	0.46
5^{th} percentile	0.43	0.43
1^{st} percentile	0.34	0.34
minimum	0.27	0.27
S-W Statistic[c]	0.57	0.62
Prob Normal[d]	<0.01	<0.01

[a]Exceedance: lead wipe samples that exceeded the HUD screening level of 25 $\mu g/ft^2$
[b]CV=coefficient of variation=standard deviation/mean
[c]S-W-Statistic: Shapiro-Wilk statistic
[d]Prob Normal: probability the data are from a normal distribution according to S-W test

APPENDIX B.

World Trade Center Indoor Dust Cleaning Program

Monitoring Contract Scope of Work

DRAFT - 8/8/02

A. Introduction

All work performed under this contract entered into between the New York City Department of Environmental Protection (DEP) and the Monitoring Contractor must be in compliance with all applicable laws and regulations, including but not limited to regulations issued by the United States Environmental Protection Agency (EPA), the United States Department of Labor Occupational Safety and Health Administration (OSHA), the New York State Department of Labor (NYS DOL), New York State Department of Health (NYS DOH) Environmental Laboratory Accreditation Program (ELAP) and the New York City Department of Environmental Protection (DEP).

The EPA and DEP will solicit participation in a direct assistance program for residents and residential building owners south of Canal Street who are concerned that their residences may have debris/dust from the collapse of the World Trade Center (WTC). A DEP/EPA telephone hotline has been established to receive requests from the public. The assistance will include various options, including cleaning within residences and common spaces by licensed asbestos contractors with follow-up asbestos sampling, asbestos air sampling only, and providing high efficiency particulate air (HEPA) vacuums.

NYS DOL licensed asbestos contractors shall perform cleaning activities for residents who wish to have their homes cleaned.

The purpose of this contract is to acquire project monitoring services including site inspections, surveys and assessments, scheduling, coordinating and monitoring the clean-up of dust/debris, and collecting samples from residences impacted by the collapse of the World Trade Center. The scope of work for the monitoring activities is identified below. The monitoring contractor shall supply all equipment and supplies necessary to perform the work specified in this contract.

B. Roles and Responsibilities

As provided in the instant contract, EPA's World Trade Center Dust Cleanup Field Personnel shall have the authority of Project Manager, in addition to DEP's Project Manager. As such, the authority of EPA World Trade Center Dust Cleanup Field Personnel shall include the following authority related to monitoring work conducted under this contract:

1. The authority to stop work for health and safety reasons.
2. The authority to stop work for non-compliance with the Scope of Work.
3. The authority to give technical direction to the contractor in the performance of the work.
4. The authority to review and approve or disapprove of the qualifications of the monitoring personnel involved in the work.
5. The right to inspect and accept or reject any work.

The Monitoring Contractor shall be responsible for:

1. Scheduling and coordinating the cleaning and monitoring work with residents, building owners, the Cleaning Contractor and EPA;
2. HVAC system evaluation and inspection;
3. Oversight of the Cleaning Contractor;
4. Inspection of the Cleaning Contractor's work;
5. Area air monitoring;
6. Wipe sampling; and
7. Personal air monitoring.

C. Qualifications

Proof of qualifications must be available on-site during the performance of work and shall be presented upon request.

Project Monitors

The Project Monitors shall be employees of the Monitoring Contractor. The Project Monitors must possess valid NYS Asbestos Project Monitor certificates. The Project Monitors must have served as a third party project monitor on at least 25 asbestos abatement projects. Project Monitor must have performed final clearance inspections on at least 25 asbestos abatement projects. The Project Monitor must have access to translation services to schedule pre-cleaning unit inspections with residents. The Project Monitor shall be familiar with NYC DOH's Mold Assessment and Remediation Guidelines.

Air Monitoring Technicians

Air monitoring technicians must possess valid NYS Asbestos Project Sampling Technician (APST) certificates. Technicians must have performed air sampling for at least 6 months.

Wipe Sampling Technicians

Wipe sampling technicians must have 1 year experience in wipe sampling for a variety of contaminants. Employees shall have received specific training in wipe sampling methods.

HVAC System Inspectors

HVAC assessments and cleanliness inspections shall be conducted by qualified personnel. At a minimum such personnel shall have an understanding of HVAC system operation and experience in utilizing accepted indoor environmental sampling practices, current industry HVAC cleaning procedures, and applicable industry standards. The HVAC System Inspection contractor shall be a certified member of National Air Duct Cleaners Association (NADCA).

Background Investigations

All contractors and subcontractors involved in the monitoring activities under this contract are responsible for completing a background check on their employees and for screening unacceptable candidates from the pool of on-site workers. Background checks shall be completed with 30 days of the award of the contract. Thereafter, background checks shall be completed prior to employees beginning on-site work. EPA will provide guidelines for evaluating the background information collected. Contractors are required to maintain records of background checks for 4 years and to make them available to the DEP and EPA when requested. At a minimum, the background check must include:

1. Law enforcement checks (5 years)
2. Professional license and certification

D. Specifications

This contract between DEP and the monitoring contractor shall be in force for 24 consecutive months from the commencement date. The monitoring contractor must be prepared to mobilize within 72 hours of the contract award. Cleaning activities shall be scheduled for 20 residences per day. Air sampling shall be scheduled and completed within 24 hours of successful visual inspection by the project monitor. Air sampling shall also be provided at an additional 10 to 20 residences per day where cleaning activities are not scheduled (i.e., where residents have requested sampling only). Work shall be scheduled 7 days per week. A sufficient number of properly trained and certified personnel shall be available for project monitoring and sampling.

Electricity and water necessary to conduct the work required under this contract will be provided by the owner or occupant of the work area.

The Monitoring Contractor shall have available sufficient quantities of sampling equipment to provide the amount and type of samples required for this project. At a minimum the following equipment is required: air-sampling pumps with maximum flow rate capacities of 15 liters per minute, tripods, rotometers, sample cassettes with mixed cellulose ester filters having pore size of 0.8 micron.

The Monitoring Contractor shall attend the mandatory pre-bid meeting and project kick off meeting prior to the start of work. The agenda for the kick off meeting shall include scope of work, sampling logistics and resource requirements and procedures for data acquisition and submittal. The monitoring contractor will demonstrate data acquisition procedures and software to be employed for this project. In addition, the Monitor Contractor shall attend meetings or conference calls with EPA to coordinate field activities, as requested.

The Monitoring Contractor shall adopt and follow the Quality Assurance Project Plan prepared by EPA for all environmental data collection activities performed under this contact. All appropriate data, original field forms/data sheets, and chain-of-custody forms shall be collected and completed in accordance with the instructions contained in the contract and provided to EPA. This information shall be provided via FormsII Lite (F2L) or an alternative electronic format that is accessible by the laboratory. All clearance air samples and copies of necessary documentation shall be hand delivered daily to EMSL Laboratories at: 307 W. 38th St., New York, New York, 212-290-0051. All wipe samples and copies of necessary documentation shall be shipped daily by courier for next day delivery to Paradigm Analytical Laboratories at: 2627 Northchase Parkway SE, Wilmington NC 28405, 910-350-2839.

Copies of all invoices for work conducted under this contract shall be provided to EPA. EPA will review submitted invoices to confirm that the work has been completed and forward the invoices to DEP for processing. Decisions regarding the reimbursement of costs will be made by DEP.

Deliverables

All deliverables shall be provided via F2L or an agreed upon alternative electronic format approved by EPA and DEP. The Project Monitor shall also maintain a copy of each deliverable and all field documentation submitted under this contract for 365 days. The Project Monitor shall review all deliverables prior to submission to EPA. The review shall assure that each deliverable is accurate and complete, technically sound, and free of clerical errors.

The Project Monitor shall direct and coordinate all services and report all findings to EPA. The scope of this project will be as follows:

1. The Project Monitor shall be responsible for accessing a secure EPA Website (url, user name and password to be provided by EPA) to obtain requestor information (address, building identification numbers, etc.). In coordination with the EPA, the Project Monitor will access residential services requested from the Website, schedule pre-cleaning inspections and schedule cleaning activities and air sampling with the tenants/owners, asbestos abatement contractors and air monitoring technicians for the various residences. The Project Monitor will then supply relevant information on activities for the EPA Indoor Air database via the secure EPA website. Data to be input may include, but is not limited to start and completion dates for the cleaning, sampling dates and sample identification numbers. All data shall be maintained as confidential.

   The Project Monitor shall provide validated addresses and scheduling information into the EPA Indoor Air web database via F2L or an agreed upon alternative electronic format or website approved by EPA within 24 hours of activity.

2. The Monitoring Contractor will schedule and conduct pre-cleaning or pre-sampling inspections of the residences, common spaces and heating, ventilation and air conditioning systems (HVAC) based on the requests for assistance from individual residents and building owners made through the DEP/EPA hotline.

   a. Inspections are to be conducted in accordance with inspection checklists prepared by EPA.

   b. Residents will be provided with a fact sheet and information prepared by EPA regarding sampling options (aggressive and modified aggressive air sampling protocols) and the handling of valuable personal items (money, jewelry, heirlooms, etc.) and fragile objects during work.

   c. The Project Monitor will obtain written authorization for access for all work to be performed for this project including inspection, sampling and cleaning of residences, common spaces and HVAC systems using the Access Agreement (to be provided).

   d. The Project Monitor will advise EPA and NYC DOH or DEP accordingly if any of the following conditions are observed:

      i. mixed residential and commercial use within a building;

      ii. dust and/or debris in common spaces;

      iii. the presence of mold on building components (walls, support beams, ceiling tiles, HVAC systems)(NYC DOH notification);

      iv. the presence of peeling, flaking or chalking paint (NYC DOH notification);

      v. the presence of potential asbestos-type insulation (e.g., fibrous materials)(NYC DOH notification if damaged);

      vi. residents with special needs or medical conditions that may be aggravated by exposure to airborne contaminants; or

      vii. other circumstances that may require deviation from the procedures specified in the scopes of work for the cleaning and monitoring contracts.

e. In consultation with EPA, the Project Monitor will make a determination of the appropriate Cleaning Contract Scope of Work (i.e. Scope A or B) to be implemented. This determination is to be made based on the descriptions included in the Cleaning Contract Scope of Work and best professional judgment.

All deliverables shall be provided in the EPA Indoor Air web database via F2L or an agreed upon alternative electronic format or website approved by EPA within 24 hours of activity. The Project Monitor shall record all pre-cleaning and pre-sampling inspection information in the EPA Indoor Air database or using an agreed upon electronic format. This information shall include, but is not limited to, building cleaned or inspected by DEP (Y/N), type of HVAC system (central, individual or none), HVAC impacted (Y/N), occupant present (Y/N), written access obtained (Y/N), space occupied (Y/N), dust present (low/high), presence of mold on building components (Y/N), peeling /flaking/chalking paint present (Y/N), suspected ACM present (Y/N), residential use (commercial/residential), residents with special needs, cleaning method (Scope A or B). Dates and times shall be associated with all activities including start and finish date.

3. In the event that mold or flaking, peeling or chalking paint is observed on building components (walls, support beams, ceiling tiles, HVAC systems) in areas where work has been requested, the Monitoring Contractor will notify EPA and fax a written request for assistance in evaluating potential health hazard to NYC DOH at 212-442-3378. Cleaning will not proceed in areas where mold or flaking, peeling or chalking paint is observed until potential hazards are evaluated and addressed as necessary. The Project Monitor shall be familiar with NYC DOH's Mold Assessment and Remediation Guidelines.
Deliverables

The Project Monitor shall record if mold or flaking, peeling or chalking paint is present and notify the NYCDOH and EPA. This information shall be provided via EPA Indoor Air web database or an agreed upon alternative electronic format or website approved by EPA within 24 hours of activity.

4. The presence of in-place materials suspected to contain asbestos shall be identified and quantified. The condition of the material shall be evaluated to identify damaged, deterioration, delamination, etc.

5. In the event that damaged, deteriorated, delaminated, etc. suspected ACM is observed, the monitoring contractor will notify EPA and fax written notification to the NYC DOH. Cleaning or air monitoring will not proceed in areas where such suspected ACM is observed until instructed otherwise.

The Project Monitor shall record if damaged, deteriorated, delaminated, etc. suspected ACM is observed and notify EPA and fax written notification to the NYC DOH. This information shall be provided via EPA Indoor Air web database or an agreed upon alternative electronic format or website approved by EPA within 24 hours of activity.

6. The Monitoring Contractor shall evaluate HVAC systems in residential buildings where cleaning will take place to determine if these systems have been impacted by dust or debris from the collapse of the World Trade Center and if these systems require cleaning.

a. In cases where cleaning is requested for an individual residence, portions of the HVAC system dedicated to that residence will be evaluated.

b. In cases where cleaning is requested for a whole building, the building's HVAC system will be evaluated as a whole.

c. HVAC assessments shall be conducted in accordance with the National Air Duct Cleaners Association (NADCA) General Specification for the Cleaning of Commercial Heating, Ventilating and Air Conditioning Systems and the NADCA Assessment, Cleaning and Restoration Standard (ACR 2002).

d. The results of the whole building HVAC system evaluations shall be documented in a letter report. This report shall be provided to EPA within 2 business days of the completion of the evaluation. If the whole system requires cleaning, a copy of the report shall be sent to DEP within 2 business days of the completion of the evaluation. This report shall include the name and qualifications of inspector, date of inspection, building location, a description of the HVAC system, the basis for the determining whether or not the system was impacted by the collapse of the WTC and if the system requires cleaning.

e. If a HVAC system requires cleaning, then the Monitoring Contractor shall prepare a scope of work for the cleaning the HVAC system or portion thereof. The scope of work shall be provided to EPA for approval within 2 business days of the completion of the HVAC system evaluation. A copy of the scope of work shall also be provided to DEP.

f. If the Monitoring Contractor is not a member of the NADCA, a subcontractor that is a member may perform the HVAC system evaluation and inspection.

The Project Monitor shall record if the HVAC systems have been impacted by dust or debris from the collapse of the WTC, if the HVAC system has been evaluated and cleaned subsequent to September 11, 2001 (if yes, then when and by whom) and if the HVAC system requires cleaning. This information shall be provided via F2L or an agreed upon alternative electronic format or website approved by EPA within 24 hours of activity.

7. HVAC systems that have been impacted by dust or debris from the collapse of the World Trade Center will be cleaned. In the event that a HVAC system for an entire building requires cleaning, a separate, site specific contract will be awarded by DEP for this work. If only a portion of a HVAC system requires cleaning, then the Cleaning Contractor will conduct the cleaning utilizing specialized labor trained and experienced in duct cleaning.

a. The monitoring contractor shall schedule and oversee the cleaning of HVAC systems.

b. The Monitoring Contractor shall inspect HVAC systems or portions thereof cleaned to verify cleanliness. If visible dust or other contaminants are evident through visual inspection or testing, then the Monitoring Contractor will direct the HVAC Cleaning Contractor to reclean those portions of the system where dust or other contaminants are present and reinspect.

c. HVAC cleaning, and cleanliness inspections shall be conducted in accordance with the National Air Duct Cleaners Association (NADCA) General Specification for the Cleaning of Commercial Heating, Ventilating and Air Conditioning Systems and the NADCA Assessment, Cleaning and Restoration Standard (ACR 2002).

8. Sampling of residences and common spaces where cleaning has not been requested:

a. Based on consultation with resident, aggressive or modified aggressive air sampling will be conducted.

i. Before beginning aggressive air sampling, a 1 horsepower electric leaf blower shall be used to direct exhaust air against walls, ceilings, floors and other surfaces. This shall continue for at least five minutes per 1,000 square feet of floor. When directing the exhaust, caution shall be taken to minimize disturbance and potential damage to furnishings and personal belongings

ii. Residents shall not be present in their residence during aggressive air sampling activities.

iii. Personal protective equipment including disposable clothing, gloves, and respirators shall be worn during aggressive air sampling activities.

iv. HVAC systems shall be shut down or isolated locally during aggressive air sampling.

v. Room and window air conditioners shall not be operated during aggressive air sampling.

vi. Leaf blowers shall not be employed for modified aggressive air sampling.

vii. All other procedures are identical for aggressive and modified aggressive air sampling, unless otherwise noted.

b. At least one 20-inch fan shall be placed in the center of each room sampled. One fan per 10,000 cubic feet of room space shall be used. The fans shall be operated on slow speed and pointed toward the ceiling. The fans shall run for at least 15 minutes prior to the start of sampling. The fans shall operate continuously throughout sampling and shall not be turned off until sampling is completed.

c. For studio apartments 3 air samples shall be collected. For 1-bedroom apartments and above, 5 air samples shall be collected. Sampling equipment shall be placed in living areas and away from obstructions. The sampling cassette must be placed on a tripod, not taped to existing surface and should be directed downward at a 45 degree angle.

d. Common spaces will be sampled without the use of forced air devices (fans, leaf blowers etc). For small spaces, less than 160 square feet, 3 samples will be collected. For large spaces greater than 160 square feet and less than 25,000 square feet 5 samples will be collected. For spaces greater than 25,000 square feet, 1 sample will be collected for each 5,000 square feet. Sampling equipment shall be placed away from obstructions. The sampling cassette must be placed on a tripod, not taped to existing surfaces and directed downward at a 45 degree angle.

e. Air samples will be collected in accordance with the procedures specified in NIOSH 7400 Method and analyzed by phased contrast microscopy (PCM) followed by Asbestos Hazard Emergency Response Act (AHERA) transmission electron microscopy (TEM). The flow rate for collection of air samples shall be at least 10 liters per minute and no more than 15 liters per minute. Air sampling cassettes need to be monitored to ensure that cassettes are not clogging by monitoring flow rates. The minimum sample volume required is 3600 liters. These air samples and copies of necessary documentation shall be hand delivered daily to EMSL Laboratories at: 307 W. 38th St., New York, New York, 212-290-0051.

f. Wipe samples will be collected at 10 percent of the residences where sampling only has been requested, up to a maximum of 13 residences, as instructed by EPA. This sampling will consist of the collection of 3 wipe samples each for dioxin, total metals and mercury (Note: a separate wipe sample is required for each parameter at each location). Metals and mercury wipe samples will be collected in accordance with procedures specified in HUD Appendix 13.1. Dioxin wipe samples will be collected in accordance with the procedures specified in ASTMD 6661-01. Wipe samples and copies of necessary documentation will be packed, sealed and shipped daily by courier for next day delivery to Paradigm Analytical Laboratories at: 2627 Northchase Parkway SE, Wilmington NC 28405.

g. 24-hour turn-around time shall be specified for the analysis of all samples collected using the aggressive air sampling method. Standard turn-around time shall be specified for analysis of modified aggressive air samples and wipe samples.

h. The Monitoring Contractor will document all the necessary information regarding sampling activities, fill out all field logs, data sheets, and chain-of-custody forms. The Monitoring Contractor will use F2L for all sample and chain-of-custody documentation. Samples must be labeled and accompanied with completed chain-of-custody forms before shipping to the designated laboratory. The label must include the EPA Project Tracking Number.

i. All information must be maintained using the secure EPA website (url, user name and password to be provided by EPA). Information on sampling activities (date, sample ID) shall be provided to EPA, via the website, within 24 hours of completion of sampling. All data shall be maintained as confidential.

The Project Monitor will keep a field notebook, document the size of the sampled area, sampling locations (including a field sketch) and equipment used during the collection of samples (leaf blower, fan, etc.). In addition, date, start and completion dates for the cleaning, sample media, flow media type, flow rates (start/final), flow rate (average), time (start/finish), total elapsed time (min), calculated sample volume (L), pump fault, weather, quality assurance samples (lot blank) sampling dates and sample identification numbers (sample IDs), complete chain-of-custody forms, EPA Project Tracking Numbers and laboratory address shall be entered into an agreed upon electronic format or website approved by EPA within 24 hours of activity.

9. Pre-cleaning and Post-cleaning Wipe Sampling Procedures:

a. The Project Monitor will collect pre-cleanup and post-cleanup wipe samples at 5 percent of the residences cleaned up to a maximum of 50 residences as instructed by EPA. This sampling will consist of the collection of 3 pre cleaning and 3 post cleaning wipe samples for dioxin, total metals and mercury (Note: a separate wipe sample is required for each parameter). Metals and mercury wipe samples will be collected in accordance with procedures specified in HUD Appendix 13.1. Dioxin wipe samples will be collected in accordance with the procedures specified in ASTMD 6661-01.

b. The Monitoring Contractor will document all the necessary information regarding sampling activities; will ensure personnel complete all field logs, data sheets, and chain-of-custody forms. The Monitoring Contractor shall use F2L for all sample and chain-of-custody documentation. Samples must be labeled and accompanied with completed chain-of-custody forms before shipping to the designated laboratory. The label must include the EPA Project Tracking Number. Samples will be packed, sealed and shipped daily by courier for next day delivery to Paradigm Analytical Laboratories at: 2627 Northchase Parkway SE, Wilmington NC 28405

c. Personnel collecting wipe samples shall be familiar with and experienced in the collection of wipe samples using the specified sampling method.

The personnel collecting the samples will keep a field notebook and document sampling locations (including a field sketch). The personnel collecting the samples shall complete chain-of-custody forms and record the number of wipe samples, EPA Project Tracking Numbers, the laboratory address, date, and sample IDs in an agreed upon electronic format or website approved by EPA within 24 hours of activity.

10. The Project Monitor shall schedule and oversee the cleaning operations of the Cleaning Contractor. Prior to initiating the cleaning of any residence, common space or HVAC system the Monitoring Contractor shall verify that the exterior of the building has been cleaned or has been inspected and found to be free of debris from the collapse of the WTC or shall obtain written authorization from EPA to proceed. No residential or common space shall be cleaned until the HVAC system has been evaluated and cleaned as necessary. If a scheduling problem arises, the Project Monitor should contact EPA. The Project Monitor shall coordinate daily access for cleaning and sampling with residents, owners, the Cleaning Contractor and sampling technicians.

11. The Monitoring Contractor shall provide sufficient personnel to provide periodic (2-4 hours/unit) oversight of the Cleaning Contractor to verify that work is being conducted in accordance with the Cleaning Contract Scope of Work.

12. The Project Monitor shall verify that the Cleaning Contractor is using properly trained and certified NYS DOL and NYC DEP asbestos certified workers.

13. The Project Monitor shall conduct routine quality assurance inspections during the course of cleaning and concur by initialing the Cleaning Checklist (to be provided by EPA) for tasks completed in compliance with the Cleaning Contract Scope of Work.

    The Project Monitor shall maintain information on the status of cleaning activities using the secure EPA website (url, user name and password to be provided by EPA). Cleaning tasks completed in accordance with the Cleaning Contract Scope of Work shall be documented on the Cleaning Checklist and reported to EPA via the website within 24 hours. The Project Monitor shall record daily activities in the field notebook.

14. Personal Air Monitoring:

    Personal air monitoring shall be performed by the Monitoring Contractor in accordance with US DOL OSHA requirements. The person who conducts sampling shall possess a valid NYS DOL

APST certificate. Personal air monitoring will be performed on a minimum of one employee of the Cleaning Contractor per shift per residence during the first 6 weeks of cleaning operations. This may be extended based on a determination made by EPA and OSHA. Thereafter personal air monitoring samples will be taken at one sample per day. Air samples will be collected in accordance with the procedures specified in NIOSH 7400 Method and analyzed by phased contrast microscopy (PCM) followed by Asbestos Hazard Emergency Response Act (AHERA) transmission electron microscopy (TEM). Analysis of these samples shall be the responsibility of the Monitoring Contractor. Results of analysis shall be provided to EPA by the Monitoring Contractor in an approved electronic format within 24 hours of collection. Copies of the results shall also be sent immediately to OSHA and the Cleaning Contractor. The Cleaning Contractor will make these results available to the employees or their designated representatives for their review in accordance with 29 CFR 1910.1020 and 29 CFR 1926.1101.

The Monitoring Contractor shall document all the necessary information regarding sampling activities, fill out all field logs, data sheets, and chain-of-custody forms. The Monitoring Contractor shall use F2L for all sample and chain-of-custody documentation. This data shall be provided to EPA within 24 hours of completion of the sampling.

The Project Monitor shall submit upon request a field package consisting of field sheets, field notes (copy), and chain-of-custody forms (copy), which shall be delivered to the EPA via fax, or an alternative format agreed upon. The Monitoring Contractor must sign and date all field sheets, field logbooks and chain-of-custody forms. This data shall be provided upon request.

15. The Project Monitor shall perform final visual inspections within 2 hours of the completion of the cleaning. If all areas are not dust free at that time, then the Project Monitor will direct the Cleaning Contractor to reclean as necessary. If all areas are dust free, then the Project Monitor will authorize final air sampling. Final inspections shall be documented using the Cleaning Checklist.

    The Project Monitor shall submit to EPA, upon request, copies of the field notebook pages via e-mail, fax, or alternative agreed upon format.

16. Post Cleaning Air Sampling Procedures:

    a. Sampling shall not begin until a visual inspection confirms the absence of visible dust and debris. Post cleaning air sampling shall be performed upon successful visual inspection and completed within 24 hours. A successful visual inspection shall be an inspection that verifies the absence of dust and debris.

    b. All surfaces must be completely dry prior to the start of sampling.

    c. Upon completion of the cleaning, air sampling will be conducted to verify attainment of the clean-up criteria. Based on consultation with the resident or owner, aggressive or modified aggressive air sampling will be conducted. Residents shall not be present during aggressive air sampling.

        i. Before beginning aggressive air sampling, a 1 horsepower electric leaf blower shall be used to direct exhaust air against walls, ceilings, floors and other surfaces. This shall continue for at least five minutes per 1,000 square feet of floor area. When directing the exhaust, caution shall be taken to minimize disturbance and potential damage to furnishings and personal belongings

ii. Residents shall not be present in their residence during aggressive air sampling activities.

iii. Personal protective equipment including disposable clothing, gloves, and respirators shall be worn during aggressive air sampling activities.

iv. HVAC systems shall be shut down or isolated locally during aggressive air sampling.

v. Room and window air conditioners shall not be operated during aggressive air sampling.

vi. Leaf blowers shall not be employed for modified aggressive air sampling.

vii. All other procedures are identical for aggressive and modified aggressive air sampling, unless otherwise noted.

d. At least one 20-inch fan shall be placed in the center of each room sampled. One fan per 10,000 cubic feet of room space shall be used. The fans shall be operated on slow speed and pointed toward the ceiling. The fans shall run for at least 15 minutes prior to the start of sampling. The fans shall operate continuously throughout sampling and shall not be turned off until sampling is completed.

e. For studio apartments 3 air samples shall be collected. For 1-bedroom apartments and above, 5 air samples shall be collected. Sampling equipment shall be placed in living areas and away from obstructions. The sampling cassette must be placed on a tripod, not taped to existing surface and should be directed downward at a 45 degree angle.

f. Common spaces will be sampled without the use of forced air devices (fans, leaf blowers etc). For small spaces, less than 160 square feet, 3 samples will be collected. For large spaces greater than 160 square feet and less than 25,000 square feet 5 samples will be collected. For spaces greater than 25,000 square feet, 1 sample will be collected for each 5,000 square feet. Sampling equipment shall be placed away from obstructions. The sampling cassette must be placed on a tripod directed downward at a 45 degree angle and not taped to existing surfaces.

g. Air samples will be collected in accordance with the procedures specified in NIOSH 7400 Method and analyzed by phased contrast microscopy (PCM) followed by Asbestos Hazard Emergency Response Act (AHERA) transmission electron microscopy (TEM). The flow rate for collection of air samples shall be at least 10 liters per minute and no more than 15 liters per minute. Air sampling cassettes need to be monitored to ensure that cassettes are not clogging by monitoring flow rates. The minimum sampling volume required is 3600 liters. All clearance air samples and copies of necessary documentation shall be hand delivered daily to EMSL Laboratories at: 307 W. 38th St., New York, New York, 212-290-0051.

h. 24-hour turn-around time shall be specified for the analysis of all post-cleaning air samples for Scope B cleanups and for all samples collected using the aggressive air sampling method. Standard turn-around time shall be specified the analysis of air samples collected for Scope A cleanups using the modified aggressive air sampling method.

i. The Monitoring Contractor shall document all the necessary information regarding sampling activities, fill out all field logs, data sheets, and chain-of-custody forms. The Monitoring Contractor shall use F2L for all sample and chain-of-custody documentation. Samples must be labeled and accompanied with completed chain-of-custody forms before shipping to the designated laboratory. The label must include the EPA Project Tracking Number.

j. All information must be maintained using the secure EPA website (url, user name and password to be provided by EPA). Dates for monitoring and/or cleaning shall be provided to EPA electronically in an EPA approved format within 24 hours. Information on sampling activities (date, sample ID) will be provided to EPA, via the website, within 24 hours of completion of evaluation. All data shall be maintained as confidential.

The Project Monitor shall record all post-cleaning information in the EPA Indoor Air database or an agreed upon electronic format. This information shall include, but is not limited to sampling technique (aggressive or modified aggressive), visually cleaned (Y/N), damage claim (Y/N), and post cleaning status (pass/fail). Dates and times shall be associated with all activities including start and finish date.

Additional information including but not limited to, absence of dust/debris, equipment used (leaf blower, fan etc.), size of space, start and completion dates for the cleaning, sample media, flow rates (start/final, flow rate (average), time (start/finish), total elapsed time (min), calculated sample volume (L), pump fault, weather, units, QC samples (lot blank), sampling dates, sample IDs, complete chain-of-custody forms, EPA Project Tracking Numbers and laboratory name shall be entered into an agreed upon electronic format or website approved by EPA within 24 hours of activity. Dates and times shall be associated with all activities including start and finish date.

17. The residence will be recleaned and retested if the clean-up criteria of 0.0009 fibers/cc (PCME measured by TEM) is not achieved or if determined necessary by EPA. This clean-up criterion may be reevaluated and revised, if determined necessary based on field conditions and analytical limitations.

18. The Project Monitor will conduct a post-cleaning inspection of the residence with the resident at the completion of the sampling. The resident should inspect the residence and identify any damage at this time and sign-off on the Project Completion Form. Any damage or loss to a residence or its contents shall be documented on this form.

The Project Monitor shall submit upon request to the EPA copies of the field notebook as requested via fax or alternative format agreed upon and within two days of request. Final air sampling shall be performed with 24 hours of final visual inspection. The Project Monitor shall ensure that the Project Completion Form is completed for each residence cleaned or sampled.

19. The Project Monitor will complete a daily report which documents site observations, cleaning starts, continuations, completions, air sampling, recleaning and any delays or difficulties encountered.

The Project Monitor shall enter appropriate data from the completed Project Completion Form into the EPA Indoor Air web database or an agreed upon alternative electronic format or website approved by EPA within 24 hours of activity.

20. EPA will notify residents of the results of sampling conducted as part of this project. No other party is authorized to release residential or common area sampling results.

21. Any damage to or loss of private property that occurs during sampling or is caused by the Monitoring Contractor or its employees while engaged in activities covered by this scope of work is the responsibility of the Monitoring Contractor. The Monitoring Contractor is not responsible for damage or loss caused by the acts of third parties not involved in activities covered by this scope of work.

22. Copies of all reports, Cleaning Checklist, Inspection Checklists, Project Completion Forms and chain-of-custody forms shall be submitted daily to the EPA.

APPENDIX C.

Evaluation Procedures to Determine the Presence of World Trade Center (WTC)-Related Dust and Debris in Residential Ventilation Systems in Lower Manhattan

C.1.0 SCOPE

The procedures contained in this document provide guidance for determining the presence of WTC-related dust in residential ventilation systems in Lower Manhattan. This document is solely concerned with determination of the presence of WTC-related dust in residential ventilation systems. Determining the exact nature of all hazardous air contaminants and contaminants other than airborne dust that may have been released during the WTC collapse and that may have potentially impacted ventilation systems operating at the time of the collapse is beyond the scope of this document.

This document provides general guidance to address the following with respect to residential ventilation systems impacted by WTC-related dust:

- Professional, health and Safety Requirements for Individuals performing the evaluations
- Evaluation Procedures (Visual Assessment, Historical Assessment, and Sampling Procedures)
- Post-Cleaning Visual Inspection Procedures

This document is limited in scope to evaluation of environmental conditions within the ventilation systems to determine whether they have been impacted by the WTC collapse. This document is not concerned with the following:

- Mechanical operation of the systems
- Environmental conditions, contaminants, or other conditions within the systems that are not related to the WTC collapse
- Recommendations and procedures that by their nature must be contaminant-specific

C.2.0 PURPOSE

The purpose of this document is to provide procedures for inspecting and evaluating residential ventilation systems in Lower Manhattan to determine if such systems have been impacted by airborne

dust from the WTC collapse, and to provide guidelines for the qualifications of personnel accomplishing such inspection and evaluation.
WTC-related dust is generally considered to have common, consistent, and readily observable characteristics visually and tactilely differentiating it from common dust. WTC-related dust generally contains extremely fine particles similar in consistency to talcum powder, is light-colored, contains pulverized concrete and/or gypsum wallboard, and may contain asbestos fibers.

Ventilation systems are reservoirs for environmental dust and dirt. Therefore, in some cases, it may not be possible to visually differentiate between WTC-related dust and environmental dust that was present in the ventilation system prior to or after the WTC collapse. In these cases, bulk dust sampling will be performed.

C.3.0 APPLICABLE DOCUMENTS

This section provides full bibliography for references made within this document. Evaluations should be conducted in a manner that is fully compliant with the guidance provided in the following documents, to the extent applicable.

ACR 2002, *Assessment, Cleaning and Restoration of HVAC Systems*, National Air Duct Cleaning Association, Washington, D.C. (2002).

> Section 3 of ACR 2002 includes procedures for performing a visual assessment of HVAC systems required in *Section C.5.5.2.1* of this document.

NADCA Standard 97-05, *Requirements for the Installation of Service Openings in HVAC Systems,* National Air Duct Cleaning Association, Washington, D.C. (1997).

> NADCA 97-05 includes procedures for installing service openings in HVAC systems and construction and material specifications for replacement panels, plates or access doors to cover such openings as required under *Section C.5.5.1.2*of this document.

SMACNA HVAC Duct Construction Standards – Metal and Flexible, Sheet Metal and Air Conditioning Contractors' National Association, Inc., 2nd Edition (1995).

> The SMACNA standard includes construction and material specifications for access doors for covering service openings as required under *Section C.5.5.1.2* of this document.

SMACNA Fibrous Glass Duct Construction Standards, Sheet Metal and Air Conditioning Contractors' National Association, Inc., 6th Edition (1992).

> The SMACNA standard includes construction and material specifications for access doors for covering service openings as required under *Section C.5.5.1.2* of this document.

NFPA Standards 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems,* and 90B, *Standard for the Installation of Warm Air Heating and Air-Conditioning Systems,* National Fire Protection Association (1999 Edition).

The NFPA standards include construction and material specifications for replacement coverings on service openings as required under *Section C.5.5.1.2* of this document.

OSHA Regulations 29 CFR 1910, Occupational Health and Safety Standards

The OSHA regulations specify health and safety requirements for protecting employees during the inspection procedures.

C.4.0 PROFESSIONAL, HEALTH AND SAFETY REQUIREMENTS FOR INDIVIDUALS PERFORMING THE EVALUATIONS

Many older ventilation system components contain both friable and nonfriable asbestos and may contain various contaminants such as mercury, PCBs, lead and microbial contamination. Aside from these contaminants, asbestos-containing pipe insulation, plaster and other asbestos-containing building materials may be disturbed during evaluation of ventilation equipment. Safety hazards such as fall hazards, electrical hazards, and mechanical hazards also may be encountered during evaluation of ventilation equipment. Due to the potential presence of these health and safety hazards, this section specifies minimum professional requirements for individuals performing the evaluations, as well as health and safety requirements pertinent to conducting the evaluations. It is not the intention of this document to provide all applicable health and safety requirements. It is expected that the entities performing work are knowledgeable in all federal, state and local health and safety requirements and standards pertinent to conducting the evaluations. This document references several key OSHA standards that are relevant to this work.

C.4.1 Evaluation Team

All evaluations shall be performed in teams consisting of a qualified HVAC/Electrical Professional and a qualified Environmental Professional. For large central air systems, it may be helpful to supplement the team with a Sheet Metal Professional.

C.4.2 HVAC/Electrical Professional - Requirements

1. The HVAC/Electrical Professional shall be an employee of a professional, licensed mechanical ventilation contracting or engineering firm.

2. The HVAC/Electrical Professional shall be able to demonstrate competency and document experience in the following areas: air handling equipment identification and access, identification of system components, and installation of service openings in sheet metal and fibrous glass ducts in accordance with NFPA, NADCA and SMACNA guidelines and NYC building codes.

3. The HVAC/Electrical Professional shall have received training from their employer for reasonably anticipated hazards during HVAC work including training required under OSHA standards, including but not limited to lockout/tagout, fall protection, and personal protective equipment standards.

NOTE: *If necessary, a licensed electrician shall be subcontracted to de-energize electrically operated equipment in accordance with OSHA's lockout/tagout requirements.*

4. The minimum personal protective equipment required for use by the HVAC/Electrical Professional includes:

   a. a supply of disposable protective coveralls
   b. a supply of disposable protective gloves
   c. safety glasses
   d. respiratory protection as specified in item 5 below

5. The HVAC/Electrical Professional shall be capable of wearing and shall be provided with a P100 air purifying respirator with appropriate medical determination, fit testing and training as required under OSHA's personal protective equipment standard.

6. The HVAC/Electrical Professional shall have received 2-hour asbestos awareness training.

7. The HVAC/Electrical Professional shall be responsible for:

   a. the lockout/tagout of electrical or mechanical hazards required to safely perform the evaluations;

   b. the HVAC/Electrical Professional's firm shall provide sound equipment as needed to meet OSHA's fall protection requirements that may be applicable to parts of the evaluations and the HVAC/Electrical Professional shall be responsible for implementing the use of such equipment;

   c. locating and identifying ventilation system components to be included in the evaluation;

   d. any disassembly of any ventilation equipment and components required to complete the evaluation, and proper re-assembly following the evaluation; and

   e. assist the Environmental Professional in making determinations required in *Section C 4.4*.

C.4.3 Sheet Metal Professional – Requirements

Requirements for the Sheet Metal Professional, if part of the evaluation team, are identical to those listed in *Section C.4.2* for the HVAC/Electrical Professional.

C.4.4 Environmental Professional - Requirements

The Environmental Professional shall hold a current EPA accreditation as an AHERA Building Inspector. The primary purpose of the asbestos certification requirement is to be able to identify asbestos-containing materials and asbestos-related hazards in order to avoid the disturbance of asbestos-containing materials during the evaluations.

1. The Environmental Professional shall have current EPA accreditation as an AHERA Building Inspector in any U.S. state.

2. The minimum personal protective equipment required for use by the Environmental Professional includes:

   a. a supply of disposable protective coveralls
   b. a supply of disposable protective gloves
   c. safety glasses
   d. respiratory protection as specified in *item 3* below

3. The Environmental Professional shall be capable of wearing and shall be provided with a P100 air purifying respirator with appropriate medical determination, fit testing and training as required under OSHA's personal protective equipment standard.

4. The Environmental Professional is responsible for:

   a. ensuring that no asbestos-containing materials are disturbed during the evaluations;

   b. determining which personal protective equipment will be used by the HVAC/Electrical Professional, the Sheet Metal Professional and by the Environmental Professional during the evaluation; and

   c. collecting any bulk, wipe, microvac or tape-lift samples that are necessary to complete the evaluation;

   d. making determinations required in *Section C.5.3*; and

   e. cleaning up any debris that may be disturbed as a result of the evaluation using a HEPA vacuum.

C.5.0 EVALUATION PROCEDURES

C.5.1 General

Ventilation systems are likely to vary widely in type, configuration and complexity. This evaluation procedure applies considers three general categories of ventilation systems that may be encountered in residential buildings in lower Manhattan:

1. Ventilators, wall air conditioning units and window air conditioning units **in common spaces**;
2. Fan coil or heat pump units **in common spaces**; and
3. Central systems with heating and/or cooling capabilities.

Wall air conditioning units and window air conditioning units which serve an individual residence are not included in this evaluation procedure. These units will be cleaned during the cleaning of residential spaces.

Note that exhaust systems such as bathroom and kitchen exhaust fans that directly remove room air to the outdoors are not included in this evaluation procedure. Components of direct exhaust systems typically include exhaust grilles, exhaust duct, exhaust fan, and rooftop or wall exhaust outlet devices. If information suggests that contamination of direct exhaust systems may be present, an evaluation may be performed using the same principles outlined for *items 1, 2*, and *3* above. Similarly, any ventilation equipment encountered that does not fall into any of these categories can be inspected using principles outlined in this section.

The locations within the ventilation system equipment expected to have the greatest impact from WTC-related dust include air intakes and intake ducts, intake air dampers, intake air filters and various system components located downstream of the intake air filters, depending on the system's filtration efficiency. Dust may collect at potential impingement points such as duct terminations, transitions and elbows, and interior system components such as control devices, dampers, thermal coils, turning vanes, fans, etc.

One factor that may be considered in performing the evaluation is whether or not the ventilation equipment operated during the WTC collapse and in the weeks immediately following the collapse. Equipment that was not operating due to power loss, or due to concerns about entrained dust, may not have been impacted as heavily as equipment that operated throughout the collapse and immediate clean-up response.

Section C.5.3 includes a listed of recommended equipment for performing the evaluation.

Section C.5.4 includes a list of system components for each equipment category.

Section C.5.5 includes the evaluation procedures that may be applied to each system component.

C.5.2 Documentation of Existing Mechanical Conditions

Prior to the start of the evaluation, the HVAC/Electrical Professional shall ensure that the ventilation system is cycled and that there are no obvious existing deficiencies affecting proper mechanical operation of the system for which the evaluation team may later be held responsible.

C.5.3 Recommended Supplies and Equipment

- Personal protective equipment (see *Section C.4.0*)
- Sampling supplies (see *Section C.5.5.2.3*)
- Disposal bags (see *Section C.5.5.2.3*)
- Spray bottle containing soapy water
- Cleaning cloths
- Ladders (as needed)
- Lifts or scaffolding (as needed)
- Extension cords
- Hand tools (screw driver, pliers, etc.)
- Rotary metal cutting saw
- For covering service openings, sheet metal plates, panels or access doors meeting NADCA 9705, NFPA 90A/90B and SMACNA specifications
- Telescoping inspection mirrors and flashlights
- Boroscope
- HEPA vacuum

C.5.4 Typical System Components for Each Equipment Category

The ventilation systems may contain, but may not necessarily be limited to combinations of the listed components in each category.

C.5.4.1 Ventilators, Wall Air Conditioning Units and Window Air Conditioning Units in Common Spaces

- Outside air intake louvers, grates and screens
- Outside air duct
- Outside air dampers
- Return air grille
- Return air plenum
- Filter rack
- Filter media
- Coils (evaporator)
- Blower assembly
- Condensate drain pan
- In-line electrical resistance strip heaters (in supply ducts connected to unit ventilators)
- Fire dampers
- Turning vanes
- Supply plenum or supply duct liner
- Supply air diffuser

C.5.4.2 Fan Coil/Heat Pump Units in Common Spaces

- Return grille
- Return air plenum
- Filter rack
- Filter media
- Blower assembly
- Thermal coils
- Supply plenum
- Supply diffusers

C.5.4.3 Central Air System

- Outside air intake louvers, grates and screens
- Outside air duct
- Outside air dampers
- Return air grilles
- Return air plenum
- Return air plenum damper
- Return air ducts
- Turning vanes
- Mixing chambers
- Filter rack
- Filter banks/media
- Pre-heat coils
- Cooling coils
- Re-heat coils

- Humidification and/or air cleaning equipment
- Fire dampers
- In-line re-heat coils
- Interior insulation
- Duct connectors
- Blower assembly including blower wheel, blower housing, air vanes, in-line noise attenuators, acoustical treatments (e.g., baffles, duct linings)
- Condensate drain pan
- Condensate accumulator
- Supply air plenum
- Supply air plenum damper
- Supply plenum or supply duct linings
- Supply air ducts (high and low pressure)
- Supply air diffusers
- Terminal boxes
- Open or ducted passive ventilation shafts

C.5.5 Evaluation Procedures

C.5.5.1 Accessibility

C.5.5.1.1 Locate System Components Accessible for Visual Inspection

The HVAC/Electrical Professional shall make an assessment of the accessibility of the various components of the system. For example, components may be enclosed within permanent sheet metal panels, or may be located above or behind solid plaster ceilings and walls.

Determine the components that are accessible. At minimum, representative surfaces of the following system components should be inspected:

- air intake (outdoor or return)
- air intake dampers
- return air grilles
- return air plenum
  - horizontal surfaces
  - impingement points (e.g. turning vanes, elbows, transitions)
- filter racks and filter media
- blower
- thermal coils
- interior surfaces of the supply air ducts
  - horizontal surfaces
  - impingement points (e.g. turning vanes, elbows, transitions)
- volume dampers
- terminal boxes
- supply diffusers

Note that depending on the size and complexity of the HVAC system, access may require the use of ladders, lifts or scaffolds using appropriate methods of fall protection.

C.5.5.1.2 Methods of Access

The following list summarizes methods of accessing HVAC system components for inspection:

- through existing service openings (i.e., access doors and panels)
- by disassembly of housing
- by installation of service openings (may range from 1" diameter holes to access doors)

The HVAC/Electrical Professional shall assess the accessibility of each HVAC system component to be inspected. If an HVAC system component is not accessible, the Environmental Professional shall be consulted to determine whether installation of a service opening will likely disturb asbestos-containing materials. After such consultation, if approved by the Environmental Professional, the HVAC/Electrical Professional shall install service openings as needed to inspect the HVAC components listed in *Section C.5.5.1.1*.

***NOTE**: Disassembly of housing and installation of service openings may only be performed by the HVAC/Electrical Professional and replacement plates, panels or access doors shall be installed in accordance with NFPA, NADCA and SMACNA standards and NYC building codes.*

The Environmental Professional shall repair or seal any interior/exterior duct insulation disturbed by the installation of service openings.

C.5.5.2 Methods of Evaluation

C.5.5.2.1 Visual Inspection Procedure

The HVAC/Electrical Professional and the Environmental Professional should jointly perform the visual inspection. At minimum, the components listed in *Section C.5.5.1.1* shall be inspected.

The visual inspection shall be accomplished using one or more of the following methods:

- direct examination
- telescoping inspection mirrors and flashlights inserted through service openings
- boroscopes inserted through supply air diffusers or other existing openings
- remotely operated video camera

C.5.5.2.2 Assessment of Conditions

<u>*Visual Assessment*</u>

All required interior surfaces in contact with the air stream shall be inspected for visible accumulations of dust and/or debris. Inspect all surfaces in contact with the air stream. Information indicates that some of the defining characteristics of WTC-related dust are that it contains extremely fine particles similar to talcum powder in consistency, is light-colored, contains pulverized concrete and/or gypsum wallboard, and may contain asbestos fibers. The visual inspection shall document:

- A general description of the appearance of interior surfaces of the various system components. The description for each component will include, but may not be limited to:

    - interior duct/fan housing surfaces are porous/non-porous
    - interior duct and fan housing surfaces are lined with insulation
    - interior duct and fan housing surfaces are double-walled (i.e. interior insulation with perforated metal cover)
    - filter loading, condition of filters and filter rack
    - interior surfaces are free/not free of visible dust and debris or suspect WTC-related dust and debris
    - description of dust color, level of dust loading that may include:
        - the depth of dust observed on each component (e.g., less than 1/16 inch, greater than or equal to 1/16 inch.).
        - the depth and location of dust on ducts and fan housing (i.e., on interior bottom, top and sides of ducts)
        - visually estimated percentage of surface area with suspect WTC-related dust
    - whether or not there are materials that are likely not associated with WTC-related dust such as building-related asbestos-containing materials, animal carcasses, delaminating lining material, visible mold growth, water damage, fecal matter, feathers or other evidence of animals, etc.

<u>*Historical Assessment*</u>

The evaluation team shall attempt to describe any other available information from site occupants or building managers, such as the known status of system operating conditions at the time of the WTC collapse, ventilation system maintenance (i.e., cleanings, filter changes, or replacement since the WTC collapse).

NOTE: *Based on these assessments, to the best of his/her ability the Environmental Professional will state a general impression of the overall cleanliness of each component, and whether or not it appears to be impacted by WTC-related dust.*

C.5.5.2.3 Environmental Sampling Procedure

If the evaluation team determines that the ventilation equipment appears to have been impacted by WTC-related dust, cleaning will be recommended and environmental sampling will not be required. This information shall be included in the HVAC system evaluation report. The HVAC system evaluation report must be sent to EPA electronically in PDF format.

In the absence of environmental sampling that indicates otherwise, WTC-related dust shall be assumed to be an asbestos-containing material and cleaning procedures shall be performed in accordance with procedures for asbestos decontamination (see *Section C.4.0*).

If dust or debris is present and it is not apparent that it is related to the collapse of the WTC, a maximum of 5 bulk samples will be collected and analyzed for pH, fibrous glass and crystalline silica. These samples and copies of necessary documentation shall be shipped daily by courier for next day delivery to EMSL Analytical Inc., 107 Haddon Avenue, Westmont, NJ 08108 (Tel: 856-858-4800). This data will be used to determine if the lapse of the WTC. Dust will be considered WTC-related if: pH is 9 or above; fibrous glass content is between 30 and 40 % and crystalline silica content is 5% or greater. Laboratory data will be reported back to the Monitoring Contractor and shall be included in the HVAC system evaluation report. The HVAC system evaluation report must be sent to EPA electronically in PDF format.

Sampling Procedures

1. Sampling of interior dust may only be performed by the Environmental Professional.

2. Minimum personal protective equipment used by the Environmental Professional shall include disposable protective coveralls, a P100 respirator, safety glasses, and disposable gloves.

3. A HEPA vacuum shall be on-site for clean-up, if needed.

4. Dust may be collected from any visible deposit. Frequently, dust will be more likely to accumulate on horizontal surfaces, although this may not always be the case.

5. Sample collection and analysis:

   Bulk samples. Bulk dust samples may be scooped or scraped into a sealable container using an appropriate sampling device. A minimum of 20 grams of sample will be collected. Wipe the device with a clean, wet cloth between samples to prevent cross-contamination. Wipe the exterior of the sample container to remove excess dust. Label the container with the sample identification. At minimum, for each sample the date, building name, and specific location of the sample, including whether or not the sample is located upstream or downstream of the air filters, shall be recorded.

6. Completion of sampling:

   The Environmental Professional shall repair or seal any interior/exterior duct insulation disturbed as a result of sample collection.

   At the completion of sampling, the Environmental Professional shall wipe the outside of his/her respirator with a clean, wet, disposable cloth and shall place the respirator into a clean, sealed plastic bag. Clean any suspect debris or contamination resulting from the sampling activities using a HEPA vacuum or wet wiping methods. All wiping cloths, disposable protective suits and gloves, and drop cloths shall be placed into a sealed polyethylene bag for proper disposal.

C.6.0 POST-CLEANING VISUAL INSPECTION

Cleanliness verification shall be performed by the evaluation team consisting of a HVAC/Electrical Professional and an Environmental Professional as described in *Section C.4.0* of this document after cleaning of one or more ventilation system components has been completed.

Following cleaning, the Environmental Professional shall ensure that all interior ventilation system components that were subject to the cleaning procedures are visibly clean. An interior surface will be considered visibly clean when it is free from non-adhered substances and debris.

To determine whether a surface if visibly clean, a thorough and comprehensive visual inspection and assessment of all cleaned components shall be performed in accordance with visual procedures established in *Sections C.5.5.2.1* and *C.5.5.2.2* of this document. In order to observe locations that are difficult to clean, additional access openings shall be installed as needed to conduct a comprehensive post-cleaning visual inspection.

APPENDIX D.

World Trade Center Indoor Dust Cleaning Program

Cleaning Contract Scope of Work

DRAFT 8/8/02

D.1.0 INTRODUCTION

All work performed under this contract entered into between the New York City Department of Environmental Protection (DEP) and the cleaning contractor must be in compliance with all applicable laws and regulations, including but not limited to regulations issued by the United States Environmental Protection Agency (EPA), the United States Department of Labor Occupational Safety and Health Administration (OSHA), the New York State Department of Labor (NYS DOL), and the New York City Department of Environmental Protection (DEP).

The EPA and DEP will solicit participation in a direct assistance program for residents and residential building owners south of Canal Street who are concerned that their residences may have debris/dust from the collapse of the World Trade Center (WTC). A DEP/EPA telephone hotline has been established to receive requests from the public. The assistance will include various options, including cleaning within residences and common spaces by licensed asbestos contractors with follow-up asbestos sampling, asbestos air sampling only, and providing high efficiency particulate air (HEPA) vacuums.

NYS DOL licensed asbestos contractors shall perform cleaning activities for residents who wish to have their homes cleaned. An independent Monitoring Contractor will schedule and monitor the work, perform a visual inspection, and perform asbestos air sampling when the cleaning is completed.

The purpose of this contract is to acquire the services of a NYS DOL licensed asbestos contractor with DEP and NYS DOL certified workers for the performance of cleaning activities at residential buildings impacted by the collapse of the World Trade Center. The scope of work for the cleaning activities is attached. The cleaning contractor shall supply all equipment and supplies necessary to perform the work specified in this contract.

D.2.0 ROLES AND RESPONSIBILITIES

As provided in the instant contract, EPA's World Trade Center Dust Cleanup Field Personnel shall have the authority of Project Manager, in addition to DEP's Project Manager. As such, the authority of EPA World Trade Center Dust Cleanup Field Personnel shall include the following authority related to cleaning work conducted under this contract:

- The authority to stop work for health and safety reasons.
- The authority to stop work for non-compliance with the Scope of Work.
- The authority to give technical direction to the contractor in the performance of the work.
- The authority to review and approve or disapprove of the qualifications and performance of the cleaning personnel involved in the work.
- The right to inspect and accept or reject any work .

An independent Monitoring Contractor will perform air monitoring. The Personal air monitoring will be performed by the Monitoring Contractor on a minimum of one employee of the Cleaning Contractor per shift per apartment during the first 6 weeks of cleaning operations. Thereafter, personal air samples will be taken randomly at a rate of one sample per day. The results of this sampling shall be sent immediately to EPA, OSHA and the cleaning contractor. The cleaning contractor shall make these results available to the employees or their designated representatives for their review in accordance with 29 CFR 1910.1020 and 29 CFR 1926.1101.

The Monitoring Contractor is responsible for:

- Scheduling and coordinating the cleaning and monitoring work with residents, building owners, the Cleaning Contractor and EPA;
- HVAC system evaluation and inspection;
- Oversight of the Cleaning Contractor;
- Inspection of the Cleaning Contractor's work;
- Area air monitoring; and
- Personal air monitoring.

The Cleaning Contractor is responsible for cleaning residences, common spaces and portions of HVAC systems identified by the Monitoring Contractor.

D.3.0 QUALIFICATIONS

This contract requires that only a NYS DOL licensed asbestos contractor and only NYC DEP and NYS DOL certified workers will be allowed to perform any of the cleaning activities under this contract. This requirement also applies to any subcontractors involved in the cleaning. A copy of these licenses and certificates must be available on-site during the performance of work and must be presented upon request.

The HVAC system cleaning contractor shall be a certified member of the National Air Duct Cleaners Association (NADCA) or shall maintain membership in a nationally recognized non-profit industry organization dedicated to the cleaning of HVAC systems. If the cleaning contractor is not a member of the NADCA, a subcontractor that is a member may perform the HVAC system cleaning.

All contractors and subcontractors involved in the cleaning activities under this contract are responsible for completing a background check on their employees and for screening unacceptable candidates from the pool of on-site workers. Background checks shall be completed with 30 days of the award of the contract. Thereafter, background checks shall be completed prior to employees beginning on-site work. EPA will provide guidelines for evaluating the background information collected. Contractors are required to maintain records of background checks for 4 years and to make them available to the DEP and EPA when requested. At a minimum, the background check must include:

1. Law enforcement checks (5 years)
2. Professional license and certification

D.4.0 SPECIFICATIONS

This contract between DEP and the cleaning contractor shall be in force for 24 consecutive months from the commencement date. The cleaning contractor must be prepared to mobilize within 72 hours of the contract award. The contractor shall have on staff and assigned to this contract a sufficient number of properly trained and certified workers to clean 20 units simultaneously and complete the cleaning activities in each residence within no more than 2 days. The contractor shall be prepared to work 7 days per week. Activities shall be coordinated with the Monitoring Contractor to ensure that the visual inspection is performed within two hours of the completion of cleaning activities. Cleaning activities shall be considered completed upon successful visual inspection by the Monitoring Contractor. Copies of all invoices for work conducted under this contract shall be provided to EPA. EPA will review submitted invoices to confirm that the work has been completed and forward them to DEP for processing. Decisions regarding the reimbursement of costs will be made by DEP.

Electricity and water necessary to conduct the work required under this contract will be provided by the owner or occupant of the work area.

All cleaning operations will be conducted in accordance with either Scope A or Scope B as described below.

HEPA means a filter system capable of trapping and retaining 99.97% of all mono-dispersed particles of 0.3 micrometers in diameter.

Vacuum or HEPA vacuum means a vacuum cleaner equipped with a HEPA filter, with a minimum static water lift of 95 inches.

Water extraction cleaner means a water extraction carpet cleaner equipped with a motorized agitator brush for carpet cleaning and upholstery nozzle with a minimum static water lift of 95 inches.

The cleaning contractor shall attend the mandatory pre-bid meeting and project kick off meeting prior to the commencement of work. The cleaning contractor shall as requested, attend meetings or participate in conference calls with EPA to coordinate field activities.

The cleaning contractor shall apply for any and all necessary permits and applications necessary to complete the work.

D.4.1 Scope of Work A

Application: These procedures apply to the cleaning of minimal dust accumulations (light coating). If a visual inspection indicates the presence of significant accumulations of dust and/or debris from the collapse of the WTC in residences or common spaces (including elevator shafts), *Scope B* procedures shall be applied (refer to *Scope of Work B*). Residents may be present during Scope A cleaning procedures.

Cleaning of Common Spaces

Common spaces including hallways, stairways and the interior of elevator cars shall be cleaned, if requested by the building owner. The Monitoring Contractor in consultation with EPA, or EPA's designee will evaluate and determine if other common areas including utility rooms, laundry rooms, compactor rooms, elevator shafts require cleaning. Work will begin from the entrance and continue through all common spaces in an orderly fashion. A detailed description of the minimum cleaning requirements for common space is as follows:

- Vacuuming will begin with the ceiling, continue down the walls and include floors. A vacuum equipped with a motorized agitator bar will be used to vacuum carpets.

- Impermeable walls and floors will be wet wiped, after consultation with and approval by owner. Wet wiping will not be conducted if it is determined that it would cause damage to the surface.

- Carpets will be cleaned with a water extraction cleaner after consultation with and approval by owner. After cleaning, red rosin construction paper will be applied to high traffic areas to protect carpets from soiling. Water extraction cleaning will not be conducted if it would cause damage to the carpet.

- Surfaces that are not cleaned by wet methods (wet wiping and water extraction cleaner) will be vacuumed two times.

Cleaning of HVAC Systems

HVAC systems that are determined by the Monitoring Contractor to be impacted by dust or debris from the collapse of the World Trade Center will be cleaned in accordance with the site-specific scope of work prepared by the Monitoring Contractor and approved by EPA. HVAC systems cleaning, if warranted, shall be completed prior to the initiation of the cleaning of common space or residences within an affected building. In the event that the HVAC system for an entire building requires cleaning, a separate, site specific contract will be awarded by DEP for this work. If only a portion of an HVAC system requires cleaning, then the cleaning contractor will conduct the cleaning utilizing specialized labor trained and experienced in duct cleaning.

HVAC cleaning shall be conducted in accordance with National Air Duct Cleaners Association (NADCA) General Specification for the Cleaning of Commercial Heating, Ventilating and Air Conditioning Systems and the NADCA Assessment, Cleaning and Restoration Standard (ACR 2002). Verification of the effectiveness of HVAC system cleaning will be determined by the Monitoring Contractor. If dust or other contaminants are evident through visual inspection, those portions of the system where dust or other contaminants are present shall be recleaned and subjected to reinspection for cleanliness**.** If the cleaning contractor is not a member of the NADCA, a subcontractor that is a member may perform this portion of the work.

Cleaning of Residential Spaces

Residences will be cleaned using HEPA vacuums, water extraction cleaners and wet wiping as described below. Surfaces to be cleaned include but are not limited to walls, floors, ceilings, ledges, trims, furnishings, appliances, equipment, etc. Encapsulating agents shall not be applied. Dry sweeping is prohibited. The cleaning contractor will not clean inside of drawers, cabinets, breakfronts and similar enclosed storage or display pieces, however, the exterior of these pieces will be cleaned. Cleaning of clothing and accessories (handbags, shoes etc.) shall be the responsibility of the occupant. A detailed description of the minimum cleaning requirements is as follows:

- Terraces, balconies, exterior window sills, window wells and window guards that are accessible from the interior of the dwelling, shall be cleaned.

- Interior windows, screens, window sills and window guards will be cleaned.

- Vacuuming will begin with the ceiling, continue down the walls and include the floor. A vacuum equipped with a motorized agitator bar will be used to vacuum carpets.

- Impermeable walls and floors will be wet wiped, after consultation with and approval by owner/resident. Wet wiping will not be conducted if it is determined that it would cause damage to the surface.

- Carpets will be cleaned with a water extraction cleaner after consultation with and approval by owner/resident. After cleaning, red rosin construction paper will be applied to high traffic areas to protect carpets from soiling. Water extraction cleaning will not be conducted if it would cause damage to the carpet.

- Fabric covered furniture will be vacuumed and then cleaned with a water extractions cleaner after consultation with and if approved by owner/resident. Water extraction cleaning will not be conducted if it would cause damage to the furniture.

- All surfaces including but not limited to floors, walls, curtains, fabric window treatments, upholstery and other materials that are not cleaned by wet methods (wet wiping and water extraction cleaning) will be HEPA vacuumed two times. Fabric covered furniture that is not cleaned by wet methods will be vacuumed using an appropriate brush attachment.

- Intake/discharge registers of HVAC systems (if present) will be removed/cleaned. The first foot of duct work will also be vacuumed; then the register will be reinstalled and covered with a layer of 6 mil polyethylene sheeting.

- Window and room air conditioners will be vacuumed, wet wiped and removed from their housing to allow access to internal portions of the air conditioner. The internal portions of the air conditioner and housing will then be vacuumed. Filters will be vacuumed and reinstalled. Air conditioners will be reassembled and reinstalled after cleaning.

- Paperwork and books will be HEPA vacuumed.

- Electrical outlets will be vacuumed.

- Appliances such as refrigerators and stoves will be cleaned and moved. The floor footprint of the appliances will be cleaned and the appliance will be reinstalled in their original positions.

- Refrigerator cooling tubes will be brushed and vacuumed.

- The first foot of all exhaust duct work (including stove, dryer and bathroom vents) where accessible, will be vacuumed. Exhaust fans will be vacuumed and wiped.

- Unobstructed closet floors will be vacuumed.
- Solid objects (electrical equipment, exercise equipment, etc.) will be wet wiped, moved to allow cleaning of the underlying surface and will be returned to their original location.

- Dishwasher toe plates will be removed and the floor beneath the appliance will be cleaned.

- Baseboard heaters will be cleaned. Protective covers on finned radiant heaters and baseboard heaters will be removed to expose heat elements. Fins are to be brushed and vacuumed to remove dust.

- All cleaning equipment will be vacuumed and/or wet wiped after completion of the cleaning and before removal from the work area.

- HEPA air filtration devices (AFDs) will run continuously during all cleaning activities, as appropriate given site conditions. AFDs shall be installed and operated to provide a minimum of one air change every 15 minutes. Make up air should be derived from a non-impacted source (i.e. open window or common spaces previously cleaned).

- A minimum of one asbestos supervisor shall be present in each building during work.

- A Cleaning Checklist (to be developed by EPA) will be completed by the cleaning contractor as tasks are completed to document the progress of the cleaning.

- The cleaning contractor shall notify the monitoring contractor immediately upon completion of the cleaning. The Monitoring Contractor will conduct a thorough visual inspection to verify the absence of visible dust accumulations. If dust is observed the cleaning contractor will reclean as necessary at no additional cost.

- Air sampling shall be performed by the Monitoring Contractor after the area is free of dust accumulations as determined by the Monitoring Contractor. The residence will be recleaned and retested if the clean-up criteria of 0.0009 fibers/cc (PCME measured by TEM) is not achieved or if determined necessary by EPA. This clean-up criterion may be reevaluated and revised, if determined necessary based on field conditions and analytical limitations.

- Any damage or loss that occurs during cleaning is the responsibility of the cleaning contractor. The cleaning contractor is not responsible for damage or loss caused by the acts of third parties not involved in the cleaning activities.

- Owner/residents may identify and tag certain furnishings (e.g. carpets and fabric covered furniture) for disposal rather than cleaning. Disposal of residents' personal property shall not occur without prior written authorization by the owner.

- Disposal of all wastes generated during the cleaning shall be the responsibility of the contractor. All waste generated shall be treated as asbestos-containing material (ACM). Transportation and disposal of generated waste shall be in compliance with all applicable rules and regulations.

- If mold or peeling, flaking or chalking paint is observed in the work area, the cleaning contractor shall immediately contact the Monitoring Contractor.

- If in-place materials suspected to contain asbestos are observed the Cleaning Contractor shall immediately notify the Monitoring Contractor. The Monitoring Contractor will evaluate the condition of the material to identify damaged, deterioration, delamination, etc. The Cleaning Contractor shall wrap suspect ACM that is in good or excellent condition with 6-mil polyethylene sheeting and seal airtight with duct tape or equivalent method prior to cleaning or air monitoring.

- In the event that damaged, deteriorated, delaminated, etc. suspected ACM is observed, the Cleaning Contractor will notify the Monitoring Contractor. Cleaning or air monitoring will not proceed in areas where such suspected ACM is observed until instructed otherwise.

D.4.2 Scope of Work B

Application: A visual inspection was performed and large or significant accumulations of dust or debris from the collapse of the WTC was observed in common spaces, residences or portions thereof (such as windows, terraces or balconies).

Residents will not be allowed in the work area. Residents may be present in the residence during cleaning in cases where the work area can be isolated by the erection of isolation barriers. In all other applications of *Scope B* it is assumed that residents will not be present in the residence. A detailed description of the minimum cleaning requirements is as follows:

- The cleaning contractor shall meet with EPA or the Project Monitor if requested, to discuss site specific procedures for debris removal, isolation of the work space and worker decontamination.

- An asbestos project notification form (NYC form ACP-7) shall be submitted, as required by Title 15, Chapter 1 of the Rules of the City of New York (RCNY), directly to the NYC DEP Asbestos Control Program prior to the start of work. NYS DOL notification may also be required.

- At least one asbestos supervisor shall be present at each work place (work place is defined in Title *15*, Chapter 1 of RCNY as the work area and the decontamination enclosure system).

- Personal protective equipment including disposable clothing, gloves, and respirators shall be worn during this cleaning activity.

- Warning signs shall be posted at all of the approach to the work area.

- A decontamination enclosure system shall be installed at the entrance to the work area.

- The shower room shall be equipped with at least a 6-foot flexible hose for waste decontamination. A remote holding area with a lockable door for waste shall be located at the site and shall comply with all applicable storage rules and regulations. Waste removal shall not occur during worker shift changes or when workers are showering or changing.

- An entry/exit log in compliance with the requirements set forth in Title 15, Chapter 1 of RCNY shall be maintained in the clean room.

- A remote decontamination enclosure system shall be considered when appropriate, i.e. inability to comply with the provision due to space limitation or other agency rules, such as for compliance with New York City Fire Department egress requirements.

- HVAC systems shall be shut down and locked out or isolated locally.

- Isolation barriers shall be installed with two layers of 6-mil polyethylene sheeting and sealed with tape.

- Negative pressure ventilation equipment (air filtration devices (AFDs)) shall be installed and operated during all cleaning activities. Equipment shall run continuously until clearance air monitoring. A minimum of one air change every 15 minutes shall be provided. When ducting to the outside is not possible, a second negative pressure ventilation unit compatible with the primary unit may be connected in series.

- When conducting cleaning of common space in apartment buildings, the elevator control shall be modified to bypass the work area.

- Prior to any cleaning of common spaces, isolation barriers (i.e. sealing off of all openings, including but not limited to windows, corridors, doorways, barriers, skylights, ducts, grills, diffusers, and any other penetrations of the workplace) shall be installed with two layers of 6-mil plastic sheeting sealed with tape. All seams of HVAC or other system components that pass through the work place shall also be sealed. All openings shall be HEPA vacuumed prior to installing the isolation barrier.

- All WTC debris shall be misted and double-bagged. Accumulation of water is prohibited. Water misting shall be sufficient to wet the material without water accumulations.

- After the removal of debris, all surfaces will be cleaned in accordance with the procedures specified in Scope A. After all surfaces have been cleaned, a second cleaning shall be performed. This results in two full cleanings of all surfaces, with the following exception. Water extraction cleaning of carpets and fabric covered furniture will be conducted only once. Surfaces include but are not limited to walls, floors, ceilings, ledges, trims, appliances, equipment and furnishings.

- Residents may identify and tag certain furnishings (e.g. carpets and fabric covered furniture) for disposal rather than cleaning. Disposal of residents' personal property shall not occur without prior written authorization.

- Disposal of all wastes generated during the cleaning shall be the responsibility of the contractor. All waste generated shall be treated as asbestos-containing material (ACM). Transportation and disposal of generated waste shall be in compliance with all applicable rules and regulations.

- A Cleaning Checklist (to be provided by EPA) will be completed by the cleaning contractor as tasks are completed to document the progress of the cleaning.

- An activity log will be maintained by the site supervisor.

- The cleaning contractor shall notify the monitoring contractor immediately upon completion of the cleaning. The Monitoring Contractor will conduct a thorough visual inspection to verify the absence of visible dust accumulations. If dust is observed, the cleaning contractor will reclean as necessary at no additional cost.

- Air sampling shall be performed by the Monitoring Contractor after the area is free of dust accumulations as determined by the Monitoring Contractor. The residence will be recleaned and retested if the clean-up criteria of 0.0009 fibers/cc (PCME measured by TEM) is not achieved or if determined necessary by EPA. This clean-up criterion may be reevaluated and revised, if determined necessary based on field conditions and analytical limitations.

- After successful clearance air monitoring, isolation barriers shall be removed in conjunction with the use of a HEPA vacuum.

- Any damage or loss that occurs during cleaning is the responsibility of the cleaning contractor. The cleaning contractor is not responsible for damage or loss caused by the acts of third parties not involved in the cleaning.

- All work shall be in compliance with all other applicable requirements of Title 15, Chapter 1 of the RCNY and New York Industrial Code Rule 56.

- If mold or peeling, flaking or chalking paint is observed, the cleaning contractor shall immediately contact the Monitoring Contractor.

- If in-place materials suspected to contain asbestos are observed the Cleaning Contractor shall immediately notify the Monitoring Contractor. The Monitoring Contractor will evaluate the condition of the material to identify damaged, deterioration, delamination, etc. The Cleaning Contractor shall wrap suspect ACM that is in good or excellent condition with 6-mil polyethylene sheeting and seal airtight with duct tape or equivalent method prior to cleaning or air monitoring.

- In the event that damaged, deteriorated, delaminated, etc. suspected ACM is observed, the Cleaning Contractor will notify the Monitoring Contractor. Cleaning or air monitoring will not proceed in areas where such suspected ACM is observed until instructed otherwise.

APPENDIX E.

Analysis of the Asbestos PCMe, Dust Lead Loading and Dust Dioxin Loading Data

Data analyzed in this report were extracted from the Residential database on September 10, 2003. A copy of the data set, with data necessary to protect the privacy of individual participants in the program redacted, is available from the EPA Region 2 Records Center.

E.1.0 SUMMARY OF DATA COLLECTED

E.1.1 Summary of TEM (PCMe) Data

Table 3-1 summarizes the sample results for asbestos. The data described in this section and *Section E.1.2* are results for asbestos phase contrast microscopy equivalent (PCMe) concentrations measured by transmission electron microscopy (TEM). A total of 28,702 sample results were available for asbestos by PCMe; 22,497 from residential units, and 6,205 from common areas within residential buildings (e.g., hallways, laundry rooms). Samples for PCMe analysis were collected from residential units that were tested only, as well as from residential units and common areas that were cleaned and tested. Results by PCMe were compared to the health-based benchmark of 0.0009 f/cc (fibers/cubic centimeter) to determine the status (i.e., exceeds or does not exceed benchmark) of the residential units/common areas.

The asbestos clearance criteria for the WTC Indoor Air Clean-up Program were based on long (i.e., ≥ 5 um) fiber counts. The use of a minimum fiber length of 5 μm for carcinogenic activity represents current scientific consensus and reflects the criteria in the EPA Integrated Risk Information System (IRIS) for attributing carcinogenic potency.

Phase Contrast Microscopy equivalence is a process to identify asbestos fibers by TEM analysis that would also be visible by PCM. The optical resolution of the phase contrast microscope is approximately 5 microns in length and 0.25 microns in width for fiber analysis. Historically, most of the occupational studies available (and reviewed in IRIS), from which estimates of cancer potency of asbestos are derived, employed PCM analysis. Therefore, in cases where TEM is used for asbestos analysis, fiber counts need to be adjusted to estimate a PCMe.

The asbestos counting rules employed for the WTC Indoor Clean-up Program were designed to record PCMe fibers. Thus TEM analyses were performed, and fibers were then counted following AHERA (Asbestos Hazard Emergency Response Act) counting rules. Fibers ≥ 5 μm (AHERA also stipulates a minimum 5:1 aspect ratio) were distinguished from total (i.e., > 0.5 μm) fiber counts, although total fibers counts were also recorded. To maximize analytical capacity for a large sampling event, no minimum width requirement was employed. This may resulted in a modest over counting bias by not eliminating extremely thin fibers (i.e., <0.25 um) from the count. However, the potential bias attributed to this counting procedure would be protective of human health. Modification was made to AHERA (by obtaining larger samples volumes) in order to achieve the lower detection limits required by the use of a risk-based clearance criteria.

E.1.2 Summary of TEM data

Table 3-2 lists the types of asbestos that were detected by TEM in the airborne asbestos samples from residences and common areas. Asbestos was detected in approximately 4% of the available TEM samples. Chrysotile asbestos was the detected in approximately 92% of the samples included in this subset of the data; amosite was detected in approximately 3%. Other forms of asbestos that were detected include actinolite, anthophyllite, tremolite, and crocidolite.

E.1.3 Summary of Wipe data

E.1.3.1 Lead and Dioxin Wipe Data

This section of the report describes lead and dioxin dust wipe data that were collected from 263 residences that were located in 157 buildings. Wipe data that were used to assess efficacy of the cleanup program are discussed in *Section E.4.0*

E.1.3.1.1 Lead Wipe Data

The database contained 1,540 wipe samples for dust lead loading that were collected from 263 residences, located in 157 buildings. Summary statistics for the data are provided in *Table 3-3*. Samples that were below the detection limit of 1.86 µg/ft^2 were set equal to the detection limit. Review of existing environmental standards/regulations identified an applicable and relevant standard to set a health-based benchmark for lead in interior dust. The Residential Lead-Based Paint Hazard Reduction Act (Title X) Final Rule (40 CFR, Part 745, 1/5/01) established uniform national standards for lead in interior dust. Thus, both EPA and the United States Department of Housing and Urban Development (HUD) have set a dust standard for lead of 40 µg/ft^2 for floors (including carpeted floors), and 250 µg/ft^2 for interior window sills. To support the development of a dust standard, EPA performed an analysis of the Rochester Lead-in-Dust Study (HUD, 1995). At 40 µg/ft^2, a multimedia analysis shows a 5.3% probability that a child's blood lead level would exceed 10 µg/dL. Thus, this standard meets the criteria established by EPA (i.e., 95% probability to be below 10 µg/dL) (EPA, 1994) for managing environmental lead hazards. However, an additional increment of protectiveness was added by setting the health-based benchmark for lead in settled dust at the more stringent HUD screening level of 25 µg/ft^2. Approximately 9% of all lead wipe samples (i.e., *test only* and *clean and test*) were above the HUD screening level of 25 µg/ft^2 (*Table 3-3*); approximately 14% of the pre-cleanup samples exceeded the HUD screening level , while approximately 3% of the post-cleanup samples exceeded the screening level (*Tables 3-4* and *3-5*). Approximately 6% of the samples were above the HUD benchmark of 40 µg/ft^2 (*Table 3-3*).

E.1.3.1.2 Dioxin Wipe Data

The database contained 1,535 wipe samples for dust dioxin loading that were collected from 263 residences, located in 157 buildings. Summary statistics for the data are provided in *Table 3-6*. The dioxin results were modified using a toxicity equivalency quotient (TEQ) that takes into account the toxicity differences between 17 congener groups**.** The results are reported in 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxicity equivalents. The TEQ values reported in *Table 3-6* represent the estimated maximum potential concentration (EMPC). The TEQ EMPC value used data that indicated the presence of a congener above zero mg/m^2 even if the sample did not meet all of the QA/QC reporting level criteria. This value represents the highest potential concentration of dioxin that may be present. At least one of the 17 congeners were detected in 1,136 of the samples; the remaining 399 samples were reported as below the detection limit for each congener. Only 8 of the 1,535 (approximately 0.5%) of the combined samples (i.e., *test only* and *clean and test*; *Table 3-6*) exceeded the health-based benchmark for residential dust dioxin loading of 2 ng/m2 (*Table 3-6*).

E.1.3.2 Wipe Data for Other Metals

Statistics for the 21 metals, and the reduction in the average dust loading rates for each, are provided in *Table 3-7*. The data are grouped into three categories in *Table 3-7*: samples collected from residences and common areas that were cleaned and tested (*clean and test samples*), samples that were collected from residences that were tested only (*test only samples*), and the combination of these two categories (*all samples*).

The database contained 1,517 results for mercury, and 1,544 results for all of the other metals. The rate of detection (based on all samples) varies widely from 0, for beryllium and thallium, to 100%, for calcium, copper, iron, magnesium, potassium and zinc. Eight of the 21 metals had detection rates of less than or equal to 5%; 4 had detection rates between 6 and 60%. Results for each metal were compared against risk-based screening levels (*Table 3-8*). Very few exceedances of the risk-based screening values were measured for any of the metals. The screening value of 627 µg/m^2, for antimony, was exceeded in 2 pre-cleanup samples (0.1% of all samples); the maximum measured value was 1,180 µg/m^2. The screening value of 157 µg/m^2 for mercury was exceeded in six samples (0.4% of all samples).

E.2.0 EFFICACY OF THE DUST CLEANUP EFFORT

E.2.1 Reductions in the Rate of Asbestos PCMe Exceedances

The efficacy of the asbestos cleanup effort was assessed using PCMe exceedances for *clean and test* data. One measure of effectiveness is the overall rate of exceedances, which equals the number of exceedances divided by the total number of samples that were collected (i.e., rate on a sample basis). The overall exceedance rate on a sample-basis for the WTC cleanup program was approximately 0.00418, or 0.42%.

An alternative measure of efficacy is the number of times a residence or a common area within a building (e.g., hallway, stairwell, laundry) had to be recleaned to achieve the clearance criteria of 0.0009 f/cc. The cleanup effort was effective in achieving the clearance criteria for PCMe approximately 99% of the time in residential units and common areas. The PCMe clearance criterion was not achieved in 35 out of 3,387 (1.03%) residences, and in 11 out of 785 common areas (1.40%) after the first cleaning. The probability of achieving the clearance on the second attempt in residential units that did not achieve clearance after the first cleaning approached 1 (>0.999; 2 out of the 25 residences that were recleaned did not achieve clearance after the second cleaning - 10 residents elected not to have their residences recleaned, or were unresponsive). The cleaning methods used were effective in reducing asbestos concentrations in residential air.

A *modified aggressive* sampling procedure was used in most of the apartments (EPA, 2003a). The modified-aggressive sampling procedure was adapted from the aggressive sampling procedure described in AHERA. The aggressive sampling procedure had a tendency to overload the sampling filter with dust, preventing the samples from being analyzed by the laboratory (EPA, 2003a). The modified aggressive sampling is thought to be more representative of typical household activity patterns (EPA, 2003a). The rate of exceedance varied between the two sampling procedures. On a sample basis, the exceedances rates in *test only* residences were 0.50 and 0.49% for the aggressive and modified aggressive sampling procedures, respectively; the exceedances rates for the *clean and test* residences were 3.4 and 0.20% for the aggressive and modified aggressive sampling procedures, respectively. The test only exceedances rates were not significantly different by Fisher's exact test ($p>0.99$); the *clean and test* exceedances rates were statistically significant by Fisher's exact test ($p<0.01$). On a residence-basis (i.e., one or more sample result from the residence equal or exceeded the benchmark for asbestos), the exceedances rates in *test only* residences were 3.0 and 1.1% for the aggressive and modified aggressive sampling procedures, respectively; the exceedances rates for the *clean and test* residences were 6.4 and 0.64% for the aggressive and modified aggressive sampling procedures, respectively. The *test only* exceedances rates were not significantly different by Fisher's exact test ($p>0.34$); the *clean and test* exceedances rates were statistically significant by Fisher's exact test ($p<0.01$).

E.2.2 Reductions in dust lead loadings

The indoor environment is considered to be a complex and dynamic system that is influenced by many interacting factors (physical, chemical, thermodynamic conditions, human activity, building design, building materials, HVAC system, etc.) Therefore, it is not uncommon to find variability in the amount of contaminants in settled dust within a building, and certainly from one building to the next. In addition to WTC proximity, the large CV is also likely due to the wide range of diversity in the housing stock, contents of the residences and common areas, and preexisting conditions, or previous activity, at these sites.

To assess the effectiveness of the cleanup program, the wipe data were divided into two groups: samples that were collected before the apartments were cleaned (*pre-cleanup)*, and samples that were collected after the apartments were cleaned (*post-cleanup)*. Pre-cleanup lead wipe samples and post-cleanup samples were collected from 214 apartments, located in 145 buildings. Samples that were below the detection limit of 1.86 $\mu g/ft^2$ were set equal to the detection limit. *Table 3-4* provides statistics for the pre-cleanup and post-cleanup lead wipe data; a more complete set of statistics is provided in *Appendix A*, *Table A-1*. On average, three pre-cleanup and three post-cleanup wipe samples were collected from each apartment (see *Section 2.2* for an overview of the cleanup program).

The data are highly positively skewed with a very large coefficient of variation (CV). The high positive skewness indicates that a few lead wipe samples contained much higher levels of lead than the majority of the samples (*Figure E-1*). The large CV indicates the data are highly variable; i.e., the lead wipe samples indicate the dust lead loadings vary over a wide range of values. One factor that is a likely contributor to variability in lead wipe sampling results is the presence of lead-based paint in older (i.e., pre 1950) housing. This factor is exemplified in the case of the two highest recorded lead wipe samples in the data set. These two samples were pre- (6,790 µg/ft2) and post-cleaning (7,250 µg/ft2) wipes obtained from the top of a storage chest. The lead loading measured in the two other pre-cleanup lead wipe samples collected from this residence was 3.57 and 91.8 $\mu g/ft^2$, and the lead loading in the two other post-cleanup samples was 7.41 and 7.56 $\mu g/ft^2$. The extremely high lead loads in these two matched samples prompted additional investigation which determined that the chest surface was remarkable for flaking paint. A paint chip sample was analyzed and contained 14% (140,000 µg/kg) lead, thus, providing a plausible explanation for the aforementioned sampling results. *Table 3-5* provides statistics for the pre-cleanup and post-cleanup lead wipe data with the above two values removed, as outliers; a more complete set of statistics is provided in *Appendix A*, *Table A-1a*. Although the above two outliers were excluded from the remainder of the analyses of the lead wipe data, their inclusion would not have changed the results of the statistical tests that are described later in this section.

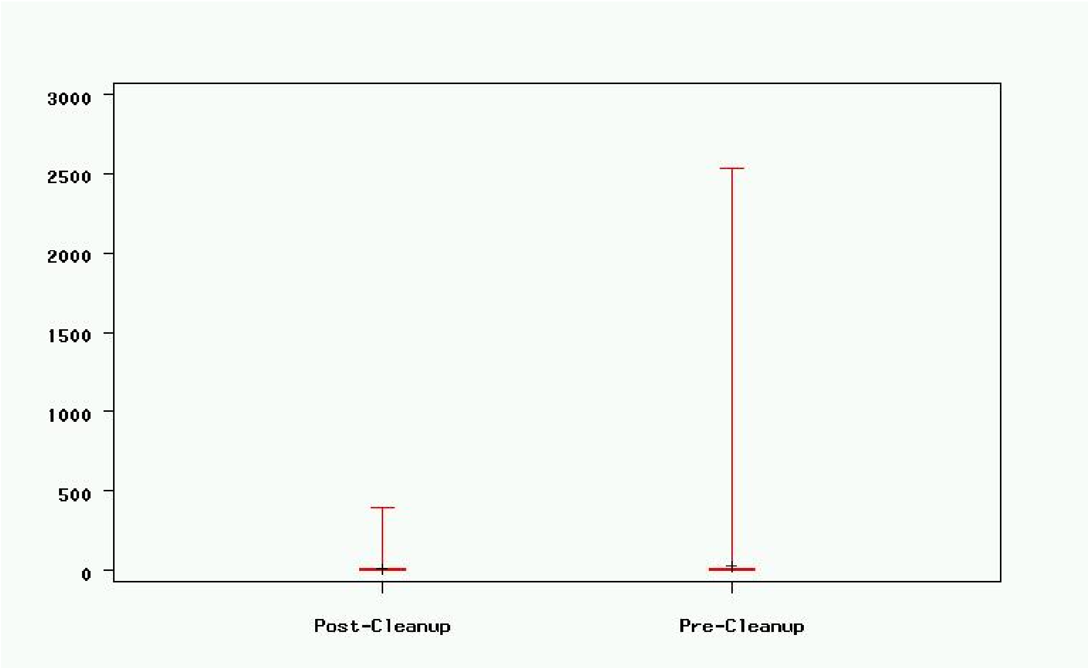

Figure E-1. Boxplots for residential dust lead loading (µg/ft^2), by sample type. The distributions of the pre- and post-cleanup average dust lead loadings exhibit extreme positive skewness. Typically (see *Figure 3-15a*), a boxplot consists of a box with a line emanating from each end. The upper part of the box is drawn at the 75 percentile (%) and the lower part of the box is drawn at the 25th %; the median is indicated by a line drawn through the box and the mean is indicated by a '+' sign. For a normal distribution, the mean and median will coincide. The line drawn out of the bottom of the box terminates at the minimum value; the line drawn from the top terminates at the maximum value. The extreme positive skewness exhibited by all the combined lead data results in the box appearing as a single line in the above figure. A log-transformation greatly improves the fit of a lognormal distribution to the data, however, the data continue to exhibit substantial positive skewness.

The high CV and skewness often mask differences between subsets of the data; e.g., between pre-cleanup and post-cleanup dust lead levels. The issue of high CV and skewness are closely related to the issue of normality. Many statistical methods for comparing two or more sets or subsets of data are based on an assumption that the data are derived from a normal distribution. As shown in *Figures E-2* and *E-3*, a normal distribution is a bell-shaped curve that is symmetric about the mean (i.e., skewness=0). One method of reducing the skewness and CV, thereby improving the fit of a normal distribution to the data, is to take the logarithms of the data. Log-transformation of the data reduced the skewness to 1.17 and 0.71 for the pre-cleanup and post-cleanup data, respectively, and the CV to 0.57 and 0.48, respectively. Likewise, tests for normality[3] indicate the log-transformation improved the fit of a normal distribution to

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[3] The following tests for normality were performed in each case: Anderson Darling, Cramer-von Mises, Kolmogorov-Smirnoff, and Shapiro-Wilk.

the pre-cleanup and post-cleanup data (S-W statistic increased to 0.90 and 0.89, respectively) however, the log-transformed data continue to display substantial departures from normality ($p<0.0001$ for both subsets).

The cleanup program reduced the overall number of exceedances from 92 (13.5 % of samples) to 20 (3.0% of samples). The mean and median of the combined post-cleanup data are less than the pre-cleanup data (*Table 3-5*).

One approach to assessing the effectiveness of the cleanup program would be to compare the distribution of the 680 pre-cleanup samples to the 673 post-cleanup samples, taking into account various factors that effect lead loading in residential areas (e.g., the amount and condition of lead-based paint, the amount of carpeted floors, the amount of upholstered furniture). This approach would provide the ability to estimate the effects of these various factors on the effectiveness of the cleanup program; however, data for these various factors are not readily available for the cleanup program.

An alternative to the above approach would be to calculate the difference between the mean pre-cleanup and mean post-cleanup lead wipe loadings for each of the 214 residences, and comparing the 214 differences. The advantage of analyzing the differences between pre-cleanup and post-cleanup loadings on a residence-by-residence basis is that it takes into consideration the multiple factors (e.g., age of buildings) that effect the dust lead loadings in an apartment, without the need to explicitly incorporate these factors in the analyses. Statistical comparisons between the pre-cleanup and post-cleanup dust lead loadings using the second approach will tend to be more powerful than those made using the first approach when multiple factors affect the dust lead loading[4]. Therefore, the second approach was adopted for this analysis.

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[4] The addition of factors in the analyses decreases the degrees of freedom that are available to compare the pre-cleanup dust lead loadings with the post-cleanup loadings.

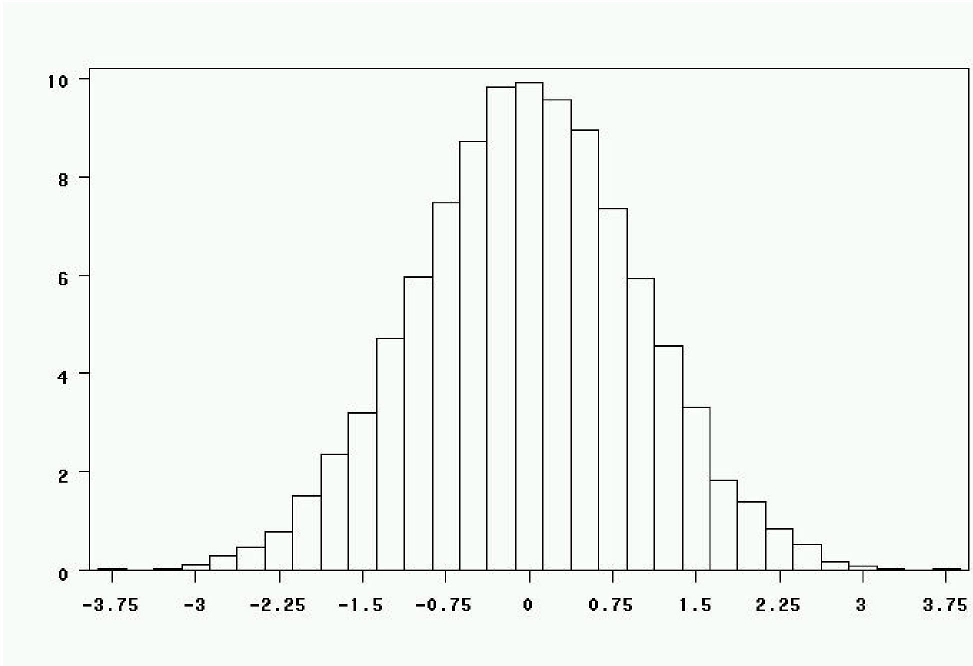

Figure E-2. Histogram for 10,000 randomly generated samples from a standard normal distribution. The value of the sample is shown on the x-axis, the y-axis shows the percent of the 10,000 samples that have the value indicated on the x-axis. For example, approximately 10% of the 10,000 samples have a value of approximately 0. The normal distribution is a bell-shaped curve that is symmetric about the mean, which equals 0 for the standard normal distribution. For any normal distribution, approximately 66% of the observations occur within a distance of 1 standard deviation of the mean; approximately 95% occur within a distance of 2 standard deviations of the mean. For example, approximately 66% of the 10,000 simulated values fall within the interval bounded by -1 and +1 and, approximately 95% of the values fall within the interval bounded by -2 and +2.

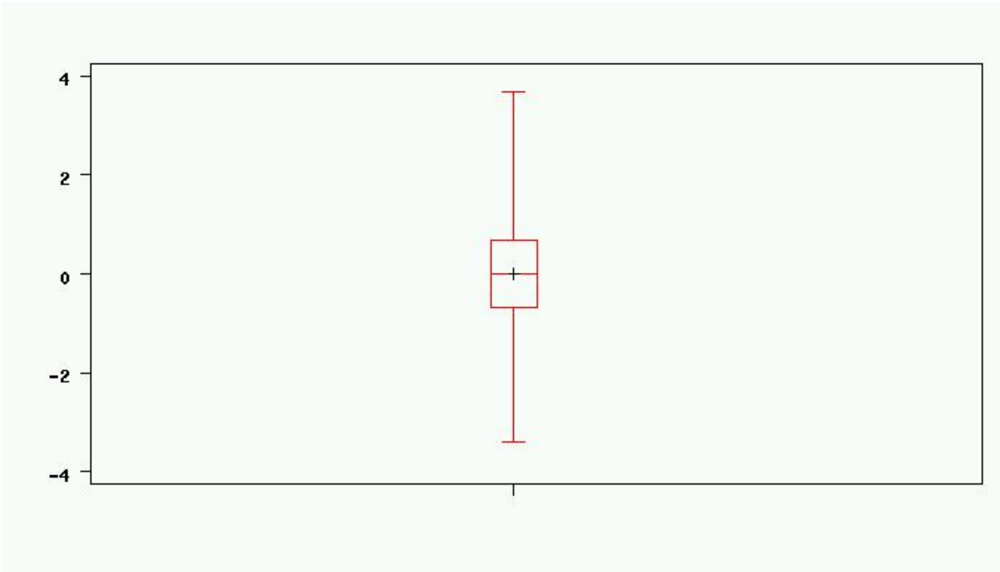

Figure E-3. Boxplot for 10,000 randomly generated samples from a standard normal distribution. The values of the samples (i.e., z-values or standard normal deviates) are shown on the y-axis. The boxplot is another method of illustrating the distribution of a sample. As shown above, the boxplot for a normal distribution is symmetric about the mean/median. The median (indicated by horizontal line that is located within the box) and mean (indicated by black '+') of a normal distribution are equal, and located at the center of the box. The 25th percentile of the distribution (indicated by the bottom of the box) and the 75th percentile (indicated by the top of the box) are equidistant from the median/mean; the extreme values (indicated by the short horizontal lines at the end of the vertical lines that emanate from the box) as are also approximately equidistant from the median/mean. The skewness of a normal distribution equals zero; a positively skewed population is characterized by a few observations that are much larger than the rest of the observation; see *Figure 3-1* for an example of extreme positive skewness.

Table E-1 presents statistics on the average pre-cleanup and post-cleanup dust lead loadings, on a residence-by-residence basis, and the reduction in the average dust lead loading for the 214 cleaned residences. A more complete set of statistics for lead wipe reductions is provided in *Appendix A*, *Table A-2*. The dust lead loadings shown in *Table E-1* are average loadings for each residence that were estimated with approximately three pre- and three post-cleanup samples collected from each residence. The distribution of the reductions is positively skewed with high variance (*Figure E-4*). Tests for normality indicate the normal distribution provides a poor fit to the data. A log-normal transformation of the data fails to substantially improve normality (S-W=0.37, $p<0.0001$). The evaluation to determine the efficacy of the cleanup program, presented below, considers the high variance, skewness and deviation from normality exhibited by the data.

On average, the cleanup program reduced the average dust lead loading in each residence by approximately 16 µg/ft^2 (95% confidence interval [CI][5], 10.0, 29.4%). The reduction in the mean dust lead loading was found to be statistically significant by the t-test ($t=3.64$, $p=0.0003$). The t-test assumes the differences are normally distributed, which is a questionable assumption for this data (*Table E-1*). As a check on the apparent violation of the normality assumption, the significance of the reduction in dust lead loadings was also tested using the nonparametric sign test. The sign test assumes only that the differences between the pre-cleanup and post-cleanup means are independent random variables[6]. The sign test considers only the direction of the difference (i.e., positive or negative), not the magnitude of the differences, which removes the effects of the extreme measurements (which produce the positive skewness) on the test results. The sign test also indicated the reduction in the dust lead loadings were significant ($M=53.5$, $p<0.0001$).

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[5] Confidence interval was determined by bootstrapping, using the bias-corrected accelerated (BCa) method (Efron and Tibshirani, 1993). The BC bootstrap method does not rely on an assumption of normality for the distribution of the mean of the reduction in dust lead loadings, and is therefore preferred over the typical method (i.e., using the t-distribution) for this data.

[6] This assumption is also not strictly valid because random sampling methods were not used to select which residences were cleaned (it was a voluntary program) and random sampling methods were not used to select the subset of the cleaned residences where dust wipe samples were collected.

Table E-1. Reduction in Average Lead Wipe Loadings (Pre- and Post-cleanup) (µg/ft^2)

Statistics for average pre-cleanup and post-cleanup residential dust lead loading measured by wipe samples are shown, and statistics for the reduction in the average dust lead loading. The average dust lead loadings and the reduction in the averages, continue to display substantial departures from normality; a log-transformation of the data fails to improve the fit of a normal distribution to the data (S-W statistic for reductions=0.37, p<0.0001; pre-cleanup averages: S-W statistic=0.95, p<0.0001; post-cleanup averages: S-W statistic=0.92). Outliers were removed from the dataset (see *Section 3.4.1* for details).

Statistic	Reduction in Average Lead Wipe Loading	Average Pre-Cleanup Lead Wipe Loading	Average Post-Cleanup Lead Wipe Loading
n	214	214	214
Mean	16.21	24.40	8.19
Standard deviation	65.16	66.34	17.10
Skewness	7.23	7.73	12.17
CV[a]	4.02	2.727	2.096
Var	4245.98	4401.40	292.29
Maximum	708.21	748.95	241.67
Median	1.77	8.66	6.79
Minimum	-163.27	1.86	1.86
S-W Statistic[b]	0.33	0.15	0.22
Prob Normal[c]	<0.0001	<0.0001	<0.0001

[a]CV=coefficient of variation=standard deviation/mean
[b]S-W Statistic: Shapiro-Wilk statistic
[c]Prob Normal: probability the data are from a normal distribution by Shapiro-Wilk test.

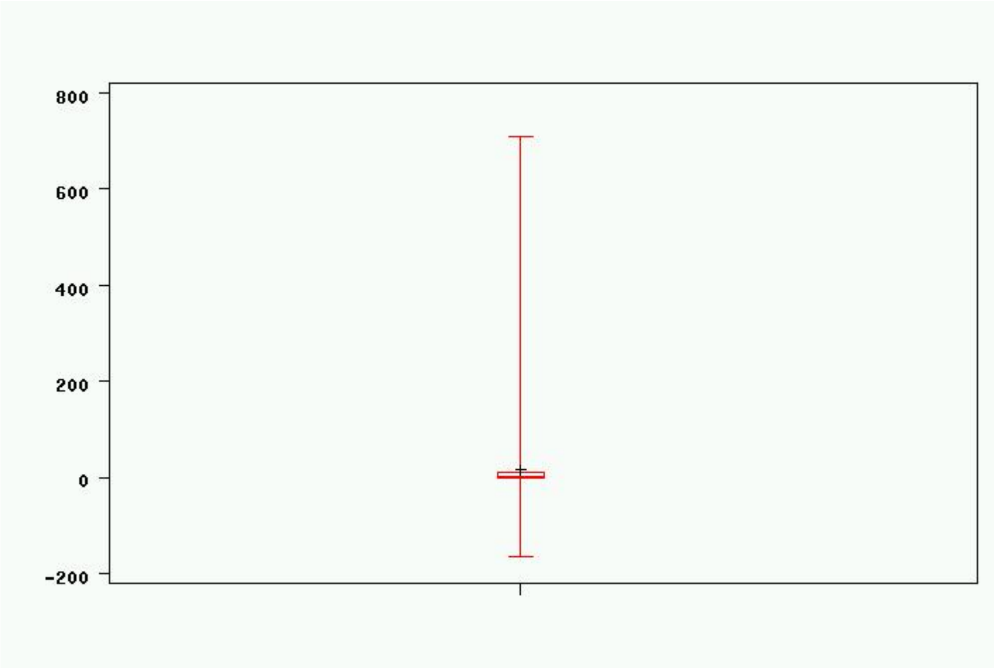

Figure E-4. Boxplot for the reduction in residential average dust lead loading (μg/ft²). The short 'box' indicates the majority of the reductions occur within a very short range of values; 50% of the reductions are between 0 and 9.50 μg/ft².

The effect of cleaning can also be expressed as a percent decrease in the dust lead loading (*Equation E-13*). The mean percent reduction in dust lead loading was 20.4% (95% CI[3], 8.8, 27.9%). The data set included two extreme negative percent decreases; an increase in mean dust lead loading of 485% that corresponded to an increase from a pre-cleanup mean loading of 4.9 μg/ft² to a post-cleanup loading of 27.1 for a 22nd floor residence, and an increase from 4.4 to 25.9 μg/ft² for a 5th floor residence. After these observations were removed from the data, the mean percent reduction in dust lead loading was 25.0% (95% CI, 17.7, 31.3%).

$$Percent\ decrease = 100 \cdot \frac{(\bar{x}_{pre} - \bar{x}_{post})}{\bar{x}_{pre}}$$ Equation E-13

Where,

$\bar{x}_{pre}$ = *average pre-cleanup dust lead loading*

$\bar{x}_{pre}$ = *average post-cleanup dust lead loading*

Another method for analyzing the effectiveness of the cleanup program in reducing dust lead loadings is to determine the rate (i.e., proportion of residences) at which the average dust lead loadings were reduced by the cleanup. In 9 of the residences, all of the average pre- and post-cleanup dust lead loading measurements were less than the detection limit. Of the remaining 205 residences, the post-cleanup average dust lead loading was greater than the pre-cleanup average in 49 residences, and lower in the other 156 residences, yielding a rate of reduction of approximately 76%. The sign test discussed in the previous paragraph is based on the number of reductions (i.e., not the magnitude of the reductions) and, therefore, provides a test for the statistical significance for the rate of reduction (i.e., the number of reductions / the number of *cleaned and tested* residences). Therefore, the sign test indicates that the rate at which the cleanup program lowered the average residential dust lead loading is statistically significant (M=53.5, p<0.0001).

E.2.2.1 Reductions in dust lead loadings in residences with pre-cleanup levels greater than the health-based benchmarks for lead loading

The effectiveness of the cleanup program at reducing dust lead loading in the 36 residences that had pre-cleanup dust lead loadings greater than the HUD screening level of 25 µg/ft^2 was assessed. *Table E-2* provides statistics for dust lead loading for these residences; a more complete set of statistics is provided in *Appendix A, Table A-3*. The dust lead loadings shown in *Table E-2* are average loadings for each residence that were estimated with approximately three pre- and three post-cleanup samples collected from each residence. As expected, the distributions of the average pre-cleanup, post-cleanup and dust lead loading reductions for this subset of the data are less skewed and have lower CVs than the distribution of the lead loadings for all 214 sampled apartments. The log-transformation of the reductions in the average loading does not substantially improve normality (S-W statistic=0.71, p<0.0001).

Thirty-six residences had pre-cleanup average dust lead loadings greater than the HUD screening of 25 µg/ft^2. The cleanup program reduced the average dust lead loading in the residences with average pre-cleanup loadings above the HUD screening level by approximately 85 µg/ft^2 (95% CI,[3] 71.2, 173.6%). The reduction in the average dust lead loading was found to be statistically significant (t-test, t=3.61, p=0.0009; sign test, M=17, p<0.0001).

The cleanup program was successful in reducing average dust lead loading in 31 of the 36 residences to below the 25 µg/ft^2 HUD screening level, a success rate of approximately 86%. In four other residences, the average post-cleanup dust lead loading was substantially reduced, but remained above 25 μg/ft^2; from 749.0 to 40.7, 149.3 to 28.8; 120.9 to 39.2; 83.2 to 40.7; and 61.6 to 31.7 μg/ft^2. The post-cleanup average increased from 78 to 242 μg/ft^2 in one residence. In three cases, a residence with a pre-cleanup average dust lead loading less than the screening level had a post-cleanup average that exceeded the screening level. The increases in post-cleanup average dust lead loadings could reflect sampling variability or site-specific factors that can not be assessed with data that are currently available.

Twenty-three residences had pre-cleanup average dust lead loadings greater than the HUD benchmark of 40 μg/ft^2. Average post-cleanup dust lead loading in residences with average pre-cleanup loadings above the HUD benchmark of 40 μg/ft^2 were approximately 120 μg/ft^2 lower than average pre-cleanup loadings. The cleanup program reduced the average dust lead leading in 21 out of the 23 residences, a success rate of approximately 91%.

Table E-2. Statistics on Reduction in Average Lead Wipe Loadings (Pre- and Post-Cleanup) (μg/ft^2) in Residences with Pre-cleanup Greater than the Health-based Benchmark of 25 ug/ft^2

The average dust lead loadings and the reduction in the averages show less variation and are less skewed than the complete distribution of average residential dust lead loadings. A log-transformation of the averages slightly improves the fit of a normal distribution to the data (S-W statistic for reductions=0.71, p<0.0001; pre-cleanup averages: S-W statistic=0.89, p<0.0001; post-cleanup averages: S-W statistic=0.88, p<0.0001); however, significant departures from the normal distribution model remain. Outliers were removed from the dataset (see *Section 3.4.1* for details).

Statistic	Reduction in Average Lead Wipe Loading	Average Pre-cleanup Lead Wipe Loading	Average Post-Cleanup Lead Wipe Loading
n	36	36	36
Mean	84.84	102.12	17.28
Standard deviation	140.85	138.37	39.62
Skewness	2.90	3.47	5.49
CV[a]	166.01	135.50	229.28
Var	19838.34	19147.47	1569.75
Maximum	708.21	748.95	241.67
Median	38.82	48.52	8.08
Minimum	-163.27	25.86	1.86
S-W Statistic[b]	0.64	0.56	0.32
Prob Normal[c]	<0.0001	<0.0001	<0.0001

[a]CV=coefficient of variation=standard deviation/mean
[b]S-W Statistic: Shapiro-Wilk statistic
[c]Prob Normal: probability the data are from a normal distribution by Shapiro-Wilk test

E.2.2.2 Effect of Floor Level / Pre-Cleanup Average Dust Lead Loading on the Reduction in Dust Lead Levels

The reduction in lead loadings (on a percent change basis) was related to building floor number, through an effect of floor number on pre-cleanup mean dust lead loadings. Lower floors tended to have higher pre-cleanup lead loadings[7] and, therefore, showed greater reduction in loading (discussed further in *Section E.4.3*). Of the 36 residences with pre-cleanup means greater than the HUD screening level of 25 µg/ft^2, 17 of them were located on lower floors (i.e., ≤ 3rd floor), 14 on floors between the 4th and 10th floors, and 5 at floors greater than the 10th (two at 11 and one at 12). *Figure E-5* shows a plot of the log-transformed pre-cleanup means vs. floor number; higher average pre-cleanup loadings tended to occur in residences that are located on floors 10 and lower.

In the following analysis, floor numbers are used as a surrogate for pre-cleanup average concentration. Typically, 30 observations or more are desired for making statistical comparisons between two or more groups of data. None of the floor levels had 30 observations and just six floor levels had 10 or more observations (i.e., differences between pre- and post-cleanup dust lead loadings). Therefore, floor levels were combined into three groups: the first group (*lower*) consisting of basement through 3rd floor residences, second group (*middle*) consisting of floors 4 through 10, and the third group consisting of all residences in floors 11 and up (*upper*). Statistics for the pre-cleanup average dust lead loadings for each floor group are shown in *Table E-5*; *Table A-4* provides additional statistics for this data. The data show moderate to high variability, and large positive skewness; log-transformation substantially improved normality for all three floor groups. The differences between the means of the pre-cleanup average dust lead loading between the lower and upper floor groups (25.3 µg/ft^2) is statistically significant (t-test with log-transformed data = 2.60, p=0.0104); the difference between the medians of the lower and upper floor groups is statistically significant by the Mann-Whitney test (W=1,375, p=0.0185).

[7] Older buildings in lower Manhattan tend to have fewer floors than newer buildings. The tendency for lower floors to contain higher pre-cleanup lead loadings may be attributable, at least in part, to the age of the building.

Table E-3. Statistics for Average Pre-Cleanup Residential Dust Lead Loading by Floor Group (µg/ft²)

The tendency for average dust lead loadings to decrease with increasing floor level is indicated by the statistics shown in the table. Also shown is a tendency for the variance to increase with increasing average dust lead loading. When grouped by floor level, the average pre-cleanup dust lead loadings show less variation and are less skewed than the complete distribution of average residential dust lead loadings. A log-transformation of the averages substantially improves the fit of a normal distribution to the data (S-W statistic for lower floor group=0.95, p=0.0149; middle: S-W statistic=0.96, p=0.0127; upper: S-W statistic=0.90, p<0.0002). Outliers were removed from the dataset (see *Section 3.4.*1 for details).

Statistic	Floor Group[a]		
	Lower	**Middle**	**Upper**
n	61	93	60
Minimum	1.86	1.86	1.86
Maximum	748.95	413.87	294.33
Median	9.20	10.03	7.25
Mean	39.52	21.08	14.18
Standard deviation	102.71	46.41	37.98
Skewness	5.84	6.97	7.06
CV[b]	2.60	2.20	2.68
S-W Statistic[c]	0.36	0.34	0.25
Prob Normal[d]	<0.0001	<0.0001	<0.0001

[a]Floor Group: Lower=floors ≤ 3; Middle=3 < floors ≤ 10; upper=floors >10
[b]CV=coefficient of variation=standard deviation/mean
[c]S-W Statistic: Shapiro-Wilk statistic
[d]Prob Normal: probability the data are from a normal distribution by Shapiro-Wilk test

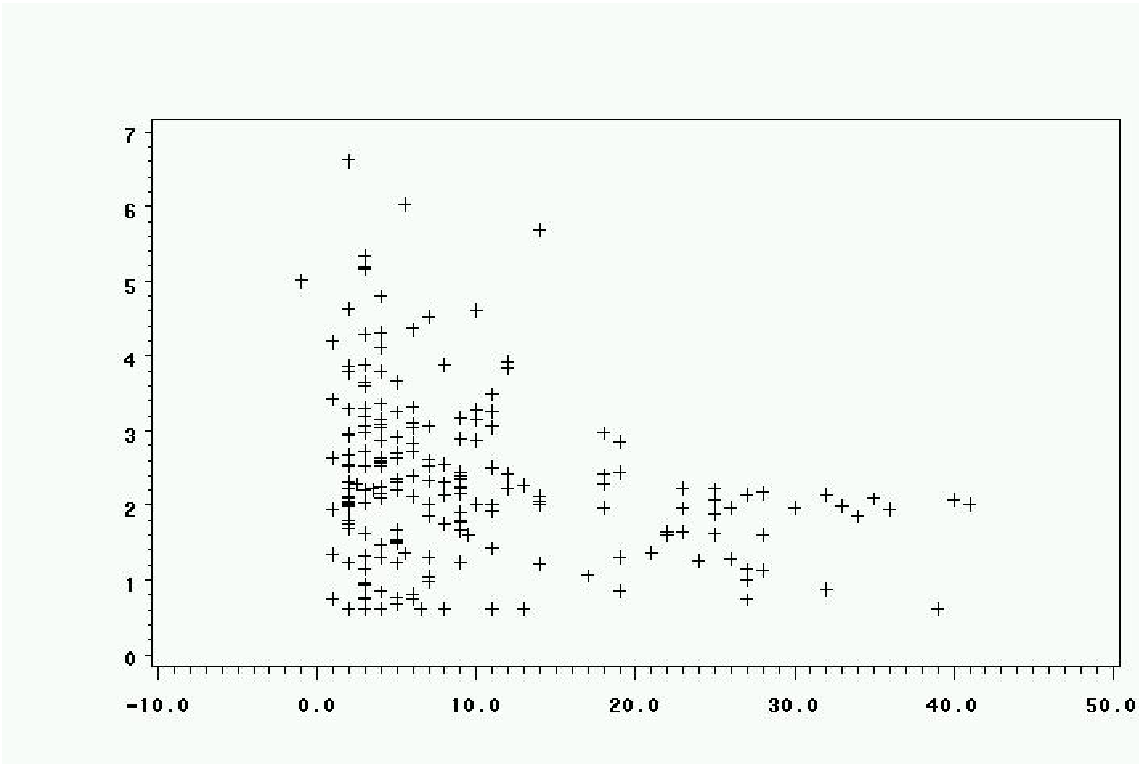

Figure E-5. Scatter plot of log-transformed pre-cleanup residential average dust lead loadings (vertical axis), by floor. The plot indicates that the pre-cleanup average residential dust lead loading decreases with increasing floor levels up to approximately floor level of 15. The mean and variability in pre-cleanup average dust lead loading is fairly constant at floors higher than 15.

The difference between the means of the middle and upper floor groups (6.9 $\mu g/ft^2$) is statistically significant (t-test with log-transformed data = 2.22, p=0.0281); the difference between the medians of the middle and upper floor groups is statistically significant by the Mann-Whitney test (W=2,067, p=0.0069).

As expected, the reduction in dust lead loading in $\mu g/ft^2$, and on a percent decrease basis, varied by floor level (i.e., pre-cleanup average loading) (*Tables E-4* and *E-5*). The differences in the reductions in dust lead loading between the lower and upper floor groups, and the middle and upper floor groups were found to be significant by the nonparametric Mann-Whitney test (W=986.0, p=<0.0001; W=2034.5, p=<0.0048, respectively). Prior to estimating the difference in the percent reduction in dust lead loadings between the different floor groups, two observations with extreme negative percent reductions were removed from the data set (see *Section E.4.1* for details). The differences in the percent reductions in dust lead loading between the lower and upper floor groups, and the middle and upper floor groups of were found to be significant by the Mann-Whitney test (W=934.5, p=<0.0001; W=1978.5, p=<0.0051, respectively). The cleanup program was successful in reducing the dust lead loading in residences with the highest pre-cleanup average loadings (i.e., located on floor numbers 3 and lower) by approximately 33.1 μg/ft^2, or 43.5 % (95% CI,[3] 17.8, 78.9 μg/ft^2; 29.71, 53.39%). Average residential dust lead loadings in the middle floors were reduced on average by 11.1 μg/ft^2, or 23.1 % (95% CI,[3] 4.40, 27.14 μg/ft^2, 17.42, 39.55 %, respectively). The dust lead loading in floors higher than 10 were reduced on average by 6.9 μg/ft^2, or 8.6% (95% CI,[3] 1.44, 28.54 μg/ft^2, -2.70, 18.35 %, respectively).

E.2.3 Reductions in Dust Dioxin Loadings

The measurable effect of the cleanup program on dust dioxin loadings was less than it was for lead due primarily to low pre-cleanup dust dioxin loadings, which limits the usefulness of the dioxin data to assess the efficacy of the dust cleanup program. For this reason, the analysis of the dioxin results is less extensive than the analysis of the lead results.

Pre-cleanup and post-cleanup dust wipe samples for dioxin were collected from 212 apartments, located in 145 buildings. *Table E-6* provides statistics for the pre-cleanup and post-cleanup dioxin wipe data; a more complete set of statistics is provided in *Appendix A, Table A-5* and *A-5a*. On average, three pre-cleanup and three post-cleanup wipe samples were collected from each apartment (see *Section 2.2* for a description of the cleanup program). The dioxin loading measured in one sample had a value of 75.3 ng/m^2, approximately 20 times higher than the next highest value (5.14 ng/m^2). This sample was removed from the data set as an outlier. The pre- and post-cleanup data exhibit moderate variance and positive skewness, and the normal distribution is found to be a poor fit to the data (*Figure E-6*). A log-normal transformation of the data fails to substantially improve normality. Given the low levels of dioxin that were found prior to cleanup, the mean and median of the post-cleanup data are very similar to the mean and median of the pre-cleanup data.

Table E-4. Reduction in Dust Lead Loading by Floor Group ($\mu g/ft^2$)

The mean reduction in average residential dust lead loading varies by floor level, as expected given the large variation in average pre-cleanup dust lead loadings between the floor groups. The difference in the reduction between the lower and upper floor groups, and between the middle and upper floor groups, are statistically significant (see *Section 3.3.2.3* for details). A log-transformation of the averages fails to improve the fit of a normal distribution to the data (S-W statistic for lower floor group=0.41, p<0.0001; middle: S-W statistic=0.41, p<0.0001; upper: S-W statistic= 0.27, p<0.0001). Outliers were removed from the dataset (see *Section 3.4.1* for details).

Statistic	**Floor Group[a]**		
	Lower	**Middle**	**Upper**
n	61	93	60
Minimum	-6.18	-163.27	-22.18
Maximum	708.21	408.96	289.03
Median	3.94	2.37	0.51
Mean	33.11	11.10	6.94
Standard deviation	97.77	48.91	38.14
Skewness	5.85	5.61	7.10
CV	2.95	4.40	5.50
S-W Statistic	0.35	0.37	0.25
Prob Normal	<0.0001	<0.0001	<0.0001

[a]Floor Group: Lower=floors ≤ 3; Middle=3 <floors ≤ 10; upper=floors >10
[b]CV=coefficient of variation=standard deviation/mean
[c]S-W Statistic: Shapiro-Wilk statistic
[d]Prob Normal: probability the data are from a normal distribution by Shapiro-Wilk test

Table E-5. Percent Reduction in Average Residential Dust Lead Loading by Floor Group (µg/ft^2)

The percent reduction in average residential dust lead loading varies by floor level. The difference in the reduction between the lower and upper floor groups, and between the middle and upper floor groups, are statistically significant (see *Section 3.3.2.3* for details). The negative skewness for each floor level is due to a few increases in average dust lead loading after cleanup. In addition to the two observations that were removed as outliers (see *Section 3.4.1*), two residences were removed from the this analysis as outliers; the average post-cleanup dust lead loading in these residences were 484% and 448% higher than the pre-cleanup average (i.e., increased from 4.4 to 25.9, and 4.9 to 27.1 µg/ft^2, respectively).

Statistic	**Floor Group[a]**		
	Lower	**Middle**	**Upper**
n	61	92	59
Minimum	-180.10	-208.25	-149.79
Maximum	95.41	98.82	98.20
Median	57.39	29.24	6.94
Mean	43.48	23.13	8.64
Standard deviation	47.02	54.51	41.71
Skewness	-1.84	-1.69	-0.70
CV	1.08	2.36	4.83
S-W Statistic	0.83	0.87	0.95
Prob Normal	<0.0001	<0.0001	<0.0085

[a]Floor Group: Lower=floors ≤ 3; Middle=3 < floors ≤ 10; upper=floors >10
[b]CV=coefficient of variation=standard deviation/mean
[c]S-W Statistic: Shapiro-Wilk statistic
[d]Prob Normal: probability the data are from a normal distribution by Shapiro-Wilk test

Table E-6. Statistics for Dioxin Wipe *Clean and Test* Data (ng/m^2)			
The data summarized in the above table are dioxin toxicity equivalents (TEQs), which are the sum of 17 different chemical forms (congeners) of dioxin. The *clean and test* subset of the data exhibit high positive skewness but low variance. Few exceedances were observed for dioxin. The raw data and log-transformed pre- and post-cleanup data fail the S-W test for normality (log-transformed data [pre-/post-]: S-W statistic=0.71/0.89, p<0.0001/p<0.0001).			
Statistic	**Pre-Cleanup**	**Pre-Cleanup[a]**	**Post-Cleanup**
Apartments sampled	213	213	213
Buildings sampled	145	145	145
Number of samples	674	673	668
Nondetects	162 (24.0%)	162 (24.1%)	228 (34.1%)
Exceedances[b]	3 (0.4%)	2 (0.3%)	4 (0.6%)
Minimum	0.27	0.27	0.27
Median	0.60	0.60	0.59
Mean	0.81	0.66	0.65
Maximum	103	5.14	4.34
Standard deviation	3.95	0.29	0.28
Skewness	25.75	6.79	5.27
CV[c]	0.49	0.44	0.42
S-W Statistic[d]	0.03	0.57	0.62
Prob Normal[e]	<0.0001	<0.0001	<0.0001

[a]Statistics for pre-cleanup data with one outlier removed (see *Section E.2.3* for details).
[a]Exceedance: dioxin wipe samples that exceeded the health-based benchmark of 2 ng/m^2 TEQ EMPC (ND=1/2).
[b]CV=coefficient of variation=standard deviation/mean
[c]SW-Statistic: Shapiro-Wilk statistic
[d]Prob Normal: probability the data are from a normal distribution deviation/mean

Table E-7 presents statistics on the average pre-cleanup, average post-cleanup and average reduction in dust dioxin loadings, on a residence-by-residence basis. The distribution of the reductions is moderately negatively skewed with high variance (*Figure E-7*). Tests for normality indicate the normal distribution provides a poor fit to the data. A log-normal transformation of the data fails to improve normality (S-W=0.85, p<0.0001).

On average, the cleanup program reduced the average dioxin loading by approximately 0.01 ng/m^2 (95% CI,[3] –0.0161, 0.0327%). The inclusion of zero within the CI indicates that the reduction in dust dioxin loading is not significant. However, the sign test (M=14, p=0.06) and, particularly, the Wilcoxon signed rank test (S=1,790, p=0.05), indicate that the reduction in dust dioxin loadings was significant. The

Wilcoxon signed rank test will tend to be more powerful at detecting differences between the pre-cleanup and post-cleanup average dust dioxin loadings than the sign test provided that the distribution of the differences in dust dioxin loading is symmetric (but not necessarily conforming to a normal distribution) (Conover, 1999). Based on *Figure E-7*, the assumption of symmetry appears to be reasonable.

The post-cleanup average dioxin loading was greater than the pre-cleanup average in 92 residences, and lower in the other 120 residences, yielding a rate of reduction of approximately 57 %. The sign test (see preceding paragraph) indicates that the rate at which the cleanup program lowered the average residential dust dioxin loading is statistically significant.

To assess the effectiveness of the dust cleanup program for residences that had measurable pre-cleanup dust dioxin loading, the comparison between residential average pre-cleanup dust dioxin loadings and residential average post-cleanup dust dioxin loadings was limited to residences where all the pre-cleanup measurements for dioxin were above the detection limit. There were 124 residences In 93 buildings that met this criterion. The pre-cleanup measurement of 75.3 ng/m^2 was not included in this data set (see preceding section). The cleanup program reduced the residential average dust dioxin loading in these 124 residences by approximately 0.01 ng/m^2, the same average reduction that was observed in the 212 residences.

Table E-7. Reduction in Average Dioxin Wipe Loadings (TEQ)[a] (Pre- and Post-Cleanup) (ng/m^2)

The reductions in average residential dust dioxin loadings are more modest than the reductions achieved for average dust lead loading, primarily due to the low average pre-cleanup dust dioxin loadings. Analysis of the reduction in the residential average dust dioxin loading in a subset of the 212 residences, where all pre-cleanup sample measurements results were greater than the detection limit, also indicated an average reduction of 0.01 ng/m^2.

Statistic	Reduction in Average Dioxin Wipe Loading	Average Pre-Cleanup Dioxin Wipe Loading	Average Post-Cleanup Dioxin Wipe Loading
n	212	212	212
Mean	0.01	0.65	0.64
Standard deviation	0.18	0.18	0.19
Skewness	-0.97	1.88	2.06
CV[b]	19.02	0.28	0.30
Var	0.03	0.03	0.04
Maximum	0.63	1.61	1.36
Median	0.01	0.60	0.60
Minimum	-0.81	0.33	0.32
S-W Statistic[c]	0.85	0.83	0.78
Prob Normal[d]	<0.0001	<0.0001	<0.0001

[a]TEQ: toxicity equivalent quotient.
[b]CV=coefficient of variation=standard deviation/mean
[c]S-W Statistic: Shapiro-Wilk statistic
[d]Prob Normal: probability the data are from a normal distribution by Shapiro-Wilk test

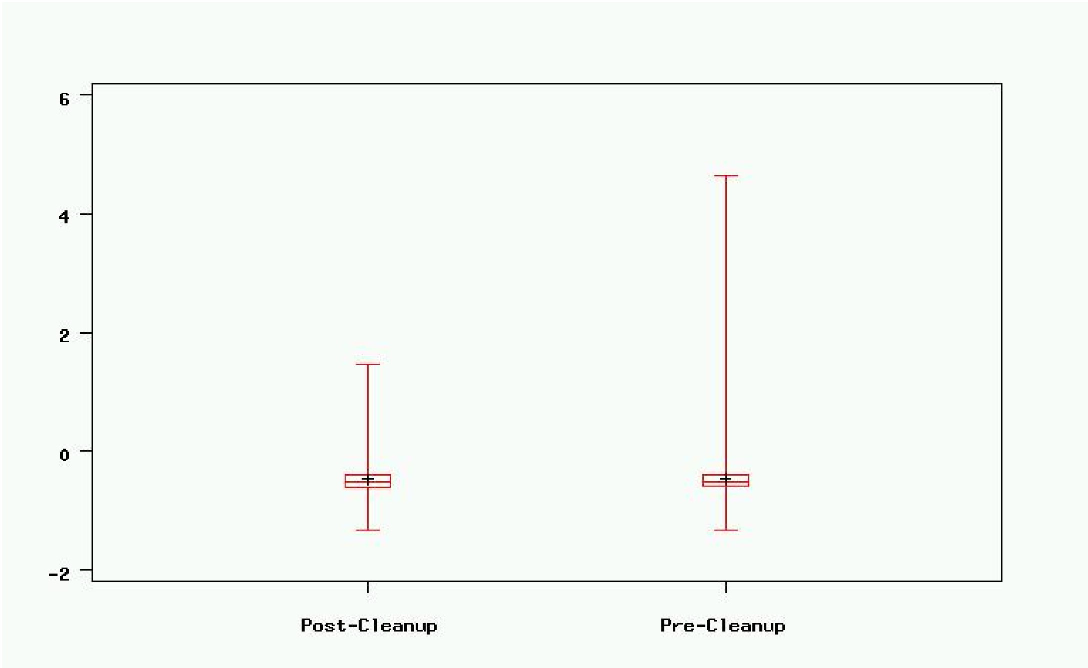

Figure E-6. Boxplots for residential dust dioxin loading (μg/ft^2), by sample type. The distributions of the pre- and post-cleanup average dust dioxin loadings also exhibit extreme positive skewness. No pre- or post-cleanup average dust dioxin loadings exceeded the health-based benchmark of 2 ng/m^2. One observation, with a value of 103 ng/m^r, was removed from the data as an outlier.

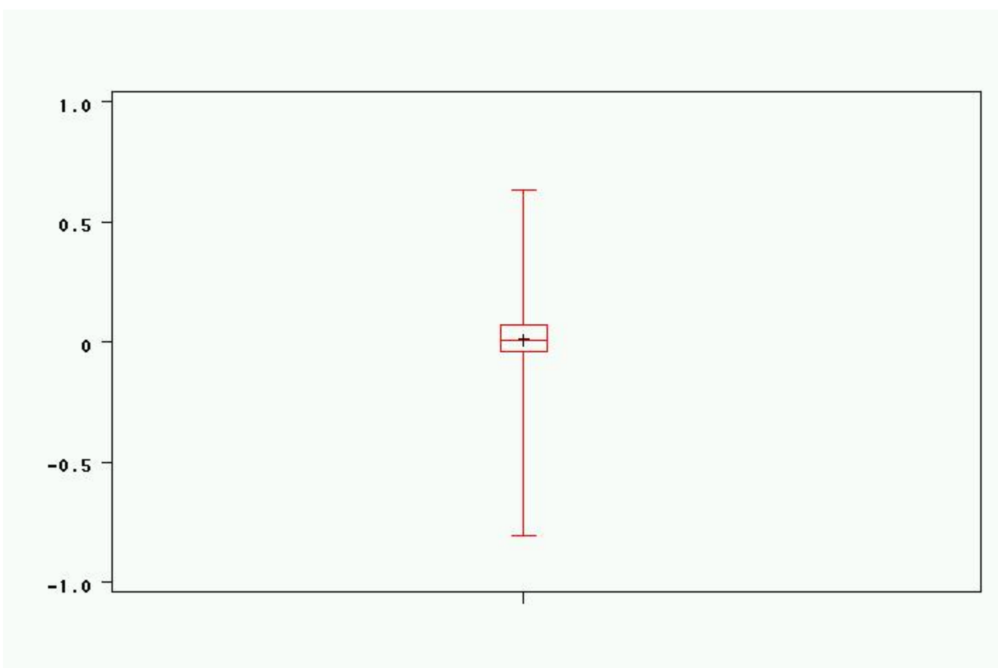

Figure E-7. Boxplot for the reduction in residential average dioxin wipe reductions. The short length of the 'box' indicates the most of the reductions are close to zero. The small reductions are due to the low pre-cleanup average dust dioxin loadings in all but one of the residences (the residence with the one high pre-cleanup dioxin dust loading of 103 ng/m^2). One observation, with a value of 103 ng/m^r, was removed from the data as an outlier. This observation was collected from the mantle of a fireplace.

E.3.0 SPATIAL PATTERN OF PCMe EXCEEDANCES

E.3.1 Analytical Approach

E.3.1.1 Purpose

Data were analyzed to detect the possible presence of spatial, or geographic patterns in the occurrence of PCMe exceedances. In this report, a PCMe exceedance is defined as a sample result that exceeded the heath-based benchmark of 0.0009 fibers/cc. Detection of spatial patterns in the exceedances could be used to identify possible sources of the exceedances, or lead to explanations for the exceedances. The latter could be used to improve future cleanup and/or monitoring efforts. The data were divided into two groups: data from residences and building common areas that were cleaned and tested (clean and test data), and data from residences that were tested only (test only data). All common areas (e.g., lobbies, laundry rooms, hallways, stairwells) were cleaned and tested.

E.3.1.2 Analytical Methods and Spatial Resolution

The methods that are used to detect and measure spatial patterns depend upon the spatial scale and resolution at which the spatial patterns are analyzed. The spatial scale refers to the geographic extent over which the analysis is performed. In this report, the geographic scale is lower Manhattan, south of Canal Street (*Figure 1-1*). Regarding geographical scale, the pattern of PCMe exceedance could be analyzed by examining the buildings where the health-based benchmark was exceeded, or by examining the number, or rate of exceedances over larger geographic areas. As resolution decreases, the data must be aggregated (e.g., summed, averaged) over the chosen geographic units (e.g., zip codes), which results in some loss of geographic information (i.e., the exact location where the individual exceedances occurred). However, aggregating the data tends to reduce variability, which may then reveal spatial patterns that had been obscured by small-scale variability in the data (i.e., fluctuations in the data over short distances).

The appropriate spatial scale and resolution depends upon the objectives of the analysis. For example, one of the objectives of this analysis was to determine if the geographic location of PCMe exceedances were clustered geographically. For this objective, the PCMe data were analyzed at the site level and the building level (the latter being the smallest geographic unit reported). The second objective was to determine if the rate of PCMe exceedance (i.e., number of exceedances/number of samples analyzed) varied across the area that was potentially affected by the collapse of the WTC buildings. For this objective, the PCMe data were aggregated over statistical summary areas (SSAs) (*Figure 1-1*). Statistical summary areas were based on census-block groups that were modified by EPA for the purposes of describing the PCMe data.

Spatial pattern analyses at the site level and building level were performed using methods of point pattern analysis (Cressie, 1993; Bailey and Gatrell, 1995). In point pattern analysis, the focus is on the location of exceedances. The goal is to determine if there are any geographic patterns exhibited by the location of the exceedances. In general, there are two types of geographic patterns that are possible: clustering and dispersion (or regularity). Clustering is exhibited by the tendency for points to be located in clumps, while dispersion refers to the tendency for points to be more regularly distributed than would be expected, based on chance. An example of a point pattern that exhibits dispersion is a square grid. The primary focus in this study is on identifying clusters of exceedances, which could indicate an asbestos source, or otherwise lead to an explanation for the elevated air borne asbestos concentrations.

Analysis of the PCMe data at the SSA scale was performed using methods from spatial autoregression analysis. Spatial autoregression is a type of statistical regression analysis that considers the spatial autocorrelation exhibited by the data, if any. In the present context, (positive) spatial autocorrelation is the tendency for SSAs with similar rates of PCMe exceedances to be located near each other. Classical regression analysis assumes the data are independent and identically distributed (iid)[8]. Data that exhibit spatial autocorrelation violate the independent portion of this assumption. Therefore, using classical regression methods with data that exhibits spatial autocorrelation will affect the accuracy of statistical tests that are made with the data; for example, testing the rates of PCMe exceedances between SSAs could lead to erroneous conclusions.

E.3.1.3 PCMe Exceedance as a Spatial Poisson Process

The spatial analysis of the PCMe exceedances that is presented in *Sections E.3.2.2* and *E.3.2.3* is based on the assumption that the exceedances can be modeled as a Poisson distribution (*Figures E-8* and *E-9*). The rationale for this assumption is as follows.

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[8] Many methods of classical statistical analysis are developed mathematically based, in part, on the assumption that the data are independent and identically distributed. The assumption of independence requires that the probability that an observation from the sample takes on a given value is not dependent upon the values of any of the other observations. The identically distributed assumption requires that all of the observations are members of the same population (i.e., the same distribution function).

The spatial analysis of the PCMe data focuses on the spatial distribution of PCMe exceedances, rather than on the spatial distribution of the PCMe concentration. When analyzed in this way, the PCMe data are converted into one of two values: one (concentrations > 0.0009 f/cc) or zero (concentrations < 0.0009 f/cc). In this format, the data can be modeled with a binomial distribution (DeGroot, 1989):

$$f(x \mid n, p) = \binom{x}{n} p^{x} (1 - p)^{n-x}$$ Equation E-1

The expression on the left hand side of *Equation E-1* is interpreted as the probability of observing *x* exceedances out of *n* air samples (i.e., tests), given the probability of observing an exceedance from any given test (*p*). The variable *x* therefore is limited to positive integers between zero and the sample size (i.e., *x* = 0, 1, 2, …., *n*). The parameter p is estimated from the data; it is the total number of exceedances divided by the number of samples (*n*). The $\binom{x}{n}$ symbol represents the number of *combinations* of *n* objects taken *x* at a time[9]. Assuming a binomial distribution provides a good fit to the PCMe exceedance data, the expected number of exceedances, given *n* samples and probability *p* is:

$$E[X] = np$$ Equation E-2

and its variance of x is:

$$Var[X] = np(1 - p)$$ Equation E-3

Notice that the number of exceedances will tend to increase with sample size. The variance also increases with sample size. The relationship between variance and sample size must be considered when comparing exceedance rates between areas with different sample sizes; this point is discussed further in *Section E.3.2.2*.

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[9] In the present context, it represents the number of ways that x exceedances could be observed in n samples, when order is not important. The right hand side of equation 1A equals the number of ways that *x* exceedances could be observed in a sample of size *n,* multiplied by the probability of observing an exceedance for any given test.

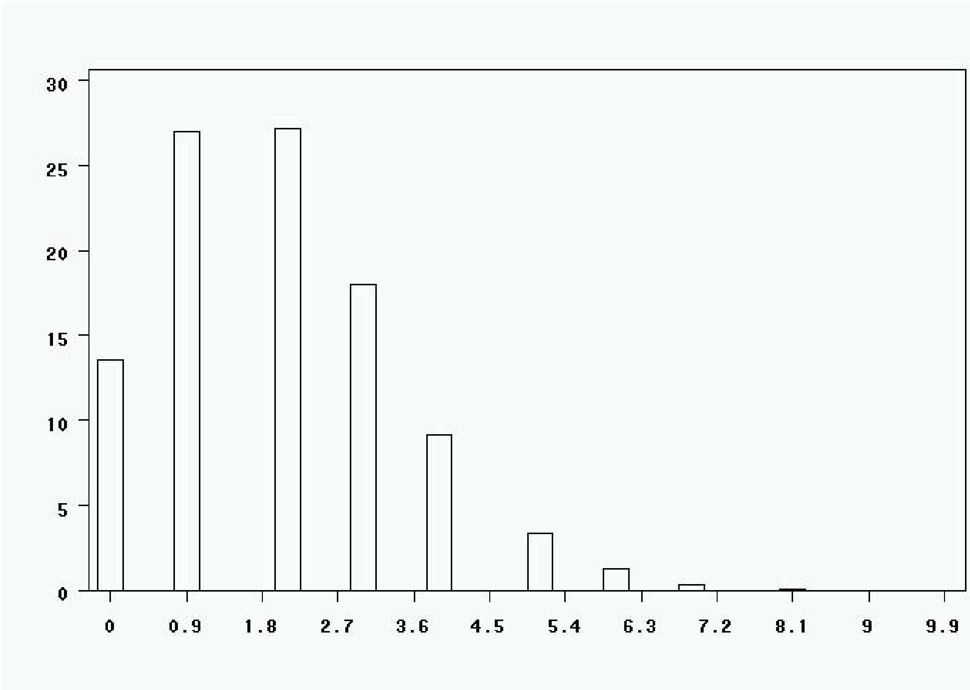


Figure E-8. Histogram for 10,000 randomly generated samples from a Poisson distribution with mean = 2. The value of the sample is shown on the x-axis, the y-axis shows the percent of the 10,000 samples that have the value indicated on the x-axis. A Poisson distribution is commonly used to model the occurrence of rare events within a fixed period of time or space. The Poisson distribution with mean = 2 is positively skewed; as the mean of a Poisson random variable increases, its distribution approaches a normal distribution.

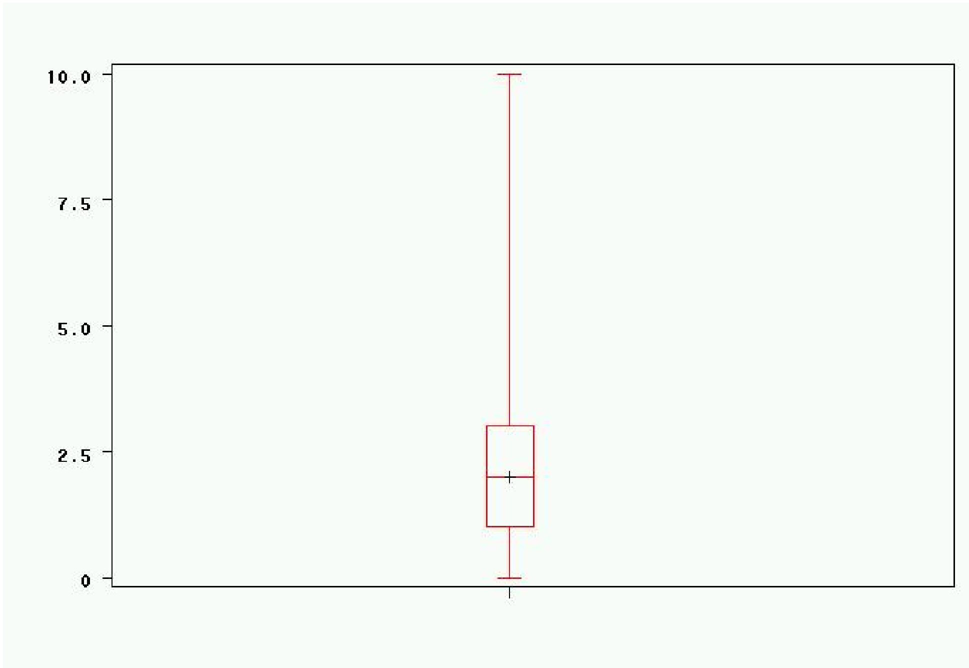


Figure E-9. Boxplot for 10,000 randomly generated samples from a Poisson distribution with mean = 2. The values of the randomly drawn samples are shown on the y-axis. As shown above, the boxplot for a Poisson distribution is positively skewed. As the mean of a Poisson random variable increases, its distribution approaches a normal distribution.

The binomial distribution can be approximated with a normal distribution. The advantages of modeling the exceedances with a normal distribution is that there are many statistical procedures that are based on the assumption of normality, and the variance of a normally distributed variable does not depend upon sample size (i.e., the variance is constant). The normal approximation improves as n increases and the value of p approaches 0.5 (DeGroot, 1989). However, the estimates for p for the *test only* and *clean and test* data (0.00487 and 0.00418, respectively), make the normal approximation untenable. For example, the normal approximation would generally be considered acceptable for a comparison of the exceedance rates between SSAs provided the following relationship was satisfied for each of the SSAs:

$$n_{SSA} \times exceedance\, rate_{SSA} > 5$$

where, n_{SSA} is the number of samples in the SSA, and exceedance rate_{SSA} is the number of exceedances located in the SSA divided by n_{SSA}. This requirement would be satisfied for just one SSA for the *test only* data, and five SSAs for the *clean and test* data.

The Poisson distribution was developed for modeling rare events, such as the exceedance rates observed in the WTC cleanup program. When n is large and p is very small, the binomial distribution can be approximated by a Poisson distribution (DeGroot, 1989):

$$f(x \mid \lambda) = \frac{e^{-\lambda} \lambda^{x}}{x!}$$ Equation E-4

The variable x is limited to positive integers between zero and the sample size (i.e., $x = 0, 1, 2, \ldots, n$). The parameter λ is estimated from the data; it is the total number of exceedances divided by the number of samples (*n)* (same as the binomial distribution). The mean and variance of a Poisson distribution are equal to the parameter λ, and do not depend upon the sample size. In *Section E.3.2.2* the Poisson distribution is shown to provide a better fit to the data than the binomial.

Possible differences in the intensity of exceedance events across the site is assessed in *Section E.3.2*, using methods from point pattern analysis (*Section E.3.2.1*) and spatial autoregression *E.3.2.2*); possible differences on a smaller scale (e.g., within SSAs) are assessed using additional methods from point pattern analysis (*Section E.3.2.3*). The effect of sample size (i.e., number of samples per building) on PCMe exceedance is also considered in *Section E.3.2*.

E.3.2 Spatial Analysis

The locations of PCMe exceedance were described by first assessing the overall (*global*) pattern of the exceedances using methods from point pattern analysis. The data were then aggregated by SSAs and analyzed using methods from spatial autoregression to describe the spatial distribution of PCMe exceedances at the SSA-scale, and to estimate the differences in the rate of PCMe exceedances between the SSAs. The local pattern of the exceedances was assessed by measuring the level of spatial autocorrelation, or spatial dependence, exhibited by the data, using additional methods from point pattern analysis. Finally, the vertical distribution of PCMe exceedances is analyzed at the site level using frequency tables and Poisson regression. When interpreting the results of this analysis, it should be kept in mind that participation in the WTC Dust Cleanup Program was on a voluntary basis. Therefore, the data were not derived from a random sample, nor do they represent a census of all the buildings and residences within the sampled area. (In the context of point pattern analysis, point patterns derived from a random sample and census are referred to as *sampled point patterns* and *mapped point patterns*, respectively.) With this in mind, the global and local patterns of PCMe exceedance are interpreted in relation to the location of the sampled buildings.

E.3.2.1 Site-Level (Global) Pattern of PCMe Exceedance

For the point pattern analysis, the PCMe data were aggregated at the building level by counting the number of sample results that exceeded the heath-based benchmark of 0.0009 fibers/cc for each building (i.e., the number of exceedances). The term exceedance event is used to refer to buildings that contain at least one PCMe exceedance. Consistent with the approach used in the analysis of the dust wipe data, the PCMe exceedances were grouped into clean and test and test only categories. Figures E-10 and E-11 show the location (centroids) of the 408 buildings that contain at least one residence or common area that was cleaned and tested (clean and test buildings), and the 219 buildings that contain at least one residence that was tested only (test only buildings), respectively. Note that the two groups of buildings are not mutually exclusive: approximately 39% of the clean and test buildings contain at least one residence that was tested only, and approximately 75% of the test only buildings contain at least one common area or residence that was cleaned and tested.

Centrographic statistics were used to describe the first order, or global pattern of the distribution of the exceedance events. The centrographic statistics that are described here are similar to the traditional univariate statistics that are used to describe the location (e.g., mean, median) and distribution (e.g., standard deviation, skewness) of a single variable. Centrographic statistics were calculated using the geographic coordinates of the centroids of the buildings. Centrographic statistics were used to describe the geographic center of the exceedance events, their distribution in space, and the orientation of the distribution. The centrographic statistics for the exceedance events were then compared to the centrographic statistics for the buildings that were sampled.

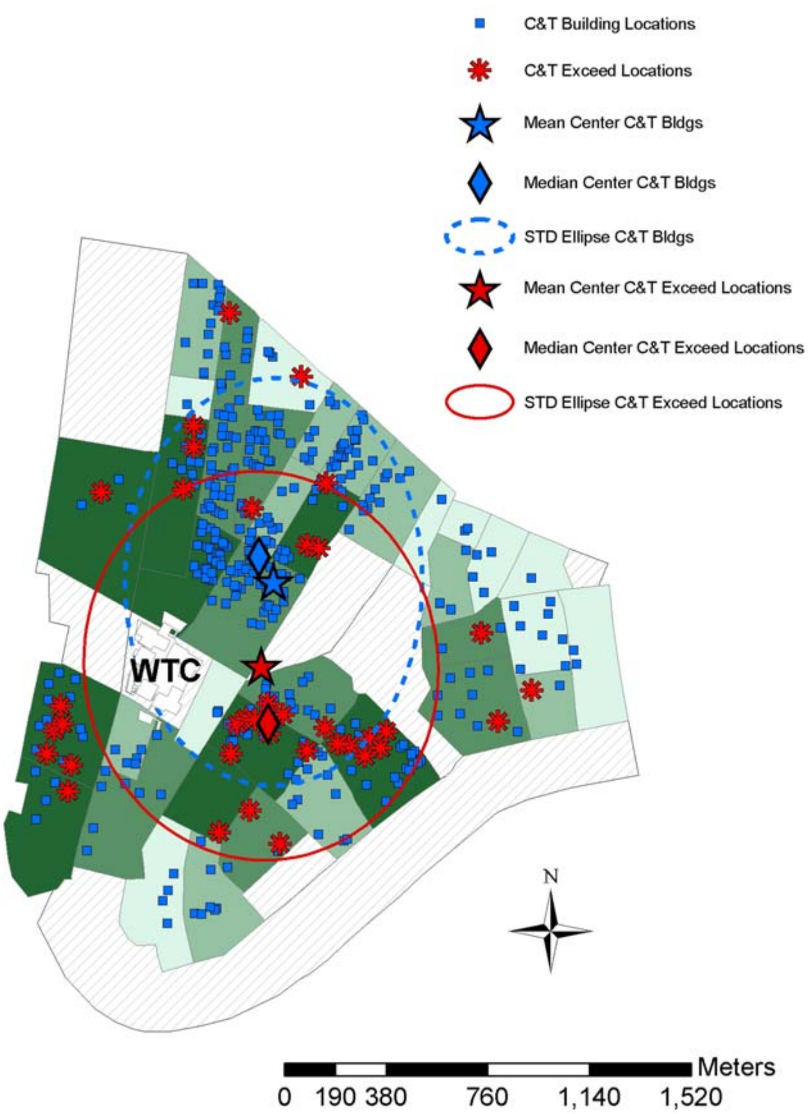


Figure E-10. Centrographic statistics for the *clean and test* data. *Clean and test* data refers to samples collected from residences where the residents had requested EPA to clean their residences and test their indoor air for asbestos. Centrographic statistics are the two dimensional counterparts of common one-dimensional summary statistics; they describe global characteristics of the data. Polygons represent statistical summary areas (SSAs); hatching indicates SSAs where PCMe data was not collected. Two-dimensional locational statistics are indicated by stars (mean center, or average of X and Y coordinates) and diamonds (median center, median of X and Y coordinates). The figure indicates the geographic center of the location of the 37 exceedances is shifted towards the south relative to the geographic center of the *clean and test* buildings. Comparison of the median center and the arithmetic mean center for the exceedances indicates that the location of the exceedances is 'skewed' slightly towards the north. Comparison of the standard deviational ellipses, which illustrate the dispersion of events around their mean centers, indicates that the pattern of exceedances is more evenly distributed across lower Manhattan than the pattern of *clean and test* building locations. The ellipse for the clean and test buildings is more elongated in the north-south direction, indicating that the building locations are more dispersed in the north-south direction than they are in the east-west direction. The median number of samples collected from *clean and test* buildings that had at least one exceedance (119) is an order of magnitude higher than the median number of samples collected from clean and test buildings that had no exceedances (12). The shades of green assigned to the statistical summary areas (SSAs) indicate the number of samples collected from each SSA. The four shades of green correspond to quartiles of the number of samples; the darkest green is assigned to SSAs with the largest number of samples (i.e., 4^{th} quartile). There is a strong relationship between the sample size and the location of exceedances; 36 of the 38 exceedances are located in SSAs with sample sizes above the median.

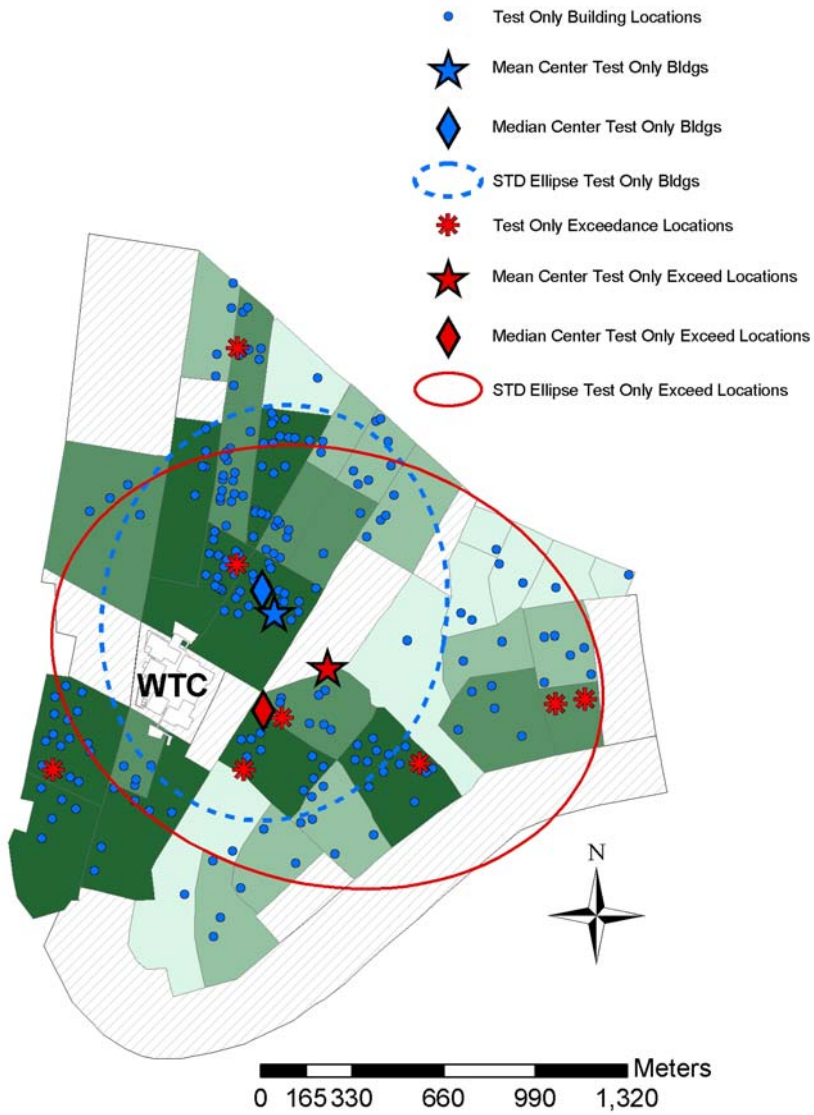


Figure E-11. Centrographic statistics for the *test only* data. *Test only* data refers to samples collected at residents where residences requested to have their indoor air tested for asbestos but declined to have their residences cleaned. The figure indicates that the geographic center of the location of the 8 exceedances is shifted towards the south relative to the geographic center of the *test only* buildings. Comparison of the median center and the arithmetic mean center for the exceedances indicates that the location of the exceedances are 'skewed' slightly towards the east. The standard deviational ellipse for the *test only* buildings shows that the exceedances are more dispersed in the north-south direction, while the exceedances are dispersed more in the east-west direction. The east-west trend may be attributable to the higher sample sizes associated with buildings where the exceedances were measured. The median number of samples in the 8 *test only* buildings that had at least one exceedance is 19.5 (range of 9 to 38 samples); the median number of samples for the *test only* buildings without exceedances is 7 (range of 3 to 256 samples). The shades of green assigned to the statistical summary areas (SSAs) indicate the number of samples collected from each SSA. The four shades of green correspond to quartiles of the number of samples; the darkest green is assigned to SSAs with the largest number of samples (i.e., 4^{th} quartile). There is a strong relationship between the sample size and the location of exceedances; all of the exceedances are located in SSAs with sample sizes above the median.

Figures E-10, *E-11*, and *E-12* show the mean centers, median centers, and standard deviational ellipses for the *clean and test* buildings and the *clean and test* exceedance events, *test only* buildings and *test only* exceedance events, and the *unique test only* buildings (described below), respectively. The X and Y coordinates of the mean center equal the mean of the X coordinates and the mean of the Y coordinates, respectively, of the building centroids. The coordinates of the median center equal the median of the X and Y coordinates of the building centroids. The median is less influenced by geographic outliers (buildings that are located far from the median or mean center of buildings) than the mean. The median is often used when there are a few extreme locations that could greatly influence the mean and distort what might be considered the geographic center of the building locations.

A standard deviational ellipse is a measure of the dispersion of the buildings around the mean center in two dimensions. Comparing the standard deviational ellipse for the exceedance events to the standard deviational ellipse for the location of the sampled buildings provides a qualitative comparison between their geographic centers, and the magnitude and direction of their dispersion. The method for calculating the standard deviational ellipse is described in *Appendix G*.

Figure E-11 shows the locations of the 219 *test only* buildings and 8 exceedance events (one exceedance event is obscured by the symbol for the median center of the exceedance events). The mean center for the exceedance events, which is shifted to the east and north of the median center, is influenced by the two exceedance events that are located near the eastern boundary of the potentially affected area, and the one event near the northern boundary. The location, shape and approximately north-south orientation of the standard deviational ellipse for the *test only* buildings reflect the high density of sampled buildings that are located northeast, east and southwest areas of the WTC site. In contrast, the spatial pattern of the *test only* exceedances events approaches an east-west oriented line; the lone exceedance event located near the northern boundary of the site has a very large influence on the shape of the ellipse. The east-west trend indicated in *Figure E-11* may be attributable to the higher sample sizes associated with buildings where the exceedances occurred. The median number of samples in the 8 *test only* buildings that had at least one exceedance is 19.5 (range of 9 to 38 samples); the median number of samples for the *test only* buildings without exceedances is 7 (range of 3 to 256 samples).

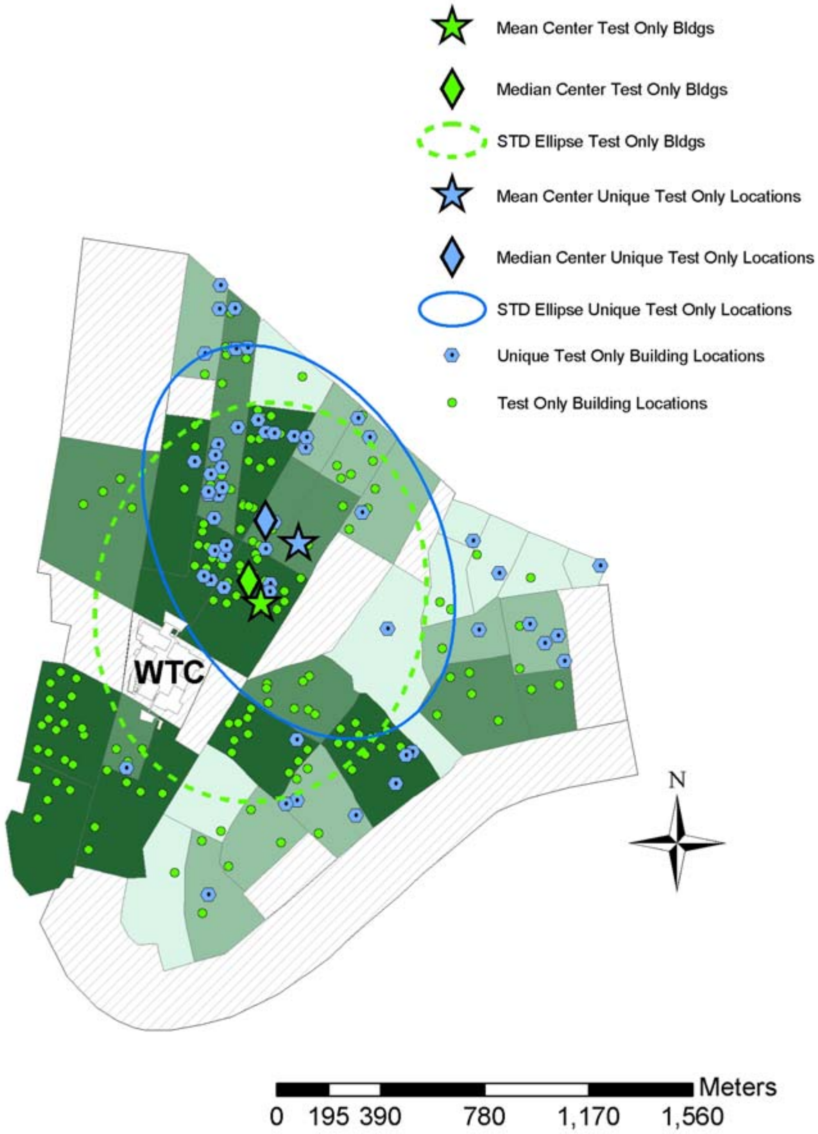


Figure E-12. Centrographic statistics for the *unique test only* buildings. *Unique test only* buildings are buildings that do not contain any residences or common areas that were cleaned. The *unique test only* buildings tend to be located north of the *test only* buildings, and are dispersed in a northeast-southwest direction. No PCMe exceedances were measured in any unique test only building. The lack of exceedance events could be attributed, in part, to the low number of samples collected from these buildings. The average number of samples collected from the *unique test only* buildings is 6.5, with a minimum of 3 and a maximum of 12; twenty-three of the 54 *unique test only* buildings had 5 or fewer samples, and 47 had fewer than 10. In contrast, the 8 *test only* buildings with one or more exceedance had an average of 22 samples, with a minimum of 6 and a maximum of 38. The shades of green assigned to the statistical summary areas (SSAs) indicate the number of samples collected from each SSA. The four shades of green correspond to quartiles of the number of samples; the darkest green is assigned to SSAs with the largest number of samples (i.e., 4th quartile).

Figure E-12 shows the location of the 60 buildings that contain exclusively *test only* residences (*unique test only*; i.e., no *clean and test* common areas or residences). There were no exceedances in the *unique test only* buildings. The geographic center of the *unique test only* buildings shows that these buildings tend to be located north of the *test only* buildings. It should be noted that the lack of exceedance events could be attributed, in part, to the low number of samples collected from these buildings. The median number of samples collected from the *unique test only* buildings is 6, with a minimum of 3 and a maximum of 21; 24 of the 60 *unique test only* buildings had 5 or fewer samples collected from them, and 52 had fewer than 10.

Figure E-10 shows the locations of the 408 *clean and test* buildings and the 37 exceedance events. The geographic center of the *clean and test* buildings is located northeast of the WTC site. The geographic center of the *clean and test* buildings that had at least one exceedance is located east of the WTC site, and south of the geographic center of the *clean and test* buildings. The standard deviational ellipse for the *clean and test* buildings and the *clean and test* exceedances both indicate a north-south orientation. The width of the standard deviational ellipse for the *clean and test* exceedances is wider than the ellipse for the *clean and test* buildings, indicating the distribution of exceedances are more dispersed in the east-west direction than are the *clean and test* building locations. The intensity of exceedances appears to be greater south and east of the WTC site compared to the areas north of the WTC site. Again, the apparent pattern may be attributable, at least in part, to differences in sample size. The median number of samples collected from *clean and test* buildings that had at least one exceedance (119) is approximately 10 times higher than the median number of samples collected from *clean and test* buildings that had no exceedances (12).

The geographic center of the exceedance events for the *test only* and *clean and test* buildings tend to be located south of the geographic center of the sampled buildings (*Figure E-10*). Except for one location, the *test only* exceedance locations occur along an east-west line that extends across lower Manhattan (*Figure E-11*). No obvious pattern to the *clean and test* exceedances is evident. Interpretation of the exceedance locations is complicated by the variability in the number of samples that were collected between buildings.

The possible differences in intensity of exceedance events across the site were further addressed using methods from spatial autoregression (*Section E.3.2.3*) and using additional methods from point pattern analysis (*Section E.2.2.3*). The effect of sample size (i.e., number of samples per building) on PCMe exceedance is also considered in both of the analyses.

E.3.2.2 SSA-Level Pattern of PCMe Exceedance

Spatial distribution of PCMe Exceedance

The primary objective of this analysis is to describe the spatial distribution of PCMe exceedances at the SSA-scale, and to estimate the differences in the rate of PCMe exceedances between the SSAs. Samples from *test only* and *clean and test* residences were collected from 36 and 38 SSAs, respectively. Rates were calculated for each SSA as the number of exceedances within the SSA divided by the number of results for PCMe for the SSA. Rates were used to account for the large difference in sample sizes between the SSAs.

Exceedance rates varied from 0 to 0.060 for the *test only* data and from 0 to 0.058 for the *clean and test* data. More than one-half of the SSAs had no exceedances for the *test only* (30/37, or 81% with 0 exceedances) and *clean and test* data (23/39, or 60% with 0 exceedances). The spatial distribution of the PCMe exceedance rates for the *test only* and *clean and test* data are shown in *Figures E-13* and *E-14*, respectively. For the *test only* data, the SSAs with the highest rates (upper quartile) coincide with the distribution of the exceedance events; every SSA with one or more exceedance falls in the upper quartile of the exceedance rate, which further indicates the rareness of the exceedance events. SSAs that fell within the upper quartile contained 1 – 9 exceedance events.

For the *clean and test* data, SSAs that fell within the upper quartile of exceedance rates for the *clean and test* data contained 2 to 32 exceedance events. All but 4 SSAs had exceedance rates less than 1%; the highest rate of exceedances was 6%. Statistical summary areas with the highest rates are located north and east of the WTC site. *Figure E-14* indicates there is a tendency for SSAs with similar rates to be located near each other (i.e., positive spatial autocorrelation). Measuring spatial autocorrelation in the PCMe exceedances is made difficult by the low rate of exceedances and the lack of data for some SSAs (discussed further in *Appendix H*).

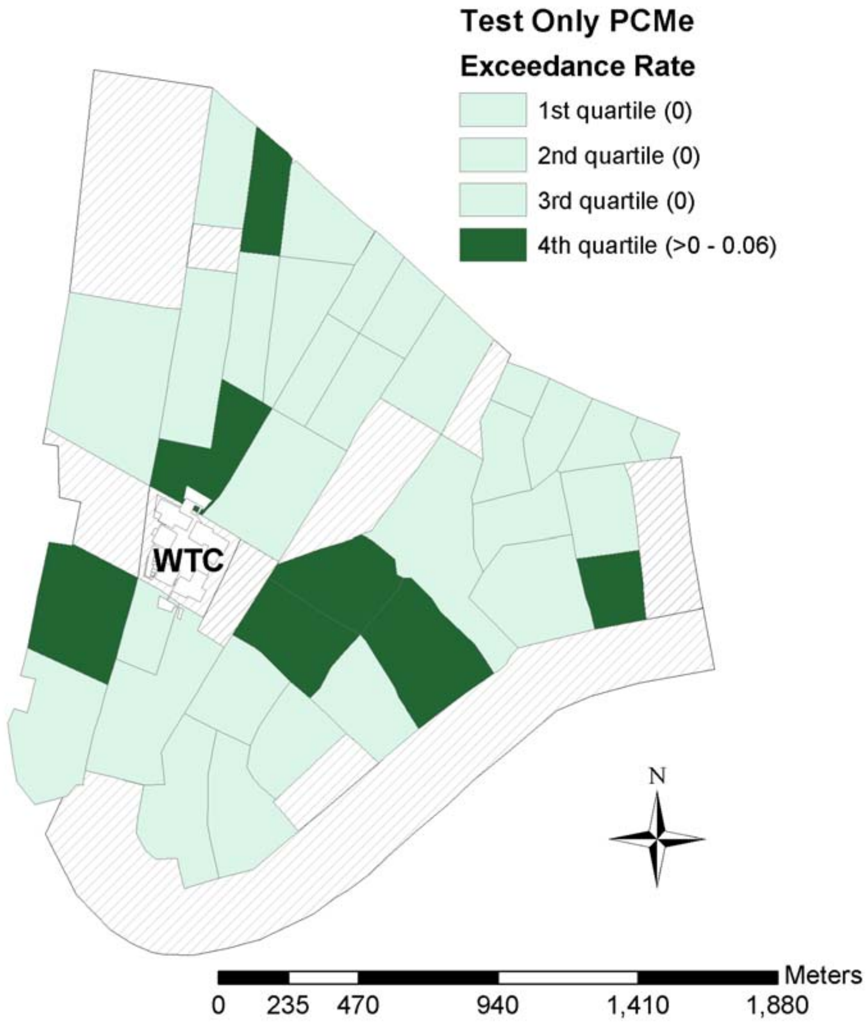


Figure E-13. Spatial distribution of PCMe exceedance rates for the *test only* data, by statistical summary areas. *Test only* data refers to samples collected at residents where residences requested to have their indoor air tested for asbestos but declined to have their residences cleaned. The exceedance rate for each statistical summary area (SSA) equals the number of PCMe results for the SSA that exceeded the health-based benchmark, divided by the number of samples collected from the SSA. Quartiles of the PCMe exceedance rate are shown. Statistical summary areas with one or more PCMe exceedance fall in the upper quartile of the exceedance rate, which indicates the rareness of the exceedance events. Six of the seven SSAs that had one or more exceedance are located east and north of the WTC site; the seventh SSA, which is located south west of the WTC had one exceedance.

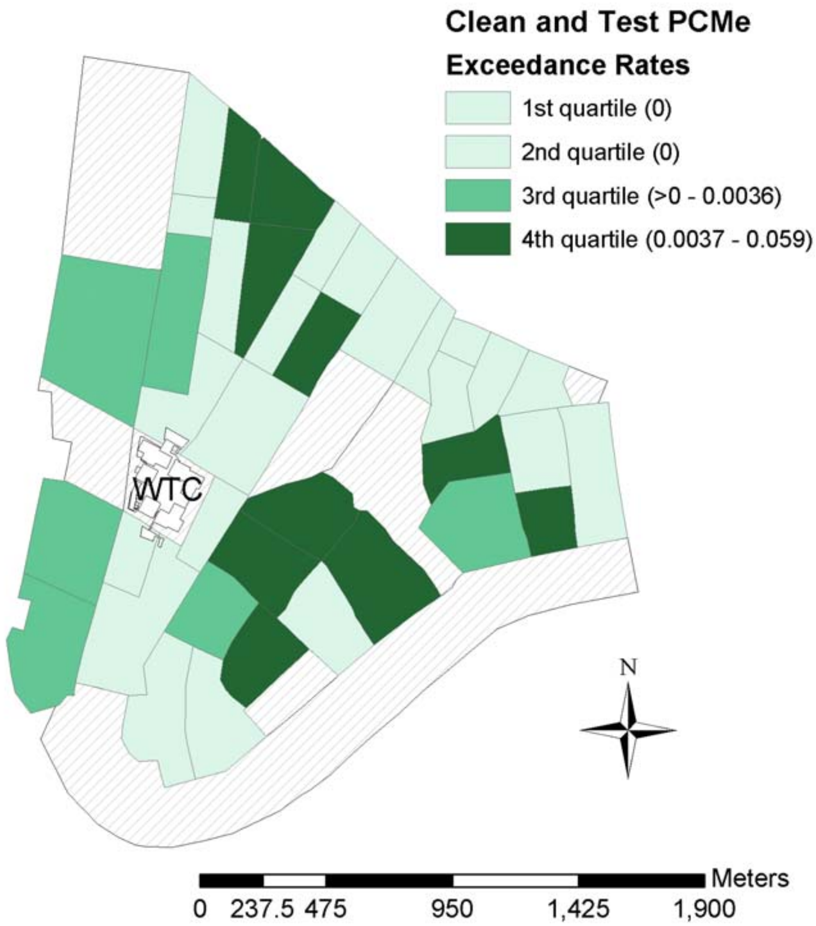


Figure E-14. Spatial distribution of PCMe exceedance rates for the *clean and test* data, by statistical summary areas. *Clean and test* data refers to samples collected from residences where the residents had requested EPA to clean their residences and test their indoor air for asbestos. Quartiles of the distribution of PCMe exceedance rates are shown. Statistical summary areas (SSAs) with one or more exceedances fall in the upper two quartiles, indicating the rareness of the exceedance events. Statistical summary areas with exceedance rates in the upper quartile of the distribution of PCMe exceedances are located north and east of the WTC site. Modest positive spatial autocorrelation in the exceedance rates is indicated by the tendency for SSAs with similar rates to be located near each other.

Fitting Poisson models to PCMe exceedances

The binomial and Poisson distributions are reasonable statistical models for the PCMe exceedances (*Section E.2.1.3*). Binomial and Poisson distributions were fit to log-transformed rates[10] for the *test only* and *clean and test data* (second and third columns of *Tables E-8* and *E-9*, respectively). The assumption of equal mean and variance, which is a feature of the Poisson model (*Section E.2.1.3*), was assessed by fitting a negative binomial model to the data (*Appendix H*). The estimates of the dispersion parameters for the fitted negative binomial models (*Tables E-8* and *E-9*) indicated that the assumption of equidispersion may be very poor for the *test only* and *clean and test* exceedance rates (i.e., the mean and variance of the rates may not be constant across the SSAs). Violation of the equidispersion assumption has affects similar to violations of the constant variance assumption with a normal distribution model (Cameron and Trivedi, 1998)[11]. A consequence of the violation is a tendency for a loss of power to detect actual differences in PCMe rates between SSAs (Griffith and Layne, 1999). Similarly, failure to consider spatial autocorrelation present in data can lead to a loss of statistical power (Griffith and Layne, 1999).

Very often, remedial measures designed to reduce one type of model violation also reduce the violation of other assumptions. With this in mind, a spatial filter approach was used to account for the spatial autocorrelation present in the data; the approach is described briefly in *Appendix H* and thoroughly in (Griffith, 2002). Estimates of the parameters for the binomial and Poisson models with the spatial autocorrelation filter added, for the *test only* and *clean and test* data, are shown in the last three columns of *Tables E-8* and *E-9*, respectively. The parameter estimates for the binomial and Poisson models are very close for both sets of exceedance rates; however, the Poisson model provides a much better fit for the *test only* exceedance rates; the fit is approximately the same for the *clean and test* exceedance rates.

Five buildings accounted for 6,470 (27%) of the *clean and test* sample results. A subset of the *clean and test* data was created by removing these 6,470 measurements from the database. The binomial and Poisson models were refit to the data to assess the effect of these five buildings on the estimates of the model parameters, and their effect on the goodness-of-fit of the models to the data. The parameter estimates differed slightly, and both models continued to account for approximately 40% of the variance

[10] The Poisson models were actually fit to log-transformed counts of exceedances, with the log of the number of samples included in the model as an offset variable. This is mathematically equivalent to fitting the Poisson model to the log-transformed rates; see *Appendix H* for further explanation.

[11] Violation of the constant variance assumption with the normal distribution model affects the significance level (p-values) reported for statistical tests, such as the comparison of the PCMe rates between SSAs. The actual error rates (i.e., type I error rate, α) will tend to be larger than the intended error rate (Griffith and Layne, 1999).

in the data. Based on these results, the spatial autocorrelation-filtered Poisson models with parameters -5.94 and -6.06 (log-transformed rates of exceedances) were used to describe the *clean and test* and *test only* data, respectively.

Table E-8. Model Estimation Results for the Log-transformed *Test Only* PCMe Exceedance Rates

The binomial and Poisson distributions are plausible models for the PCMe exceedances as both distributions can be used to describe count data. A spatial filter derived from the spatial autocorrelation that is expressed by the data was added to both models. Addition of the filter has a substantial impact on the parameter estimates. The apparent violation of the equidispersion assumption (i.e., equal mean and variance) of the Poisson model was rendered inconsequential after the spatial filter was added (see *Appendix H* for details). The Poisson model is more appealing for the PCMe exceedances due to the rarity of their occurrence and provides a better fit to the data, accounting for approximately twice the variance that is explained by the binomial model.

	Prior to Considering Spatial Autocorrelation[a]		With Spatial Filter Added to Models[a]		
Model	**Parameter Estimate**	**Equi-dispersion**	**Parameter Estimate**	**Equi-dispersion**	**% Variance Accounted for**
Binomial	-5.3183	NA	-6.0572	NA	30%
Poisson	-5.3232	NA	-6.0625	NA	60%
Negative binomial[b]	-5.0964	4.6066	-6.1506	0.4476	

[a]Spatial autocorrelation is accounted for in the statistical models using an eigenfunction spatial filter (Griffith, 2002); see *Appendix E* for details.
[b]A negative binomial distribution was fit to the PCMe exceedances to assess the assumption of equidispersion (equal mean and variance), which is a feature of a Poisson random variable.

Table E-9. Model Estimation Results for the Log-transformed *Clean and Test* PCMe Exceedance Rates

The binomial and Poisson distributions are plausible models for the PCMe exceedances as both distributions can be used to describe count data. A spatial filter derived from the spatial autocorrelation that is expressed by the data was added to both models. The apparent violation of the equidispersion assumption (i.e., equal mean and variance) of the Poisson model was reduced by the addition of the spatial filter to the model (see *Appendix H* for details). The Poisson model is more appealing for the PCMe exceedances due to the rarity of their occurrence; both models explain approximately the same percent of the variance in the data.

	Prior to Considering Spatial Autocorrelation[a]		**With Spatial Filter Added to Models**[a]		
Model	**Parameter Estimate**	**Equi-dispersion**	**Parameter Estimate**	**Equi-dispersion**	**% Variance Accounted for**
Binomial	-5.4713	NA	-5.9347	NA	40%
Poisson for rates	-5.4756	NA	-5.9383	NA	40%
Negative binomial[b] for rates	-5.2098	2.8692	-[c]		

[a]Spatial autocorrelation is accounted for in the statistical models using an eigenfunction spatial filter (Griffith, 2002); see *Appendix E* for details.
[b]A negative binomial distribution was fit to the PCMe exceedances to assess the assumption of equidispersion (equal mean and variance), which is a feature of a Poisson random variable.
[c]The negative binomial not estimable; however, the deviance measure for the Poisson model (1.38) indicates overdipsersion has been reduced.

Comparison of PCMe Exceedance Rates

Exceedance rates for each SSA with a sample size of 30 or more were compared to each other to assess whether or not statistically significant differences exist. Aggregate sample sizes less than 30 were considered too small to include in the comparisons. The sample size restriction left 22 SSAs for the *test only* data and 32 for the *clean and test* data. Comparisons were based on the spatial autocorrelation-filtered Poisson models described above. These comparisons essentially consist of calculating the difference between the rates for two SSAs, and determining if the absolute value of the difference is statistically different from zero. In general, the differences in the exceedance rates will approach a normal distribution as the means for the rates increases. The normal approximation is very good when the number of exceedance for each SSA exceeds 4. The low number of exceedances in most SSAs indicated the normal approximation would be poor. This was confirmed by a simulation experiment which showed that the normal distribution would not be reasonable for either the *test only* or *clean and test* exceedance rates comparisons. Therefore, the significance of each of the pairwise comparisons between SSA exceedance rates was determined by nonparametric simulation analysis. The simulation experiments are described in *Appendix H*.

Pairwise comparisons that were significant at type I error rates (α) of 0.01, 0.05 and 0.10 are shown in *Appendix H*, *Tables H-1* and *H-2*. The type I error rates reported are global error rates that take into consideration the multiple comparisons that are being made. When performing multiple statistical tests, the probability of rejecting the null hypothesis when it is true (Type I error, α) increases. In the present context, this means the probability of incorrectly concluding that a difference exists between the exceedance rates for two SSAs would be greater than intended, unless the error rate was adjusted to compensate for the multiple tests. The error rates reported in *Tables H-1* and *H-2* reflect a Bonferroni adjustment to account for the multiple tests (see *Appendix H* for details).
The comparisons of the *test only* exceedance rates between SSAs indicate there are three SSAs with exceedance rates that are statistically significantly different (at $\alpha = 0.01$) than the exceedance rates observed in approximately one-half of the other SSAs (*Figure E-15a*)

Results of the comparison of the *clean and test* exceedance rates between SSAs are indicated in *Figure E-15b*. The number of significant pairwise comparisons at $\alpha = 0.01$ are shown for SSAs that had one or more exceedance. Three SSAs that differ from the majority of the other SSAs are located east of the WTC. The number of exceedances for these three SSAs range from 17 – 32; the exceedance rates range from 0.006 to 0.059.

The SSA-level analysis has shown that the Poisson model provides a reasonable model for the PCMe exceedance rates after the model is modified to account for the positive spatial autocorrelation that is exhibited by the exceedance rates. The comparisons of the exceedance rates indicate that the rates are not constant across the SSAs. Statistical summary areas having the highest rate of PCMe exceedances are located east of the WTC site.

E.3.2.3 Building-Level Pattern of PCMe Exceedance

Two methods for testing for the presence of clusters in the exceedance events, Nearest Neighbor distances and Ripley K functions, are briefly described in this section. Both methods can be used to produce plots of the spatial distribution of sample locations, and the spatial distribution of PCMe exceedance locations. Visual comparison of these plots can provide useful qualitative information regarding the presence or absence of spatial clustering of the PCMe exceedance events. A formal statistical test for spatial randomness is available for the nearest neighbor distance. A semi-quantitative, graphical method is used with the Ripley K function to test for spatial randomness. The underlying assumption behind both methods, as they are employed in this analysis, is that PCMe exceedances follow a homogeneous spatial Poisson process as described in *Section E.2.1.3*.

The location of the *test only* and *clean and test* buildings are not evenly distributed across the potentially affected area. For example, the buildings can be grouped into five sub areas. The largest dimension of these areas varies from approximately 750–1,500 meters. Therefore interpretation of these analyses should be limited to distances of 500–750 meters, as distances greater than these may be overly influenced by global trends in the events, rather than the local spatial dependence between events.

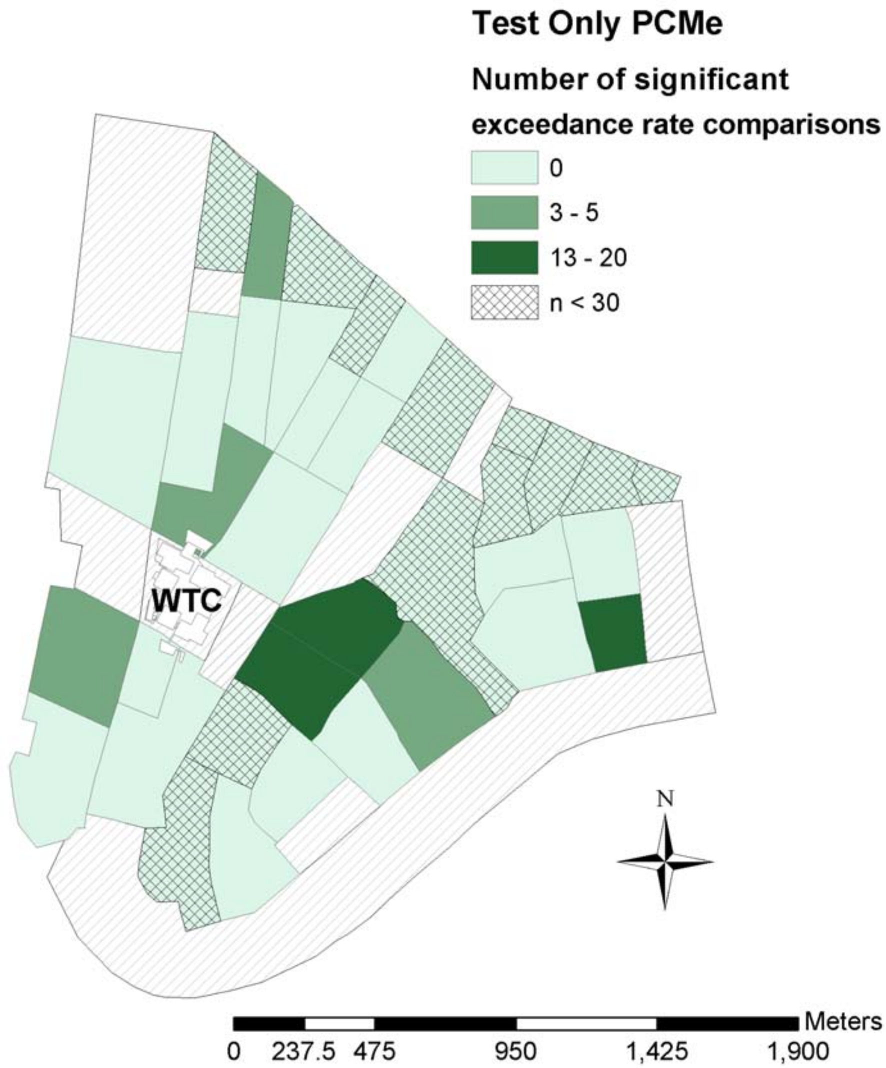


Figure E-15a. Significant differences between estimated exceedance rates for *test only* data. Estimates are based on the spatially-filtered Poisson model (see *Section 3.2.3.2* and *Appendix H* for details). The number of significant pairwise comparisons at an experiment-wise α = 0.01 (with a Bonferroni adjustment) are shown for SSAs that had one or more exceedances. Comparisons with SSAs with sample sizes less than 30 (indicated in figure by cross-hatching, and in figure legend by "n<30") were deemed unreliable and were therefore not included in the analysis. The 3 SSAs that were found to have the most number of significant comparisons are located east of the WTC. The numbers of exceedances for these three SSAs range from 2 to 9; their exceedance rates range from 0.021 to 0.060. The spatial pattern exhibited above is similar to the pattern of exceedance rates that is shown in *Figure 3-13* however, 4 of the 7 SSAs with exceedance rates in the 4th quartile (*Figure 3-13*) were found to be significantly different from 5 or fewer of the other SSAs.

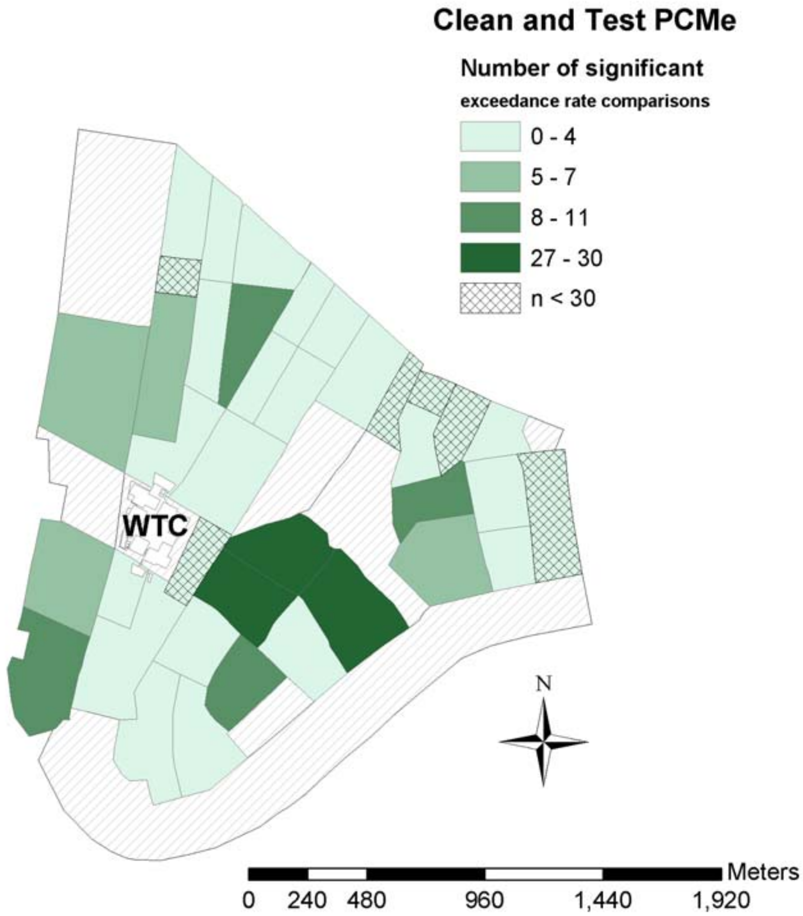


Figure E-15b. Significant differences between estimated exceedance rates for *clean and test* data. Estimates are based on the spatially-filtered Poisson model (see *Section 3.2.3.2* and *Appendix H* for details). The number of significant pairwise comparisons at an experiment-wise $\alpha = 0.01$ (with a Bonferroni adjustment) are shown for SSAs that had one or more exceedances. Comparisons with SSAs with sample sizes less than 30 (indicated in figure by cross-hatching, and in figure legend by "n<30") were deemed unreliable and were therefore not included in the analysis. Three of the SSAs that were found to have the most number of significant comparisons are located east of the WTC. The numbers of exceedances for these three SSAs range from 17 to 32; their exceedance rates range from 0.006 to 0.059. The spatial pattern exhibited above is similar to the pattern of exceedance rates that is shown in *Figure 3-14* however, 3 of the 9 SSAs with exceedance rates in the 4th quartile (*Figure 3-14*) were found to be significantly different from 4 or fewer of the other SSAs.

Nearest Neighbor Method

In nearest neighbor analysis, the focus is on the distance between the exceedance events. The observed nearest neighbor distance $\overline{NNd}$ is the average distance between each exceedance events and its closest neighbor (i.e., another exceedance event). It is calculated by determining the distance between each event and its nearest neighbor, then taking the average of the distances. The observed $\overline{NNd}$ is compared to the average distance between nearest neighbors that would be expected if the events were randomly distributed in space (i.e., if they followed a spatial Poisson process). The expected distance is provided by:

$$E(NNd) = \frac{1}{2\sqrt{\hat{\lambda}}}; \qquad \hat{\lambda} = N / A$$ Equation E-5

where, E(NNd)=expected average distance between nearest neighbors, under the assumption that the events follow a spatial Poisson process; λ=mean, or intensity, of the spatial Poisson process, which is estimated by the total number of events (N), divided by the area of the site (A). The ratio of the observed nearest neighbor distance to the expected nearest neighbor distance yields the nearest neighbor index (NNI):

$$NNI = \left(\overline{NNd}\right) / E\left[NNd\right]$$ Equation E-6

Nearest neighbor indexes equal to one indicate complete spatial randomness (CSR; i.e., homogeneous Poisson process); NNIs less than one indicate spatial clustering, and NNIs greater than one indicate dispersion, or regular spacing (e.g., a square grid).

An important concern in this analysis is how much lower (greater) than one does the NNI have to be to conclude the events are clustered (dispersed). A test for the significance of NNI (i.e., lack of clustering or dispersion in the location of PCMe exceedances) may be performed by computing the standardized estimate of the NNd (Z) (*Equation E-7*) and then comparing the calculated Z to a table of the standard normal distribution (Clark and Evans, 1954):

$$Z = \frac{\overline{NNd} - E[NNd]}{SE_{\overline{NNd}}}$$ Equation E-7

Where $SE_{\overline{NNd}}$ =standard error of the estimate of the mean nearest neighbor distance:

$$\mathrm{SE}_{\overline{\mathrm{NNd}}} = \sqrt{\frac{(4-\pi)}{4\pi \mathrm{N}}} \qquad \text{Equation E-8}$$

A shortcoming of the above test is that it assumes the data are a random sample from the population (Bailey and Gatrell, 1995; Dixon, 2001), which has already been determined to be invalid for the PCMe data. A second shortcoming of the test is that it ignores the correlation between nearest neighbor distances (Cressie, 1993; Dixon, 2001). An extreme case of the correlation is two exceedance events that are the nearest neighbor of each other (i.e., *reflexive nearest neighbors*). Under the assumption of complete spatial randomness (CSR) in two dimensions, approximately 62% of the events of a spatial point pattern are reflexive nearest neighbors (Dixon, 2001). Finally, nearest neighbor analysis assumes that exceedance events are from a continuous, isotropic surface. The geographic distribution of the sampled buildings represent a distribution of discrete objects rather than a continuous surface, and it is not equal in all directions (i.e., the distribution is anisotropic).

Given the shortcomings of the above approach, a numerical simulation approach was used to test the significance of the NNd. The simulation approach generates a list of possible ways of assigning *N* exceedance 'labels' to *B* buildings, where *N* equals the number of exceedance events (i.e., *N*=8 for *test only* and 37 for *clean and test* data) and *B* equals the number of sampled buildings (i.e., *B*=219 for *test only* and 408 for *clean and test* data). The observed pattern of exceedance events is then compared to the list of possible patterns to test the hypothesis that the exceedance events are randomly distributed geographically (the average NNd for the observed pattern of events is compared to the ranked list of NNDs for the simulated values). If the observed NNd is typical of the simulated values, the null hypothesis of first order spatial randomness is not rejected; if the observed value is smaller or larger than most of the simulation NNds, the null hypothesis is rejected.
Another advantage of the simulation test is it removes the assumption that the exceedance events follow a random spatial Poisson process. The simulation test detects departures from spatial randomness, rather than departures from a specific type of random process.

The numerical simulation was executed by randomly selecting *N* buildings (without replacement) from the list of *B* buildings that were sampled for PCMe. The NNd was then calculated for the *N* randomly selected buildings and saved. This process was repeated 9,999 times, producing 9,999 NNds. The NNd that was calculated for the actual data was then added to the list of 9,999 simulated values. The 10,000 NNds were then ranked from lowest to highest. A two-sided test of the null hypothesis that the exceedance events are consistent with a first order spatial random process can be made by comparing the rank of the observed NNd divided by 10,000 to (1–α/2), where α is the chosen level of significance, and rejecting the null hypothesis if the simulated p-value is greater than (1–α/2).

In addition to calculating a NNI for the distances between the closest nearest neighbors (i.e., first order nearest neighbors), it is often informative to calculate NNIs for second, third, …, K-th nearest neighbors. For example, the k=2 (*second order*) NNI is the ratio of the average distance between each PCMe exceedance and its second nearest neighbor $\left(\overline{NND}\right)_{k=2}$, and the expected NND for k=2 $\left(E\left[NNd\right]_{k=2}\right)$:

$$\left(E\left[NNd\right]_{k=2}\right) = \frac{K(2K)!}{(2^K K!)^2 \sqrt{N/A}}$$ Equation E-9

Evaluating the average nearest neighbor distance at orders greater than one provides a description of the interaction between events at increasing separation distances. *Equations B-8* and *B-9* are appropriate for first order NNds; significance tests for higher order NNds have not been developed.

The NNIs for the exceedance events should be compared to the NNIs for the sampled buildings to account for the nonrandom sampling methods that were employed. A relative NNI is calculated as the ratio between the NNI for the exceedance events and the NNI for the sampled buildings. Relative NNIs less than (greater than) one indicate clustering (dispersion) of events that is not explained by the spatial distribution of the sampled buildings. The relative NNI is a qualitative measure; statistical tests for significance are not available.

Nearest Neighbor Results

The simulation test for the significance of the *test only* NNd failed to reject the null hypothesis of first order spatial randomness, although the small number of exceedances (8) should be considered. The simulation test for the *clean and test* exceedance events also failed to reject the null hypothesis of first order spatial randomness (p=0.33). The p-value indicates that 33% of the simulated patterns of *clean and* *test* exceedance events had NNds smaller than the observed NNd. These results argue against significant spatial clustering of the PCMe exceedances at the site (i.e., more than would be expected by chance).

Table E-10 shows the NNI and relative NNI for the first 5 'orders' of neighbors. The table indicates that the *test only* events are more dispersed than the *test only* buildings. These results should be interpreted with caution due to the small number of *test only* exceedance events (8). The *clean and test* exceedance events exhibit clustering that is consistent with the clustering observed in the sampled buildings. *Figure E-16* shows the NNI for the first 20 orders of neighbors. The *test only* and *clean and test* events plot above the sampled buildings, indicating that the events are not clustered. At higher orders of neighbors, the *clean and test* events are slightly more dispersed relative to the spatial distribution of sampled buildings. The results for higher orders also should be interpreted with caution due to the low number of exceedances (37). Overall, results from the nearest neighbor method lead to a rejection of the null hypothesis that the exceedance events are clustered.

<u>*Ripley's K Function*</u>

Ripley's K function (K function) is another method for assessing whether the exceedance events are clustered. While the NNd looks at the distance between nearest events at increasing orders, the K function looks at the number of neighbors at increasing distances. The number of neighbors is determined by drawing a circle of radius *r* around each event and counting the number of other events ('neighbors') that fall within the circle (*Figure E-17*). This is repeated for every event. Ripley's K function for distance *r* equals the total number of neighbors that were counted over all the events:

$$K(r) = \frac{A}{N^2} \sum_{i=1}^{N} \sum_{j=1}^{N} I(d_{ij})$$

<u>Equation E-10</u>

Table E-10. Nearest Neighbor Statistics for the PCMe Exceedances

The nearest neighbor distance (NNd) for *order 1* is the average distance between the location of each PCMe exceedance and its nearest neighbor. Second order NNds correspond to the average distance between the location of each PCMe exceedance and its second nearest neighbor, etc. Nearest neighbor indexes (NNIs) equal the NNd divided by E[NNd]. NNIs less than (greater than) 1 indicate spatial clustering (dispersion) of PCMe exceedances. The NNIs for the spatial distribution of sampled buildings indicate the buildings tend to be clustered, which is typical for the geographical distribution of buildings in an urban environment. Proper interpretation of the NNIs for the exceedances requires comparing the nearest neighbor indexes (NNIs) for the exceedances to the NNI for the sampled buildings. The relative NNIs for the *clean and test* and *test only* PCMe exceedances indicate a lack of spatial clustering (i.e., they are greater than 1). The results shown are approximate; the E[NNd] assumes the PCMe data were gathered using random sampling methods, or the that the entire population was measured; neither assumption is valid given the data were obtained by voluntary participation in the WTC dust cleanup program.

***Test Only* Buildings**				***Test Only* Exceedances**			
Order	**NNd[a]**	**E[NNd][b]**	**NNI[c]**	**NNd[a]**	**E[NNd][b]**	**NNI[c]**	**Rel-NNI[d]**
1	50.87	62.10	0.82	406.42	324.91	1.25	1.53
2	73.80	93.15	0.79	725.19	487.37	1.49	1.88
3	91.54	116.44	0.79	910.49	609.21	1.49	1.90
4	110.03	135.84	0.81	1071.27	710.74	1.51	1.86
5	124.26	152.82	0.81	1253.63	799.59	1.57	1.93
***Clean and Test* Buildings**				***Clean and Test* Exceedances**			
Order	**NNd[a]**	**E[NNd][b]**	**NNI[c]**	**NNd[a]**	**E[NNd][b]**	**NNI[c]**	**Rel-NNI[d]**
1	33.74	45.50	0.74	118.45	151.08	0.78	1.06
2	52.59	68.24	0.77	170.72	226.62	0.75	0.98
3	65.61	85.31	0.77	224.41	283.28	0.79	1.03
4	76.22	99.52	0.77	278.31	330.49	0.84	1.10
5	85.79	111.96	0.77	326.16	371.80	0.88	1.14

[a]NNd: nearest neighbor distance (meters)
[b]E[NNd]: expected nearest neighbor distance, under assumption of complete spatial randomness (CSR)
[c]NNI: nearest neighbor index
[d]Rel-NNI: relative nearest neighbor index=NNI for exceedances/NNI for all buildings

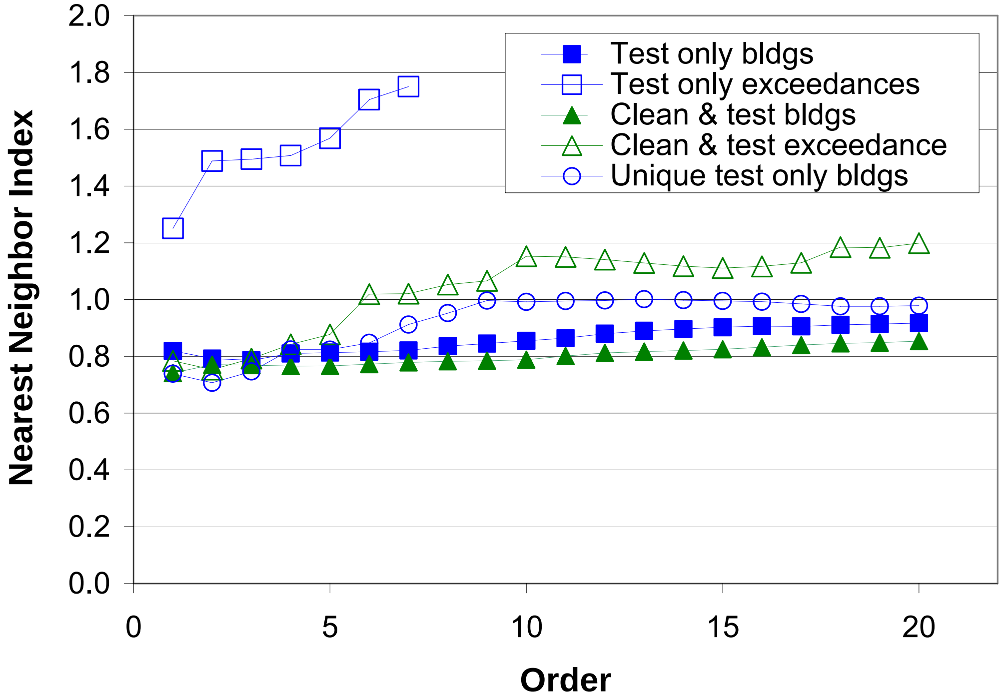


Figure E-16. Nearest neighbor analysis for the PCMe asbestos data. The nearest neighbor index (NNI) is the ratio of the observed nearest neighbor distance (NNd; average distance between each PCMe exceedance and its closest neighbor) to the expected value of the NNd, under the assumption of complete spatial randomness (CSR). A NNI of 1 indicates a random spatial distribution of events; NNIs < 1 indicate clustering, NNIs >1 indicate dispersion (e.g., spatial distribution of PCMe exceedances on a square grid). The x-axis of the figure indicates the average distance between neighbors of increasing *orders*; e.g., the NNI of *order =2* is the ratio of the average distance between each PCMe exceedance and its *second* closest neighbor, and the expected distance between neighbors of order = 2. The NNIs for the building locations indicate spatial clustering at small spatial scales (i.e., low *orders*). The buildings approach a random distribution (i.e., NNI = 1) at larger spatial scales (i.e., higher orders). This pattern is typical of the geographic distribution of buildings in an urban landscape. The NNIs for the clean and test exceedances are very similar to the NNIs for the clean and test buildings;, up to order =5, indicating a lack of spatial clustering of the exceedances, relative to the building locations; clean and test exceedances events appear to be randomly distributed among the sampled clean and test building locations. At orders greater than 5, the clean and test exceedance events appear to be spaced further apart on average than expected for a random distribution. However, given the small number of clean and test exceedances (37), the NNIs at higher orders should be interpreted with caution. The test only exceedance events appear to dispersed; however the very low number of test only exceedance events (8) preclude drawing definitive conclusions. All of the *test only* exceedances occurred in buildings that also contained at least one residence that was also cleaned and tested. Furthermore, the analysis of spatial trends (further discussed in Section 3.2 of the report) indicate that buildings with only *test only* residences (*unique test only*) tend to be located north of the buildings that also contained *clean and test* residences. This difference between the spatial distribution of the *test only* and *unique test only* buildings probably contributes to the dispersion indicated by the NNI for the *test only* exceedance events.

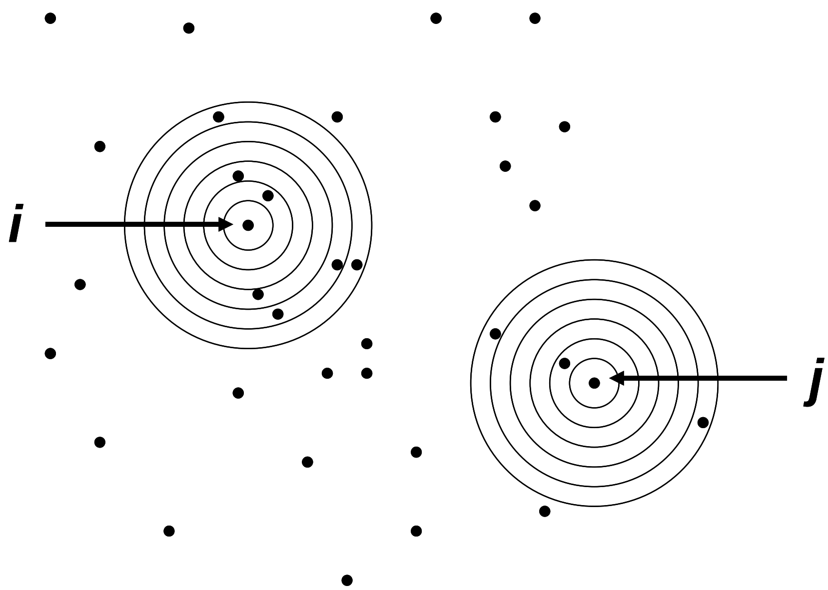


Figure E-17. Calculation of the Ripley K function. The Ripley K function is estimated by counting the number of other exceedance events that are located within a distance *r* of an exceedance event. The calculation is repeated for every event, *i*, *j*, ….*N*, where *N* = the number of events. The Ripley K function for separation distance r is the sum of all counts over all events (*Equation 6, Section 3.2.2.2.3*). Ripley's K function is typically repeated for increasing separation distances and plotted vs the separation distances (e.g., *Figures 3-11, 3-12*). Shown above is the calculation for two events, *i* and *j*, for six separation distances (corresponding to the six circles). The concentric circles represent increasing separation distances (*r*). For example, Event *i*: 0 other events (i.e., other exceedances) within distance of 1 unit, 7 other events within a distance of 6 units; event *j:* 1 other event within a distance of 3 units, and 3 other events within a distance of 6 units.

Where, r=radius of circle that is used to define neighbors, A=area of site, N=number of exceedance events, d_{ij}=distance between points i and j, I=indicator variable that=1 if $dij < r$ and 0 otherwise.

This calculation is repeated, each time increasing the radius r of the circle that is used to define *neighbors*, up to the desired maximum value of r.

Interpretation of the K function is typically performed by plotting a conversion of K(r), L(r), versus r:

$$L(r) = \sqrt{\frac{K(r)}{\pi}} - r$$ Equation E-11

The conversion to L(r) is made to make the plot easier to interpret. Values of L(r) greater than 0 indicate clustering; values less than 0 indicate dispersion.

Under the assumption that the exceedance events are distributed according to a random spatial Poisson process, the expected number of events within distance r of a given event is:

$$E[K(r)] = \frac{N}{A}\pi r^2$$ Equation E-12

where, N=number of events, A=area of site, and r=radius of circle that is used to define neighbors.

The expected value of the K-function, after conversion to L(r) (Equation E-11), plots as a horizontal line at L(d)=0. If the number of other exceedance events found within a distance r from an exceedance event is greater than E(K[r]), clustering is indicated at that distance; conversely, if the number of events at r is less than the expected value, dispersion is indicated.

The weighted Ripley's K function was estimated for the two groups of exceedance events, where the events are weighted by the number of samples that were collected from each building. The weights account for the increased likelihood of measuring an exceedance in buildings where more samples are collected (Levine, 2002).

The sampling distribution of K(r) has not been determined. Therefore, a test for CSR was performed using a simulation approach that is similar to the one that was used to test the significance of the NNI. The numerical simulation was executed by randomly selecting N buildings (without replacement) from the list of *B* buildings that were sampled for PCMe. The values of L(r) were then calculated for the *N* randomly selected buildings for different values of *r* and saved. This process was repeated 9,999 times, producing 9,999 estimates of L(r) at each distance, *r*. *Simulation envelopes* were created by plotting extreme values of the simulated L(r) at each distance. The significance of the estimated K-function at each distance *r* was made by comparing it to the s*imulation envelopes*.

Ripley's K Function Results

Figures E-18 and *E-19* show the K-function for the *test only* and *clean and test* events plot below the *test only* and *clean and test* buildings, respectively, which indicates that the exceedance events are more dispersed than the geographic distribution of the sampled buildings. The exceedances also appear to be dispersed relative to the location of the sampled buildings, after the Ripley K function is adjusted to consider the number of samples that were collected from each building. At separation distances greater than approximately 400 feet, the curve for the exceedances falls at or below the curve that corresponds to the 5^{th} percentile of the simulated Ripley K values, indicating that the pattern of *test only* exceedances may be more dispersed than expected based on chance alone for a spatially random process. However, given the small sample number of exceedances (*n*=8), these results should be interpreted with caution.

The Ripley K function for the *clean and test* exceedances indicates that the exceedances are slightly dispersed relative to the location of the sampled buildings. Some slight clustering of exceedance events may be indicated at the smallest separation distance considered (i.e., approximately 100 meters) when the exceedances are compared to the Ripley K function for the sampled buildings after it is adjusted to consider the number of samples that were collected from each building. However, the curve for exceedance events falls between the 5^{th} and 95^{th} percentile of the simulated Ripley K values, indicating that the pattern of exceedances does not differ significantly from a spatially random process. Overall, the analyses provide no convincing evidence of clustering in either the *clean and test* or *test only* exceedance events.

E.3.2.4 Site-Level Vertical Pattern of PCMe Exceedance

Analysis of the vertical pattern of PCMe exceedances was performed using contingency tables and by fitting Poisson regression models to the data. Floor levels were used as a surrogate for elevation. Early attempts at fitting a Poisson model using individual floor levels were unsuccessful due to the rarity of exceedances. To address this problem, floors were grouped into three categories: lower floors (floors 3 and lower), middle floors (floors between 4 and 9, inclusive), and upper floors (floors 10 and higher). The analysis was performed in two ways. The first approach was performed at the sample level (*sample-basis*); each sample result was used in the analyses (i.e., the exceedance events were *not* aggregated at the building level). In the second approach (*residence-basis*), the data were aggregated at the residence level; any residence that had one or more exceedance was treated as an exceedance.

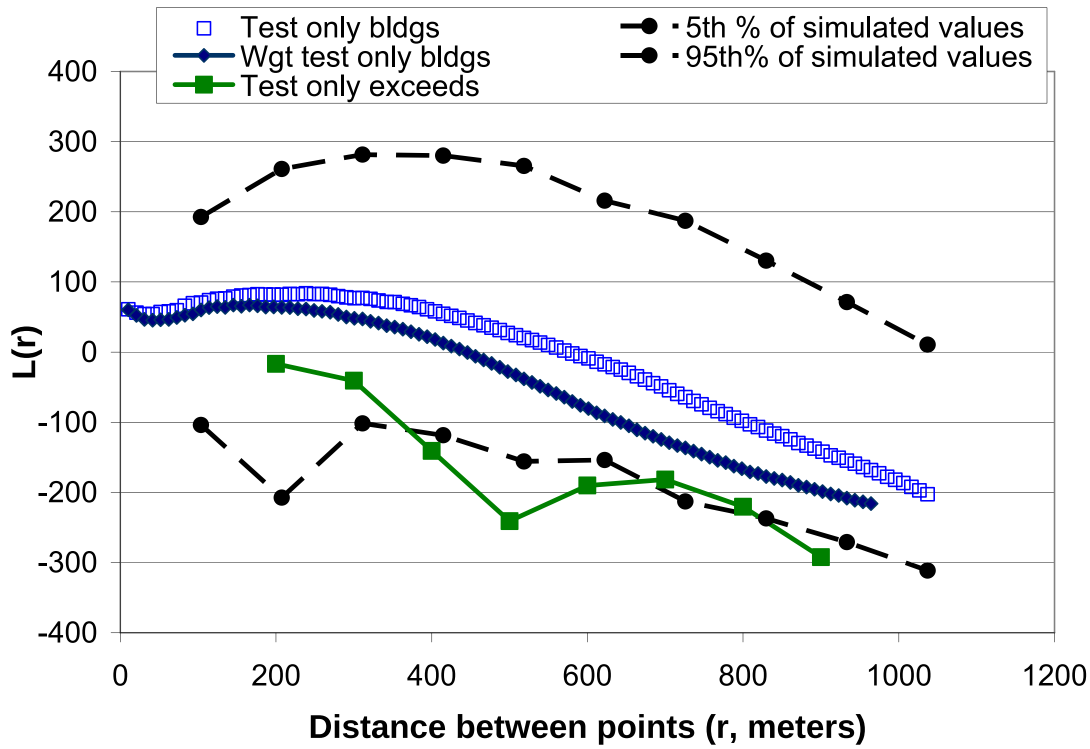


Figure E-18. Ripley's K plot for the *test only* PCMe exceedance event data. A Ripley's K plot is used to compare the number of neighbors for each exceedance event (i.e., location of building with at least one PCMe results > 0.0009 f/cc) to an expected number of neighbors based upon the null hypothesis that the events are randomly distributed across the geographic landscape according to a homogenous spatial Poisson process (see *Section 3.2.1.3* for explanation). The number of neighbors is determined by drawing a circle of radius *'r'* around each event and counting the number of other events ('neighbors') that fall within the circle. This is repeated for every event. Ripley's K function for radius 'r' equals the total number of neighbors that were counted over all the events. This calculation is repeated, each time increasing the size of the circle that is used to define *neighbors*; the increasing radius is shown on the x-axis. A conversion of K(r) to L(r) (see *Section 3.2.2.2.3* for definition) is made to make the plot more linear (i.e., easier to interpret). Values of L(d) greater than 0 indicate clustering; values less than 0 indicate dispersion. Ripley's K for the *test only* PCMe events is consistent with the nearest neighbor plot (*Figure 3-7*); the geographical distribution of the *test only* events exhibit less clustering than the *test only* buildings, respectively. A weighted Ripley's K function was estimated for the sampled buildings, where the events are weighted by the number of samples that were collected from each building. The weights account for the increased likelihood of measuring an exceedance in buildings where more samples are collected. A comparison of the Ripley K function for the *test only* events to the weighted Ripley K indicates that the exceedances are dispersed relative to the sampled buildings. The location of the Ripley K plot for the exceedances within the simulation envelope (see *Section 3.2.2.2.3* for details), which is defined by the 5th and 95th percentile of the simulated Ripley K function at each distance interval (*r*), supports a conclusion that there is insufficient evidence to indicate clustering of the test only exceedance events.

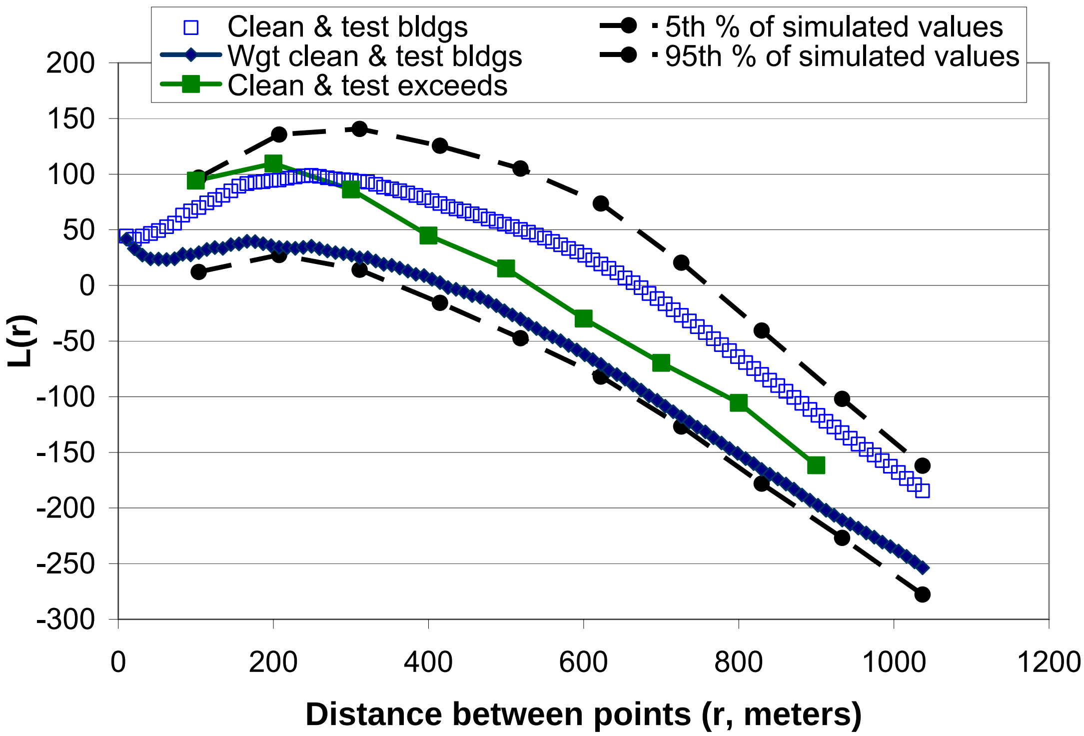


Figure E-19. Ripley's K plot for the *clean and test* PCMe exceedance event data. The Ripley's K plot for the *clean and test* PCMe events is consistent with the nearest neighbor plot (*Figure 3-7*); the geographical distribution of the *clean and test* events exhibit less clustering than the *clean and test* buildings. A comparison of the Ripley K function for the *clean and test* events to the weighted Ripley K function indicates that the exceedance events appear to be slightly more clustered than the sampled buildings, particularly at short distances. The location of the Ripley K plot for the exceedances within the simulation envelope (see *Section 3.2.2.2.3* for details), which is defined by the 5th and 95th percentile of the simulated Ripley K function at each distance interval (r), fails to support a conclusion that the exceedance events are clustered.

<u>*Sample-Basis Analysis*</u>

Contingency tables for the *test only* and *clean and test* data are provided as *Tables E-11* and *E-12*.

All of the exceedance rates are less than 1%. Fisher's exact test for the *test only* data indicates the difference in exceedance rates between floors is marginally significant (p=0.08, 2-sided). A higher exceedance rate was observed for the middle floor group (0.73%) then either the lower (0.11%) and upper (0.37%) floor groups. Additional tests were performed between the floor groups to determine which exceedance rates were significantly different, if any. The difference between the *lower* floor group and the *middle* floor group was found to be significant by Fisher's exact test (p=0.04, 2-sided); differences between the middle and upper, and lower and upper floor groups were not statistically significant by

Fisher's exact test (p=0.17 and p=0.43, respectively; 2-sided). The Poisson model for the *test only* data was not significant.

Fisher's exact test for the *clean and test* data indicates the difference in exceedance rates between floors is statistically significant (p=0.02, 2-sided). The exceedance rate was highest for the lower floor group (0.66%), lower for the middle floor group (0.44%), and the lowest for the upper floor group (0.32%). Additional tests were performed between the floor groups to determine which exceedance rates were significantly different. The difference between the lower and upper floor groups was found to be statistically significant by Fisher's exact test (p=0.01; 2-sided). The differences between the *lower* and *middle* floor group, and the *middle* and *upper* floor group were found to be not significant by Fisher's exact test (p=0.12, p=0.20, respectively; 2-sided). The odds ratios for the Poisson model indicate lower floors are twice as likely to have exceedances as the upper floors (95% CI 1.2, 3.4) (p-value for chi-square test for parameter = 0.01).

Table E-11. Contingency Table for *Test Only* PCMe Exceedances, on a Sample-Basis

The exceedance rate in the middle floor group is higher than the exceedance rates observed in the lower and upper floor groups. The p-value for Fisher's exact test is 0.08, indicating the differences between the floor groups is marginally statistically significant.

Floor Group	**Not PCMe Exceedances**	**PCMe Eceedances**	**Totals**
lower	873[a] 99.89[b]	1[c] 0.11[d]	874
middle	1768 99.27	13 0.73	1781
upper	1617 99.63	6 0.37	1623
Totals	4258 99.53	20 0.47[e]	4278[e]

[a]Number of samples that did not exceed health-based benchmark for asbestos
[b] Percent of samples that did not exceed health-based benchmark for asbestos
[c]Number of samples that exceeded the health-based benchmark for asbestos
[b] Percent of samples that exceeded the health-based benchmark for asbestos
[e] The table does not include samples where the floor was not provided in the database, therefore sample sizes and percent of exceedances will differ from those provided elsewhere in the report.
[e] The table does not include samples where the floor was not provided in the database, therefore sample sizes and percent of exceedances will differ from those provided elsewhere in the report.

Table E-12. Contingency Table for *Clean and Test* PCMe Exceedances, on a Sample-Basis

The observed exceedance rate increases with floor level. The p-value for Fisher's exact test is 0.02, indicating the differences between the floor groups is statistically significant at the 0.05 level.

Floor Group	Not PCMe Exceedances	PCMe Exceedances	Totals
lower	4233[a] 99.34[b]	28[c] 0.66[d]	4261
middle	8971 99.56	40 0.44	9011
upper	10488 99.68	34 0.32	10522
Totals	23692 99.57	102 0.43[e]	23794[e]

[a]Number of samples that did not exceed health-based benchmark for asbestos
[b] Percent of samples that did not exceed health-based benchmark for asbestos
[c]Number of samples that exceeded the health-based benchmark for asbestos
[b] Percent of samples that exceeded the health-based benchmark for asbestos
[e] The table does not include samples where the floor was not provided in the database, therefore sample sizes and percent of exceedances will differ from those provided elsewhere in the report.

Residence-Basis Analysis

Contingency tables for the *test only* and *clean and test* data are provided as *Tables E-13* and *E-14*. Fisher's exact test indicates the exceedance rates do not differ significantly between floor groups for the *test only* and *clean and test* data (p=0.74 and 0.84, respectively), when the data are analyzed at the residence level.

Table E-13. Contingency Table for *Test Only* PCMe exceedances, on a Residence-Basis

The exceedances are extremely rare across the floor groups. The p-value for Fisher's exact test is 0.74, indicating the differences between the floor groups is not statistically significant.

Floor Group	**Not PCMe Exceedances**	**PCMe Exceedances**	**Totals**
lower	147[a] 100[b]	0[c] 0[d]	147
middle	303 99.02	3 0.98	306
upper	292 99.32	2 0.68	294
Totals	742 99.33	5 0.67[e]	747[e]

[a]Number of samples that did not exceed health-based benchmark for asbestos
[b] Percent of samples that did not exceed health-based benchmark for asbestos
[c]Number of samples that exceeded the health-based benchmark for asbestos
[b] Percent of samples that exceeded the health-based benchmark for asbestos
[e] The table does not include samples where the floor was not provided in the database, therefore sample sizes and percent of exceedances will differ from those provided elsewhere in the report.

Table E-14. Contingency Table for C*lean and Test* PCMe exceedances, on a Residence-Basis

Very little difference in the exceedance rate is observed between floor groups. The p-value for Fisher's exact test is 0.84, indicating the differences between the floor groups is statistically significant.

Floor Group	**Not PCMe Exceedances**	**PCMe Exceedances**	**Totals**
lower	534[a] 99.07[b]	5[c] 0.93[d]	539
middle	1306 99.24	10 0.76	1316
upper	1497 99.27	11 0.73	1508
Totals	3337 99.23	26 0.77[e]	3363[e]

[a]Number of samples that did not exceed health-based benchmark for asbestos
[b] Percent of samples that did not exceed health-based benchmark for asbestos
[c]Number of samples that exceeded the health-based benchmark for asbestos
[b] Percent of samples that exceeded the health-based benchmark for asbestos
[e] The table does not include samples where the floor was not provided in the database, or common areas, therefore sample sizes and percent of exceedances will differ from those provided elsewhere in the report.

APPENDIX F.

Other Fiber Analyses

The WTC Clean-up Program recorded three distinct fiber measurements in indoor air. Residents were provided a report that detailed the results of each of these three analyses. One measurement was employed specifically to provide a risk-related basis for clearing residential dwelling. The other two measurements provide ancillary information on a wider range of asbestos and other man-made vitreous fibers. Listed below is a summary of each fiber measurement protocol with applicable reference values.

1. The clearance criteria for the WTC Clean-up Program was based on phase-contrast microscopy equivalent (PCMe) measurements of asbestos in indoor air. This counting method employs transmission electron microcopy (TEM) for analysis but registers only asbestos fibers greater than 5 microns in length with a minimum length-to-width ratio of 5:1. The minimum length of 5 um represents the current scientific consensus that attributes cancer-causing potential to long (i.e. >5 microns) asbestos fibers. The health-based benchmark for the PCMe measurement is .0009 f/cc, which equates to an excess lifetime cancer risk of one-in-ten thousand based on the conservative assumption of 30 years of continuous exposure at the benchmark concentration.

Phase Contrast Microscopy (PCM) was used for airborne asbestos analysis in the preponderance of occupational epidemiology studies which provide the robust dose-response data base on asbestos-related carcinogenesis. However, advancements in asbestos analysis by electron microscopy have made TEM the analytical method of choice. Consequently, EPA counts fibers by TEM, but employs a fiber counting metric derived from phase contrast microscopy (PCM) for quantifying cancer risk associated with asbestos exposure. TEM analysis is typically performed under a magnification of 20,000 X, whereas PCM analysis is performed at 400 X magnification. In order to make any statement regarding quantitative cancer risk associated with exposures estimated via TEM fiber counts (as directed by AHERA) a PCM “equivalence” count must first be obtained. In effect, PCM “equivalence” is an exercise to convert TEM counts to structures that would be visualized had the analysis been done by PCM. (It should be noted that the correlation between total PCM fiber and TEM fiber counts is not straightforward and varies between analysts; therefore, no standard conversion factor exists for these two measurements.)

In addition to evaluating cleaning techniques against the health-based clearance criteria for asbestos in air (.0009 f/cc, PCMe), two additional analyses were conducted to measure airborne fibers.

2. The first is similar to the analytical approach (i.e., TEM) used to establish the clearance criteria except that in this case all asbestos fibers greater than 0.5 microns are counted. This is the asbestos fiber counting method used in the Asbestos Hazard Emergency Response Act (AHERA). All fibers greater than (>) 0.5 um are counted as per AHERA counting methods for school reentry. This is the method used under EPA standards to determine whether an asbestos clean-up project has left behind residual contamination. The standard for school clean-ups is 0.022 fibers/cubic centimeter (f/cc) as converted from 70 structures/mm2.

3. Airborne fibers were also measured using phase contrast microscopy (PCM). A light microscope is used to identify the presence of fibers in the air. The fibers are stained to help in their identification. This method cannot reliably visualize fibers that are thinner than .25 microns in width. Consequently, based on the typical aspect ratio range of asbestos fibers, most fibers less than 5 microns in length cannot be seen. Nor can PCM accurately identify different types of fibers. This is the method used by OSHA to determine compliance with its asbestos standard for workers of 0.1 f/cc of air. Because it is not specific for asbestos, the PCM analysis also serves as a measure of non-asbestos fibrous material (such as fibrous glass) that was released from the WTC disaster. The OSHA workplace standard for fibrous glass is 1 f/cc. There are no environmental standards for fibrous glass, but a PCM concentration of .01 f/cc (derived by adding a safety factor of one hundred (100X) to the occupational standard) is believed to be protective of the general public.

Syracuse Research Corporation
301 Plainfield Road, Suite 350
Syracuse, NY 13212

Memo

To: Dennis Santella, Mark Maddaloni and Pat Evangelista, Region 2

From: Bill Thayer, Syracuse Research Corporation

Date: April 9, 2004

Re: Correlation Analysis for PCMe, AHERA and fibers

Per your direction, the Pearson and Spearman correlation coefficients were calculated for the PCMe, AHERA, total fiber (PCM) and non-asbestos fiber results, using data from the WTC database. *Tables F-1* and *F-2* indicate that the correlation between PCMe and AHERA results is high, and a weak relationship is indicated between non-asbestos fibers and PCMe. There does not appear to be a linear or nonlinear relationship among the other pairs of results. Scatter plots (*Figures F-4*) are consistent with these results. Correlations were calculated using only the records where both pairs of measurements were detected. This greatly reduced the number of total pairs that could be included in the calculation, particularly the correlations between PCMe and total fibers, and between AHERA results and 'total fibers'. However, visual inspection of scatter plots that were prepared using all of the data showed that the fiber results varied (approximately) from 0 to 0.06 f/cc when asbestos fibers were not detected by the AHERA and PCMe methods (*Figures F-5* and *F-6*), which is approximately the same range in total fibers that was observed when asbestos was detected with PCMe and AHERA methods. Non-asbestos fibers ranged from approximately 0 to 0.24 f/cc (*Figure F-7*) when asbestos fibers were not detected by the PCMe method, which is also approximately equal to the total range of measured non-asbestos fibers.

Please feel free to contact me at 315-452-8424 or thayer@syrres.com with any questions or comments.

Table F-1. Pearson Correlations

Variable	PCMe	AHERA	Fibers	Non-Asbestos Fibers
PCMe	1.00	**0.86** (<0.0001) 579	0.12 (0.003) 579	0.32 (<0.0001) 532
AHERA	**0.86** (<0.0001) 579	1.00	0.08 (0.006) 1215	0.25 (<0.0001) 1087
Fibers	0.12 (0.003) 579	0.08 (0.26) 1215	1.00	0.15 (<0.0001) 24,706
Non-asbestos fibers	0.32 (<0.0001) 532	0.25 (<0.0001) 1087	0.15 (<0.0001) 24,706	1.00

The Pearson correlation coefficient measures the linear relationship between two variables.

The correlation between a given pair of observations is provided in the cell that occurs in the row and column for that pair of observations; e.g., the correlation between the PCMe and AHERA measurements = 0.86. The first number in each cell is the estimated correlation coefficient, the second number (in parenthesis) is the probability for the null hypothesis that the correlation = 0, and the last number is the number of pairs that were used to estimate the correlation. Low correlations are often found to be significantly different from zero when the sample size is large (e.g., the Spearman correlation between 'Fibers' and 'AHERA').

Table F-2. Spearman Correlations

Variable	PCMe	AHERA	Fibers	Non-Asbestos Fibers
PCMe	1.00	**0.73** (<0.0001) 579	0.12 (0.003) 579	0.17 (<0.0001) 532
AHERA	**0.73** (<0.0001) 579	1.00	0.06 (0.03) 1215	0.13 (<0.0001) 1087
Fibers	0.12 (0.003) 579	0.06 (0.03) 1215	1.00	0.19 (<0.0001) 24,706
Non-asbestos fibers	0.17 (<0.0001) 532	0.13 (<0.0001) 1087	0.19 (<0.0001) 27,706	1.00

The Spearman correlation coefficient measures the nonlinear relationship between two variables; it is calculated using the ranks of the data.

The correlation between a given pair of observations is provided in the cell that occurs in the row and column for that pair of observations; e.g., the correlation between the PCMe and AHERA measurements = 0.73. The first number in each cell is the estimated correlation coefficient, the second number (in parenthesis) is the probability for the null hypothesis that the correlation = 0, and the last number is the number of pairs that were used to estimate the correlation. Low correlations are often found to be significantly different from zero when the sample size is large (e.g., the Spearman correlation between 'Fibers' and 'AHERA').

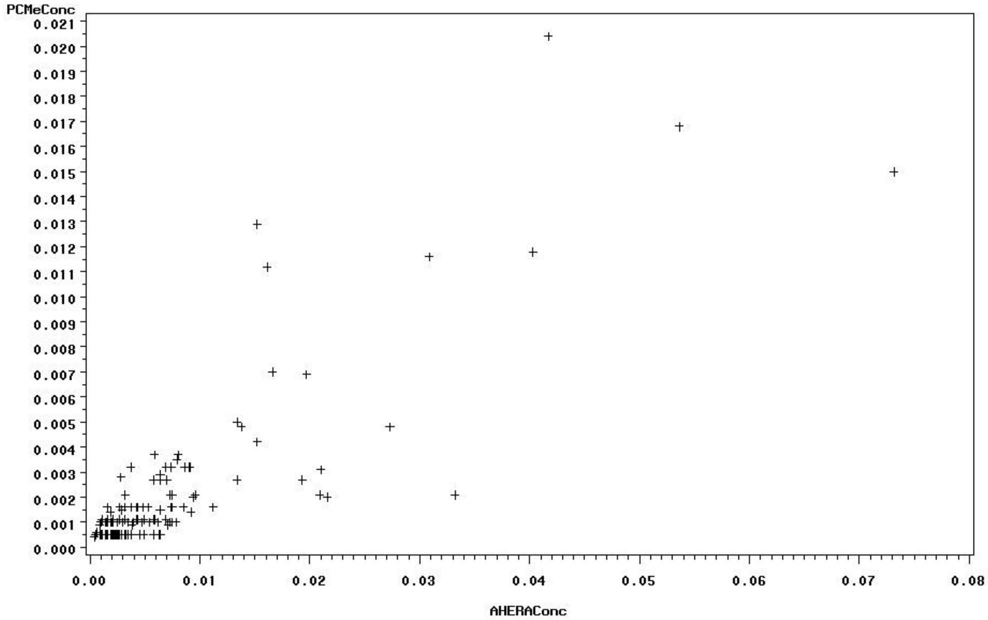


Figure F-1. Scatter plot between PCMe results (structures/cubic centimeter) (vertical axis) and AHERA results (structures/cubic centimeter). The plot indicates a good linear relationship between the two measurements; the Pearson correlation coefficient = 0.86 ($p < 0.0001$).

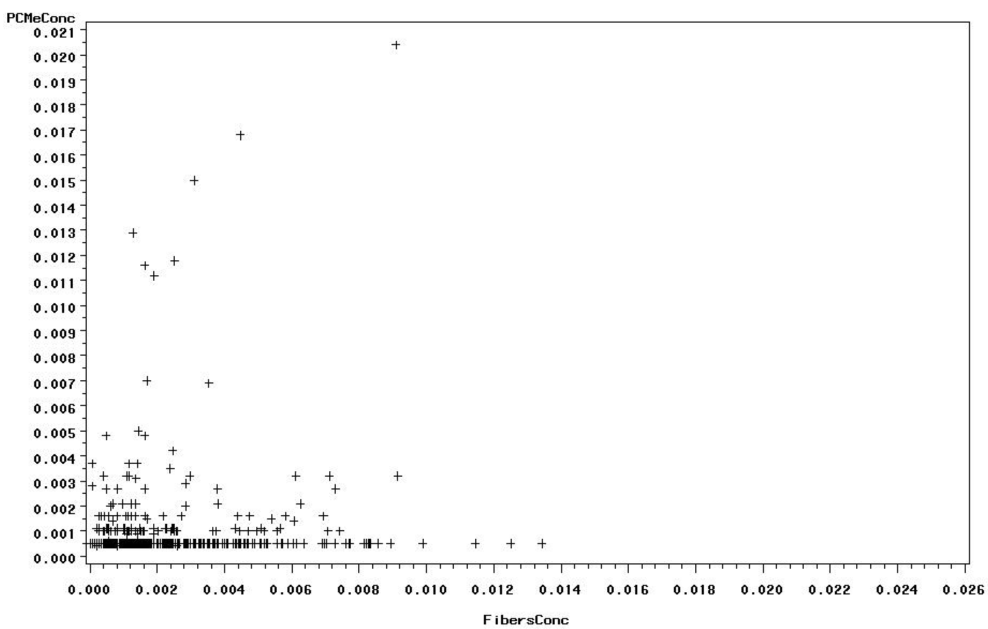


Figure F-2. Scatter plot between PCMe results (structures/cubic centimeter) (vertical axis) and total fibers results (fibers/cubic centimeter). The plot indicates a lack of a relationship between the two measurements; the Pearson correlation coefficient = 0.12 ($p = 0.003$).

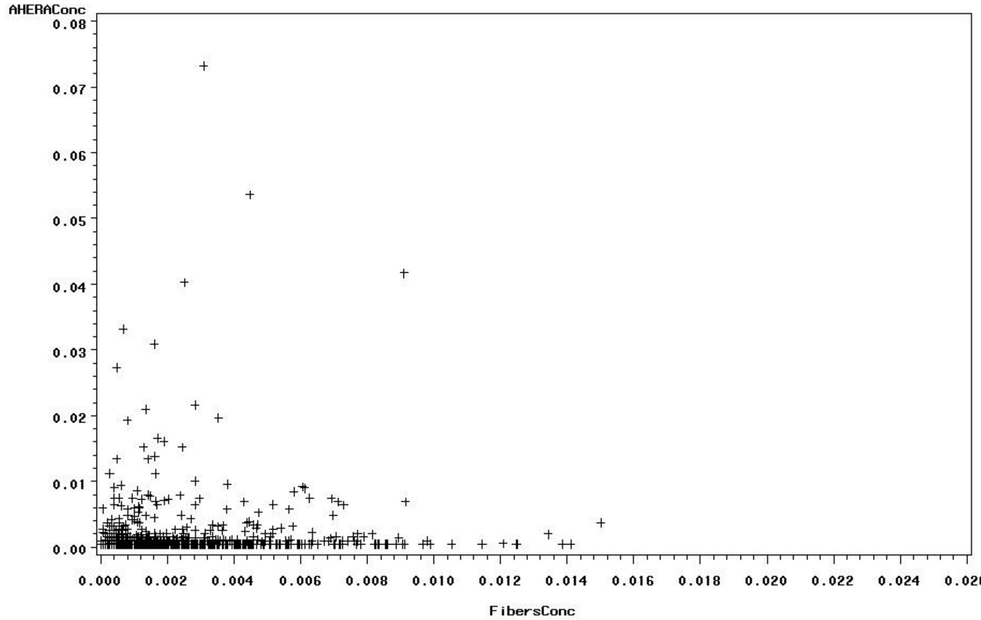


Figure F-3. Scatter plot between AHERA results (structures/cubic centimeter) (vertical axis) and total fibers results (fibers/cubic centimeter). The plot indicates a lack of a relationship between the two measurements; the Pearson correlation coefficient = 0.08 (p = 0.006).

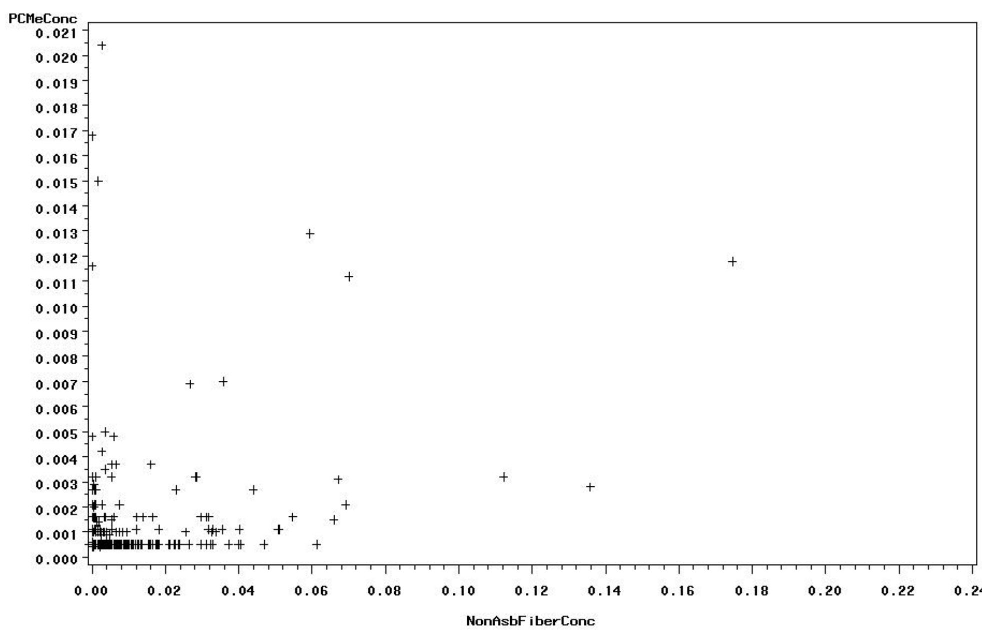


Figure F-4. Scatter plot between PCMe results (structures/cubic centimeter) (vertical axis) and non-asbestos fibers results (fibers/cubic centimeter). A relationship between the two measurements is not apparent from the plot; the Pearson correlation coefficient = 0.32 ($p < 0.001$).

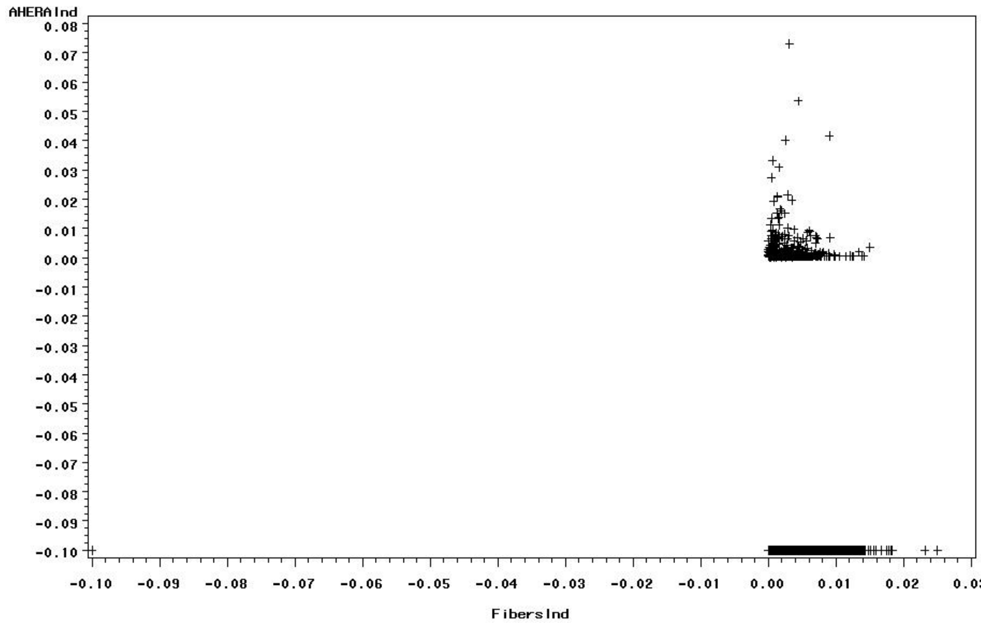


Figure F-5. Scatter plot between AHERA results (structures/cubic centimeter) (vertical axis) and total fibers results (fibers/cubic centimeter). Non-detects for both measurements were set = -0.1 to allow plotting. Total fiber results varied from approximately 0 to 0.03 (f/cc) when asbestos fibers were not detected by the AHERA method.

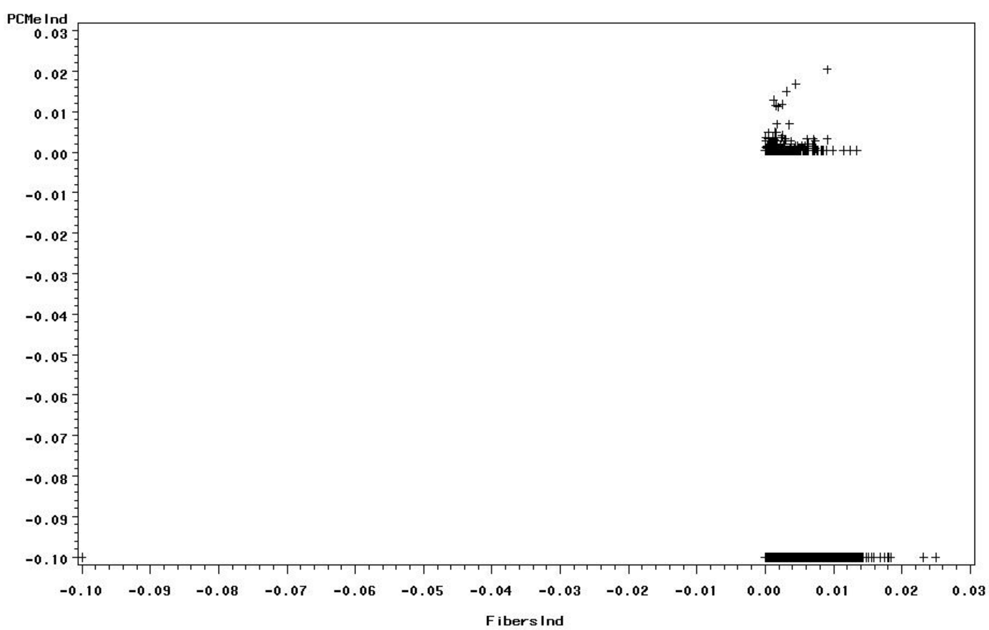


Figure F-6. Scatter plot between PCMe results (structures/cubic centimeter) (vertical axis) and total fibers results (fibers/cubic centimeter). Non-detects for both measurements were set = -0.1 to allow plotting. Total fiber results varied from approximately 0 to 0.03 (f/cc) when asbestos fibers were not detected by PCMe.

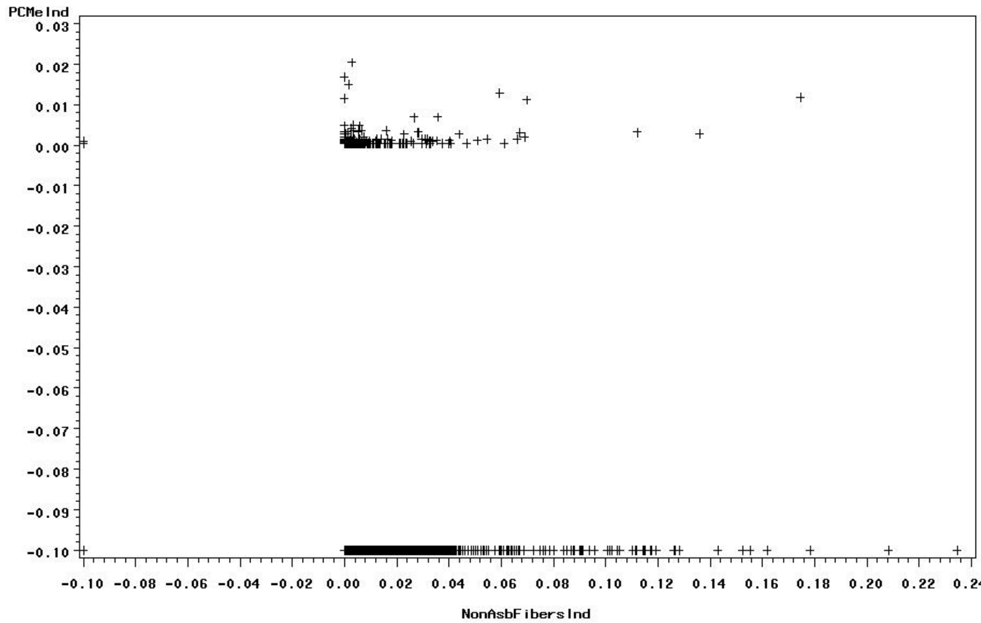


Figure F-7. Scatter plot between PCMe results (structures/cubic centimeter) (vertical axis) and non-asbestos fibers results (fibers/cubic centimeter). Non-detects for both measurements were set = -0.1 to allow plotting. The non-asbestos fiber results varied from approximately 0 to 0.24 (f/cc) when asbestos fibers were not detected by PCMe.

Table F-3. Phase-Contrast Microscopy Equivalent (PCMe) Measurements

Analyte	Clean Or Test	Sampling Procedure	Count		Fibers		Concentration	
			Samples	Detects	Average	Max	Average	Max
PCMe	Clean and Test	aggressive	1396	96	2.90	17	0.0017	0.0129
	Clean and Test	modaggressive	17162	290	1.41	22	0.0008	0.0204
	Test	aggressive	212	2	1.50	2	0.0008	0.0011
	Test	modaggressive	4356	78	1.44	7	0.0007	0.0037
TEM	Clean and Test	aggressive	1396	135	6.96	62	0.0040	0.0403
	Clean and Test	modaggressive	17162	663	2.00	48	0.0012	0.0732
	Test	aggressive	212	6	1.17	2	0.0006	0.0011
	Test	modaggressive	4356	148	2.24	20	0.0011	0.0101
PCM	Clean and Test	unknown	20	20	12.85	31.5	0.0019	0.0040
	Clean and Test	aggressive	1396	1319	10.90	112	0.0021	0.0150
	Clean and Test	modaggressive	17162	15113	13.68	136	0.0026	0.0440
	Test	unknown	16	14	17.68	42	0.0029	0.0060
	Test	aggressive	212	198	11.44	84	0.0020	0.0110
	Test	modaggressive	4359	3824	16.14	185	0.0031	0.0570
Nonasbestos Fibers	Clean and Test	Unknown	20	10	5.90	11	0.0030	0.0053
	Clean and Test	Aggressive	1396	835	10.32	204	0.0057	0.1747
	Clean and Test	Modaggressive	17161	8562	7.38	482	0.0038	0.2345
	Test	Unknown	16	9	10.56	34	0.0055	0.0177
	Test	Aggressive	212	137	20.26	119	0.0103	0.0609
	Test	Modaggressive	4359	2414	8.74	330	0.0045	0.1619

Note: The averages reported above for fibers and concentrations do not include the non detects. For example the average PCMe (aggressive sampling) fiber count of 2.9 is the average for the 96 samples where asbestos was detected. The 1300 non detects were not used to determine an average value for all the PCMe samples.

APPENDIX G.

Calculation of the Standard Deviational Ellipse

The standard deviational ellipse is derived from the bivariate distribution (Ebdon, 1988):

$$\text{Bivariate Distribution} = SQRT\frac{\sigma^2{}_x + \sigma^2{}_y}{2} \qquad \text{Equation 1}$$

The standard deviational ellipse is calculated in two steps (Ebdon, 1988). In the first step, the orientation of the axes of the ellipse is determined by minimizing the sum of squares of the distances between the building locations and the x and y:

$$\theta = Arc\tan\frac{\left[\left(\sum_{i=1}^{N}(x_i-\bar{x})^2 - \sum_{i=1}^{N}(y_i-\bar{y})^2\right) + \left\{\left(\sum_{i=1}^{N}(x_i-\bar{x})^2 - \sum_{i=1}^{N}(y_i-\bar{y})^2\right)^2 + 4\left(\sum_{i=1}^{N}(x_i-\bar{x})(y_i-\bar{y})\right)^2\right\}^{1/2}\right]}{2\sum_{i=1}^{N}(x_i-\bar{x})(y_i-\bar{y})} \qquad \text{Equation 2}$$

The y-axis is rotated clockwise through angle θ. The standard deviations are then calculated using the rotated x- and y-axes:

$$S_x = \sqrt{\left\{2\sum_{i=1}^{N}\left[(x_i-\bar{x})\cos\theta - (y_i-\bar{y})Sin\theta\right]^2 \Big/ N-2\right\}} \qquad \text{Equation 3}$$

$$S_y = \sqrt{\left\{2\sum_{i=1}^{N}\left[(x_i-\bar{x})\sin\theta - (y_i-\bar{y})\cos\theta\right]^2 \Big/ N-2\right\}} \qquad \text{Equation 4}$$

APPENDIX H.

Spatial Autoregression Analysis of the PCMe Data

Daniel A. Griffith, Department of Geography, University of Miami

H.1.0 TEST ONLY DATA

Description of Sample

A total of 4,316 samples were collected, of which 10 have no geographic labels. The total number of samples with a value that exceeds the threshold level is 21. These sample asbestos measurements were aggregated by location into 45 statistical summary areas (SSAs) for lower Manhattan (south of Canal Street). One of these SSAs is the site that housed the WTC; no data were collected for this plus an additional 8 SSAs.

Initial Data Analysis

The rareness of exceedances suggests that these data may be described by a Poisson model. One feature of a Poisson random variable is that its mean, μ, and its variance are equal (equidispersion), a property frequently violated by real world data. "Failure of the Poisson assumption of equidispersion has similar qualitative consequences to failure of the assumption of homoskedasticity" associated with the Gaussian distribution (Cameron and Trivedi, 1998, p. 77). The standard way of accommodating overdispersion (the presence of more variation than is expected for a Poisson random variable) is by replacing a Poisson random variable with a negative binomial random variable—which can be viewed as a gamma mixture of Poisson random variables. In doing so, the distribution of counts is viewed as either (1) having missing variables for the mean specification, or (2) being dependent (i.e., the occurrence of an event increases the probability of further events occurring). The most popular implementation of the negative binomial probability model specifies the variance as being quadratic in the mean, or

$$\mu + \eta\mu^2 = (1 + \eta\mu)\mu,$$

with the dispersion parameter, η, to be estimated. The magnitude of η may be interpreted as follows (after Cameron and Trivedi, 1998, p. 79):

$\eta = 0$ implies no overdispersion;

$\eta \approx \frac{1}{\mu}$ implies a modest degree of overdispersion; and,

$\eta \geq \frac{2}{\mu}$ implies considerable overdispersion.

In other words, if $0 \leq \eta < \frac{0.5}{\mu}$, a spatial analyst may consider overdispersion detected in georeferenced data to be inconsequential, with little to be gained by replacing a Poisson with a negative binomial model specification. Meanwhile, recognizing that these exceedances are constrained by the number of samples collected suggests that these data may be described by a binomial model. Recoding counts of exceedances to a binary (0-1) presence/absence measurement suggests that these data may be described by a logistic model. Simple estimation results for each of these four models appear in *Table H-1*.

Table H-1. Selected Model Estimation Results

Model	Intercept	Equidispersion
Poisson	-5.3232	NA
Negative binomial	-5.0964	4.6066
Binomial	-5.3183	NA
Logistic	1.4213	NA

One important implication from the tabulated results appearing in *Table H-1* is that a Poisson model description of rates may suffer from a marked violation of the equidispersion assumption. The following evidence supports this claim:

$$\frac{2}{\hat{\mu}} = \frac{2}{0.58333} \approx 3.42857 < 4.6066.$$

In other words, the mean and variance may not be constant across the 36 SSAs.

Accounting for Spatial Autocorrelation

A conventional spatial autocorrelation analysis is hindered by two features of the collected data. One is the rareness of exceedance. In order to further explore spatial dependency in this context, average measures of asbestos also were analyzed. The other drawback is the absence of data for 9 SSAs. Because these areal units are dispersed across the study region, computing a Moran Coefficient (MC) becomes problematic.

MC scatterplots appear in *Figure H-1*. No conspicuous geographic pattern is apparent for either rates or averages, in part because of the presence of a large number of zeroes.

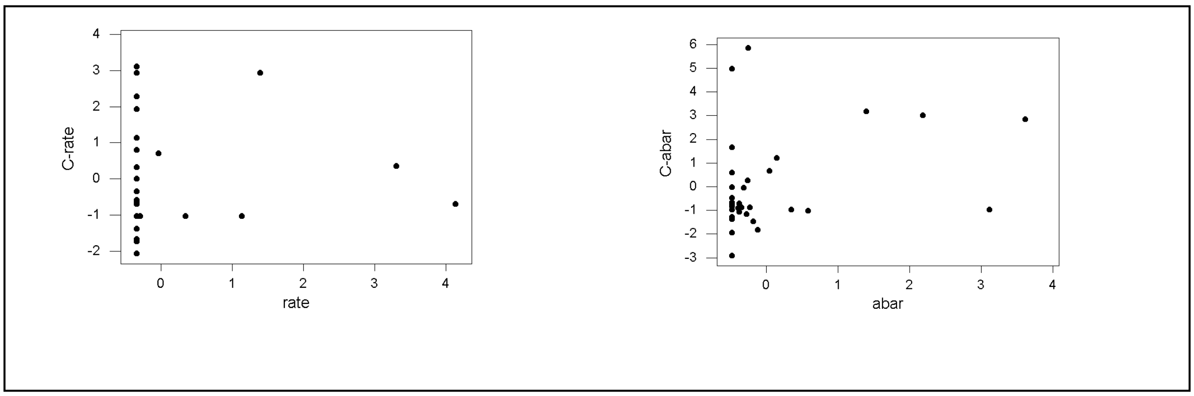


Figure H-1. Left: MC scatterplot for the rate of exceedance. Right: MC scatterplot for the average measure of asbestos.

Latent map patterns also can be assessed with eigenvectors derivable from a MC. Here four of the 11 eigenvectors (E_1, E_8, E_{10}, E_{22}; these were selected using the stepwise options for PROC LOGISTIC in SAS, and SWPOIS in STATA) denoting consequential positive spatial autocorrelation help describe the geographic distribution of exceedance rates. Maps of these synthetic geographic variables appear in *Figure H-2.*

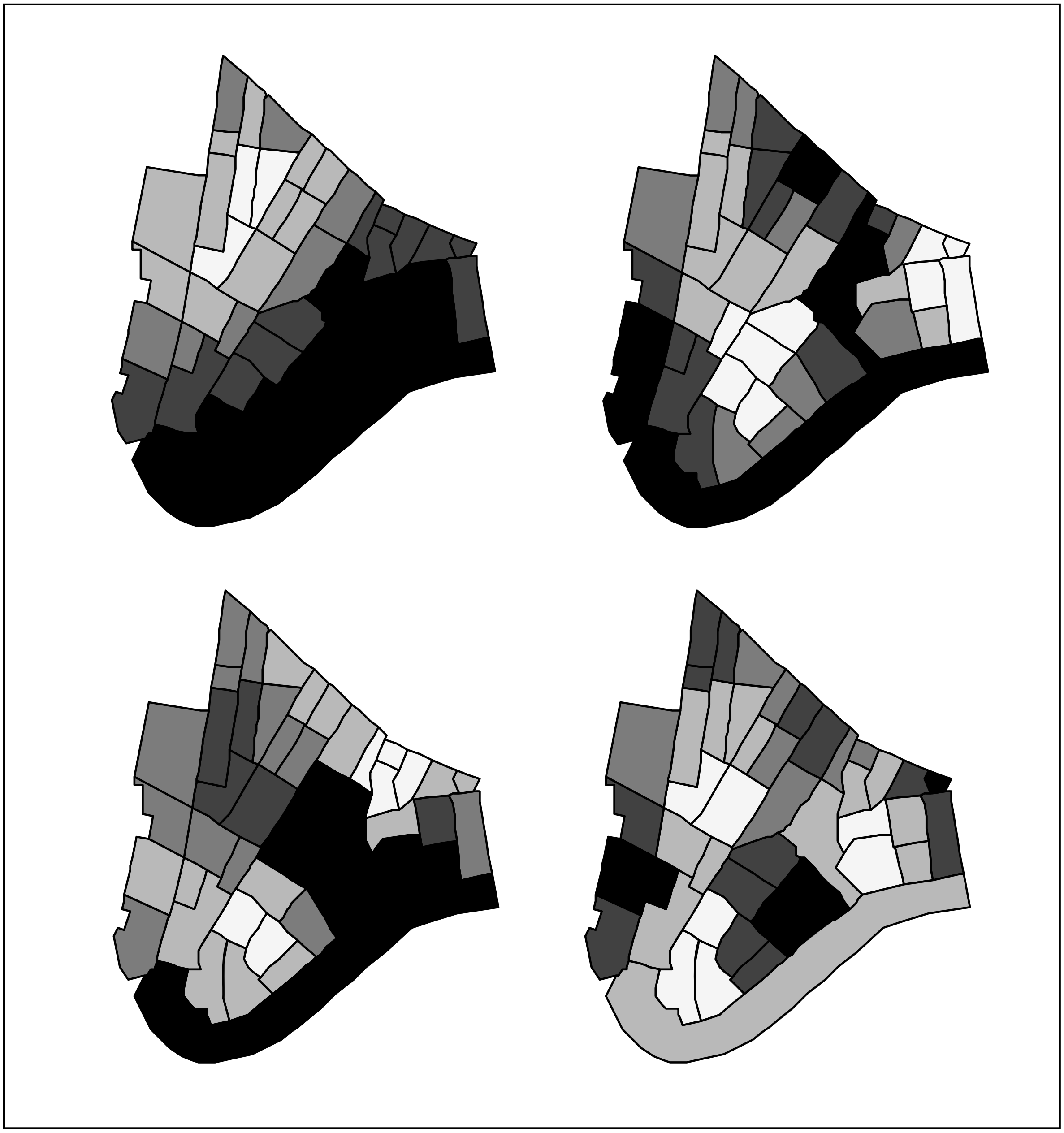


Figure H-2. Geographic distribution of relevant eigenvectors. Top left: E_1. Top right: E_8. Bottom left: E_{10}. Bottom right: E_{22}.

The MC values for the four eigenvectors range from 0.37 to 0.97. Estimation results that include these eigenvectors in the specifications of each of the four models appearing in *Table H-1* are reported in *Table H-2*. The Poisson model with an assumption of equidispersion appears to be reasonable here. This specification accounts for nearly 60% of the variation in the geographic distribution of rates. The binomial model specification accounts for about 30%. The logistic model description seems inappropriate.

Table H-2. Selected Model Estimation Results When Spatial Dependence is Included

Model	Intercept	Equidispersion	E_1	E_8	E_{10}	E_{22}
Poisson	-6.0625	NA	4.6209	-9.2072	3.9665	NA
Negative binomial	-6.1506	0.4476	3.8439	-8.9830	4.5748	NA
Binomial	-6.0572	NA	4.6680	-9.3192	3.9896	NA
Logistic	2.0052	NA	NA	NA	-9.3199	-6.6709

One important finding that can be gleaned from *Table H-2* is detected overdispersion accompanying the simple Poisson model description principally is attributable to latent spatial autocorrelation (0.4476 << $\frac{0.5}{0.58333} \approx 0.8571$). Accordingly, these data can be well described with a Poisson model when the model specification captures spatial dependencies.

Pairwise Comparisons Between SSAs

Pairwise comparisons of SSA asbestos exceedance sampling results were made to assess whether or not statistically significant differences exist. Aggregate sample sizes less than 30 are considered too unreliable, and were not included in this assessment. The outcome of this sample size restriction is 22 SSAs with a sufficient number of samples, allowing ($22 \times 21/2=$) 231 pairwise comparisons.

Pairwise Comparisons Statistical Theory

The rareness of exceedances suggests that an analysis of differences of means cannot easily be based upon a binomial model. For a normal approximation to be reasonable here, each SSA sample would need to satisfy the constraint of (sample size) $\times$ (exceedance rate) > 5.

Although both the binomial and the Poisson regression models produce very similar descriptive results for the lower Manhattan asbestos data, the Poisson model seems to furnish a better model-based inferential basis.

Consider the difference between two Poisson random variables with means μ_1 and μ_2. Mathematical statistical theory states that the expected value of the difference of any two random variables equals the difference of their expected values. Therefore, the difference of means for two Poisson random variables equals $\mu_1 - \mu_2$. If these two Poisson random variables are independent, then their difference has a known statistical distribution (Skellam, 1946). The respective sampling variance of each is $\frac{\mu_1}{n_1}$ and $\frac{\mu_2}{n_2}$; the sampling variance of their difference is $\frac{\mu_1}{n_1} + \frac{\mu_2}{n_2}$, which parallels a standard result for normal curve theory. As the two means, μ_1 and μ_2, increase to infinity, the distribution of the difference of these two independent Poisson variables rapidly converges to normality. Convergence on a normal probability distribution is quick, with a very good approximation attained once μ_1>4 and μ_2>4. But for small values of μ_1 and/or μ_2 this normal approximation is poor. In these latter cases, the difference of two Poisson random variables still tends to conform to a Poisson distribution.

When multiple comparisons are being made, the overall level of significance often should be adjusted downward to compensate for an increase in chance null hypothesis rejections (i.e., Type I errors). For example, in the single WTC asbestos study for which 231 difference of means null hypotheses are being evaluated, each hypothesis with a single test, setting the global Type I error probability at α=0.05 means that at least one in twenty of the hypotheses tested will turn up significant, merely due to chance fluctuation. In other words, there is a very good chance of finding at least one test (and as many as 11 or 12) to be statistically significant solely due to sampling variability, incorrectly concluding that a difference exists in the population. The Bonferroni correction/adjustment is the most basic procedure for modifying α to compensate for this increase in Type I error probability. When the samples are independent, the modification becomes $\frac{\alpha}{\#\ \text{of tests}}$. For the WTC study, and a two-tailed test, this becomes $\frac{0.005}{231}$ for an overall α=0.01, $\frac{0.025}{231}$ for an overall α=0.05, and $\frac{0.05}{231}$ for an overall α=0.10. As correlation between the samples increases, the denominator of this adjustment effectively decreases toward 1. Uncorrelated variables require a full Bonferroni adjustment, perfectly correlated variables require no adjustment, and partially correlated variables required an adjustment between these two extremes.

Differences of Exceedance Rates

The estimated spatially filtered Poisson model produces sample mean estimates for uncorrelated Poisson variables. These models include LN (# of cases) as an offset variable. Therefore, dividing both sides of the estimated equation for $\hat{\mu}_i$ (i.e., the mean rate for areal unit i) by the corresponding number of samples yields the set of estimated rates, assuming an underlying Poisson process, of $\frac{\hat{\mu}_i}{n_i}$, i=1, 2, …, 22. The accompanying set of null hypotheses becomes

$$H_o\text{: } \frac{\mu_i}{n_i} - \frac{\mu_j}{n_j} = 0\ ,\ i \neq j,\ i=1, 2, \ldots, 22 \text{ and } j=i+1, i+2, \ldots, 22\ .$$

The estimated standard error for this difference of rates test is given by $\sqrt{\frac{\hat{\mu}_i}{n_i^2} + \frac{\hat{\mu}_j}{n_j^2}}$.

A simulation experiment involving 50,000 difference of means replications (total=$231 \times 50{,}000$) was conducted using the spatially filtered Poisson model estimation results. The simulated Poisson random variable, Y, then was used in a bivariate linear regression analysis, which yielded

$$\frac{\hat{\mu}_i}{n_i} - \frac{\hat{\mu}_j}{n_j} = -0.00000 + 1.00012\,\overline{\frac{y_i}{n_i} - \frac{y_j}{n_j}} + e\ ,\ R^2 = 1.00, \text{ and}$$

$$\sqrt{\frac{\hat{\mu}_i}{n_i^2} + \frac{\hat{\mu}_j}{n_j^2}} = -0.00000 + 1.00031\, s_{\overline{\frac{y_i}{n_i} - \frac{y_j}{n_j}}} + e\ ,\ R^2 = 1.00.$$

In both cases, the intercept is not significantly different from 0, and the slope is not significantly different from 1. These simulations confirmed the preceding theoretical results.

The model-based mean estimates range from roughly 0.01 to 7.22, implying that most all of the difference of rates sampling distributions should be non-normal. Each simulated dataset was subjected to a diagnostic Kolmogorov-Smirnov goodness-of-fit test for a normal distribution, producing test statistics ranging from roughly 0.48 to 0.53. In other words, the simulated sampling distributions fail to conform to normal distributions. Consequently, the pairwise difference of rates assessments are based upon a Hope-type nonparametric simulation analysis, involving 99,999 replications coupled with each observed difference. The simulated distribution is based on a pair of Poisson random variables, each with the same mean of $\frac{n_1\mu_2 + n_2\mu_1}{2n_1n_2}$, which yields a null hypothesis difference of 0 and the correct theoretical variance of $\frac{\mu_1}{n_1} + \frac{\mu_2}{n_2}$. Because a two-tailed test is employed here, an observed rank of 1-2 or 99,999-100,000 results in a rejection of the null hypothesis for α=0.01, an observed rank of 3-12 or 99,990-99,998 results in a rejection of the null hypothesis for α=0.05, and an observed rank of 12-22 or 99,979-99,989 results in a rejection of the null hypothesis for α=0.10. Based on these criteria, 21 pairs of exceedance rates are significantly different at the 10% level, 17 pairs are significantly different at the 5% level, and 48 pairs are significantly different at the 1% level. Basically, roughly 37% of the extreme MCGB mean pairs tend to be significantly different. These differences arise from four clusters of mean sizes. The first is dominated by the largest MCBG mean of roughly 9 (MCBG 10015022). The second is dominated by the second and third largest means of approximately 2-3 (MCBG 10008002, MCBG 10015021). The third is dominated by the medium mean of approximately 1.5 (MCBG 10015012). The fourth group is dominated by the relatively small mean of roughly 0.1 (MCBG 10317019D). Significant pairwise contrasts appear in *Tables H-3a* and *H-3b*, and *Figure H-3*.

These results need to be moderated by keeping in mind that the estimated Poisson model accounts for only about 50% of the variance in the observed exceedances.

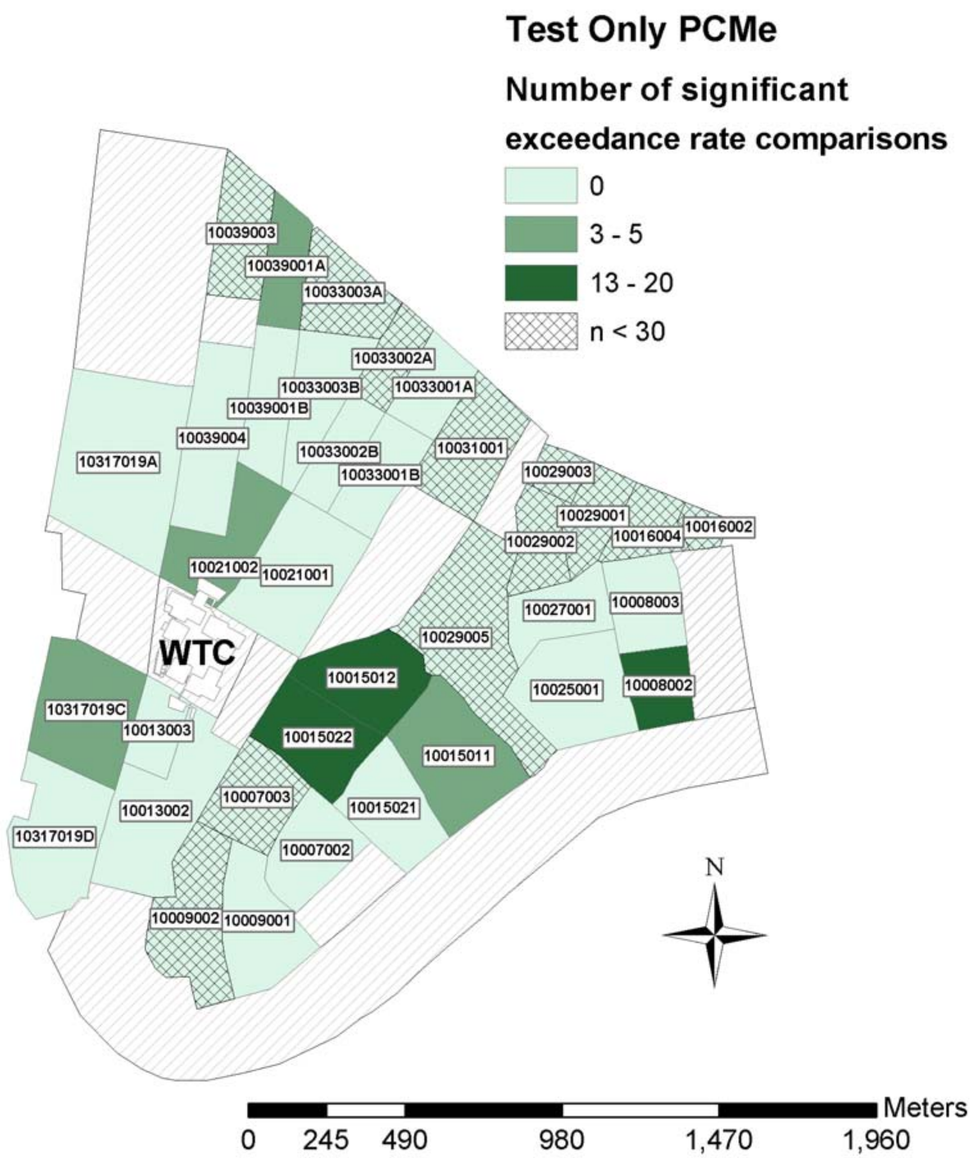


Figure H-3. Significant differences between estimated exceedance rates for *test only* data, with Statistical Summary Areas labeled. Estimates are based on the spatially-filtered Poisson model (see *Section 3.2.3.2* and *Appendix D* for details). The number of significant pairwise comparisons at an experiment-wise $\alpha = 0.01$ (with a Bonferroni adjustment) are shown for SSAs that had one or more exceedances. Comparisons with SSAs with sample sizes less than 30 (indicated in figure by cross-hatching, and in figure legend by "n<30") were deemed unreliable and were therefore not included in the analysis. The 3 SSAs that were found to have the most number of significant comparisons are located east of the WTC. The numbers of exceedances for these three SSAs range from 2 to 9; their exceedance rates range from 0.021 to 0.060. The spatial pattern exhibited above is similar to the pattern of exceedance rates that is shown *in Figure 3-13* however, 4 of the 7 SSAs with exceedance rates in the 4^{th} quartile (*Figure 3-13*) were found to be significantly different from 5 or fewer of the other SSAs.

Table H-3a. *Test only* SSAs Pairs Having Significant Pairwise Comparisons of Exceedance rates			
Significantly Different Means at the α=0.10 Level			
10008002	10015011	10015011	10033001B
10008002	10039004	10015011	10033001A
10015011	10039001A	10033003B	10033001A
10015011	10033002B	10033002B	10033001A
Significantly Different Means at the α=0.05 Level			
10007002	10015012	10015011	10039004
10008002	10021001	10015011	10039001B
10013002	10015011	10015011	10033003B
10013003	10015011	10015011	10317019A
Significantly different means at the α=0.01 level			
10007002	10015022	10015012	10027001
10008002	10013002	10015012	10039004
10008002	10013003	10015012	10039001B
10008002	10015022	10015012	10039001A
10008002	10021002	10015012	10033003B
10008002	10039001B	10015012	10033002B
10008002	10039001A	10015012	10033001B
10008002	10033003B	10015012	10033001A
10008002	10033002B	10015012	10317019A
10008002	10033001B	10015012	10317019C
10008002	10033001A	10015012	10317019D
10008002	10317019A	10015021	10015022
10008002	10317019C	10015022	10021001
10008002	10317019D	10015022	10021002
10013002	10015012	10015022	10025001
10013002	10015022	10015022	10027001
10013003	10015012	10015022	10039004
10013003	10015022	10015022	10039001B
10015011	10015012	10015022	10039001A
10015011	10015022	10015022	10033003B
10015011	10021002	10015022	10033002B
10015011	10317019C	10015022	10033001B
10015011	10317019D	10015022	10033001A
10015012	10015021	10015022	10317019A
10015012	10021001	10015022	10317019C
10015012	10021002	10015022	10317019D

[a]See figure H-3 for a map of the statistical summary areas (SSAs).

Table H-3b. Distribution of Significant Difference of Means by MCBG, *Test Only*

MCBG	Number of Significant Differences	MCBG	Number of Significant Differences
10007002	2	10021002	4
10008002	19	10025001	3
10008003	2	10027001	5
10009001	1	10033001A	5
10013002	4	10033002B	8
10013003	8	10033003B	5
10015011	5	10039001A	5
10015012	17	10039001B	6
10015021	17	10317019A	9
10015022	21	10317019C	8
10021001	4	10317019D	14

[a]See figure H-3 for a map of the statistical summary areas (SSAs).

H.2.0 CLEAN AND TEST DATA

Description of Sample

A total of 24,375 samples were collected, of which 17 have no geographic labels. The total number of samples with a value that exceeds the threshold level is 102. These sample asbestos measurements were aggregated by location into 45 statistical summary areas (SSAs) for lower Manhattan (south of Canal Street). One of these SSAs is the site that housed the WTC; no data were collected for this plus an additional 6 SSAs.

Initial Data Analysis

The rareness of exceedances suggests that these data may be described by a Poisson model. One feature of a Poisson random variable is that its mean, μ, and its variance are equal (equidispersion), a property frequently violated by real world data. "Failure of the Poisson assumption of equidispersion has similar qualitative consequences to failure of the assumption of homoskedasticity" associated with the Gaussian distribution (Cameron and Trivedi, 1998, p. 77). The standard way of accommodating overdispersion (the presence of more variation than is expected for a Poisson random variable) is by replacing a Poisson random variable with a negative binomial random variable—which can be viewed as a gamma mixture of Poisson random variables. In doing so, the distribution of counts is viewed as either (1) having missing variables for the mean specification, or (2) being dependent (i.e., the occurrence of an event increases the probability of further events occurring). The most popular implementation of the negative binomial probability model specifies the variance as being quadratic in the mean, or

$$\mu + \eta\mu^2 = (1 + \eta\mu)\mu,$$

with the dispersion parameter, η, to be estimated. The magnitude of η may be interpreted as follows (after Cameron and Trivedi, 1998, p. 79):

$\eta = 0$ implies no overdispersion;

$\eta \approx \frac{1}{\mu}$ implies a modest degree of overdispersion; and,

$\eta \geq \frac{2}{\mu}$ implies considerable overdispersion.

In other words, if $0 \leq \eta < \frac{0.5}{\mu}$, a spatial analyst may consider overdispersion detected in georeferenced data to be inconsequential, with little to be gained by replacing a Poisson with a negative binomial model specification. Meanwhile, recognizing that these exceedances are constrained by the number of samples collected suggests that these data may be described by a binomial model. Recoding counts of exceedances to a binary (0-1) presence/absence measurement suggests that these data may be described by a logistic model. Simple estimation results for each of these four models appear in *Table H-4*.

Table H-4. Selected Constant Mean Model Estimation Results for Rates

Model	Intercept	Equidispersion
Poisson for rates	-5.4756	NA
Negative binomial for rates	-5.2098	2.8692
Binomial	-5.4713	NA
Logistic	0.3185	NA

Note: rates were modeled by including the log of the number of cases as an offset variable.

One important implication from the tabulated results appearing in *Table H-4* is that a Poisson model description of rates may suffer from a dramatic violation of the equidispersion assumption. The following evidence supports this claim:

$$\frac{2}{\hat{\mu}} = \frac{2}{2.68421} \approx 0.74510 << 2.8692.$$

In other words, the mean and variance may not be constant across the 38 SSAs.

<u>*Accounting for Spatial Autocorrelation*</u>

A conventional spatial autocorrelation analysis is hindered by two features of the collected data. One is the rareness of exceedance. In order to further explore spatial dependency in this context, average measures of asbestos also were analyzed. Both the rates and the average measures were transformed, using a logarithmic (i.e., Box-Cox 0 power) transformation with a translation parameter, to better conform to a bell-shaped curve (see *Figure H-4*). The other drawback is the absence of data for 7 SSAs. Because these areal units are dispersed across the study region, computing a Moran Coefficient (MC) becomes problematic.

MC scatterplots appear in *Figure H-5*. A conspicuous geographic pattern of positive spatial autocorrelation is apparent for the averages, and a possible positive spatial autocorrelation pattern may be present for the rates. Both patterns are corrupted by the presence of a number of zeroes.

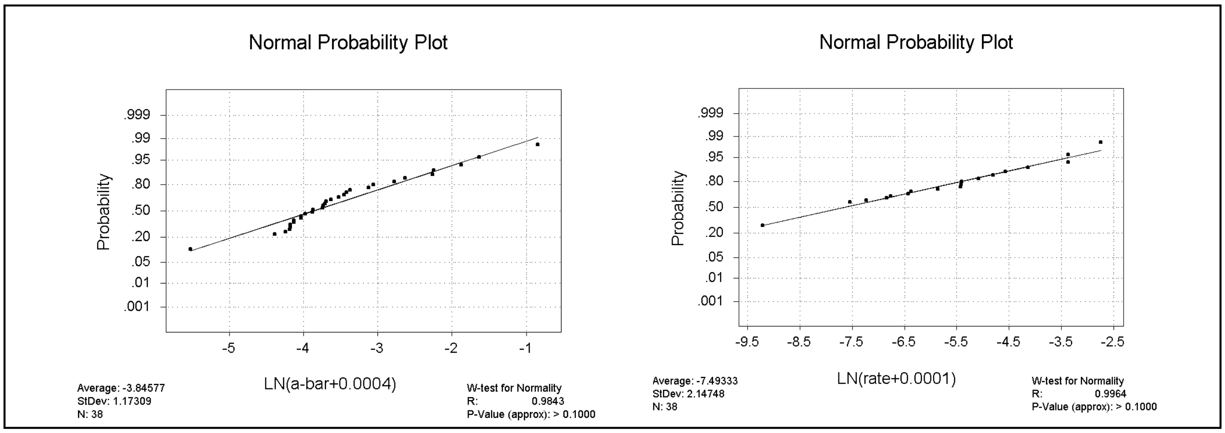


Figure H-4. Left: quantile plot for LN($\overline{\text{asbestos}}$ + 0.004). Right: quantile plot for LN(rate + 0.0001).

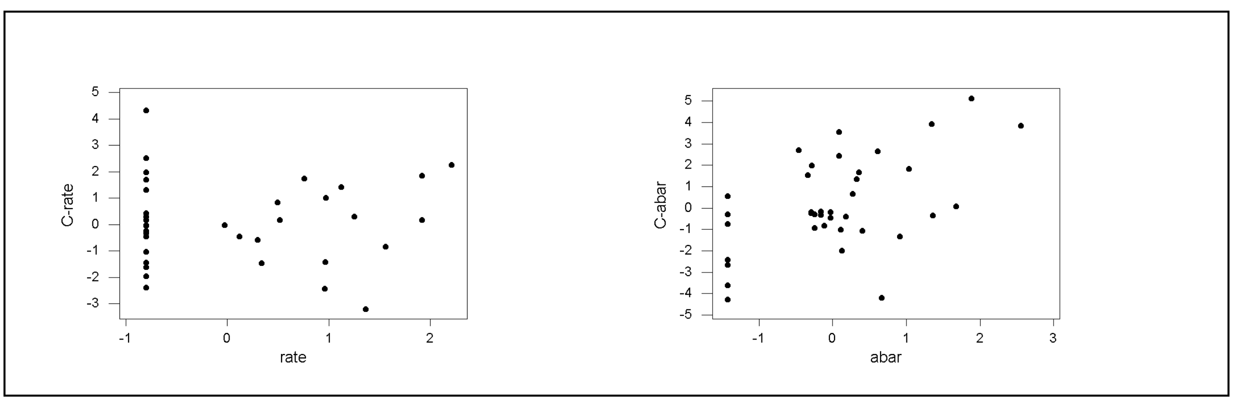


Figure H-5. Left: MC scatterplot for the rate of exceedance. Right: MC scatterplot for the average measure of asbestos.

Latent map patterns also can be assessed with eigenvectors derivable from a MC. Here five of the 11eigenvectors (E_2, E_3, E_8, E_{17}, E_{22}; these were selected using the stepwise options for PROC LOGISTIC in SAS, and SWPOIS in STATA) denoting consequential positive spatial autocorrelation help describe the geographic distribution of exceedance rates for the Poisson and binomial models. The negative binomial model failed to be estimable, yielding a negative maximum likelihood estimate for dispersion; but, the deviance measure for the estimated Poisson model is 1.36, suggesting a lack of serious overdispersion. One eigenvector (E_{10}) relates to the logistic version of the variable. Maps of three of the five synthetic geographic variables appear in *Figure H-6*.

The MC values for the five eigenvectors range from 0.38 to 0.93. Estimation results that include these eigenvectors in the specifications of each of the four models appearing in *Table H-4* are reported in *Table H-5*. The Poisson model with an assumption of equidispersion appears to be reasonable here. This specification accounts for roughly 40% of the variation in the geographic distribution of rates. The binomial model specification renders very similar results. The logistic model description seems inappropriate.

One important finding that can be gleaned from *Table H-2* is even detected modest overdispersion accompanying the Poisson model description largely is attributable to latent spatial autocorrelation.

Table H-5. Selected model estimation results for rates when spatial dependence is included

Variable	Poisson model	Negative binomial model	Binomial model	Logistic model
intercept	-5.9383	Failed to be estimable	-5.9347	0.2773
equidispersion	NA		NA	NA
E_2	-4.2422		-4.2812	NA
E_3	4.4056		4.4575	NA
E_8	-5.4424		-5.5115	NA
E_{10}	NA		NA	-4.4191
E_{17}	-2.2640		-2.2961	NA
E_{22}	4.2200		4.2615	NA

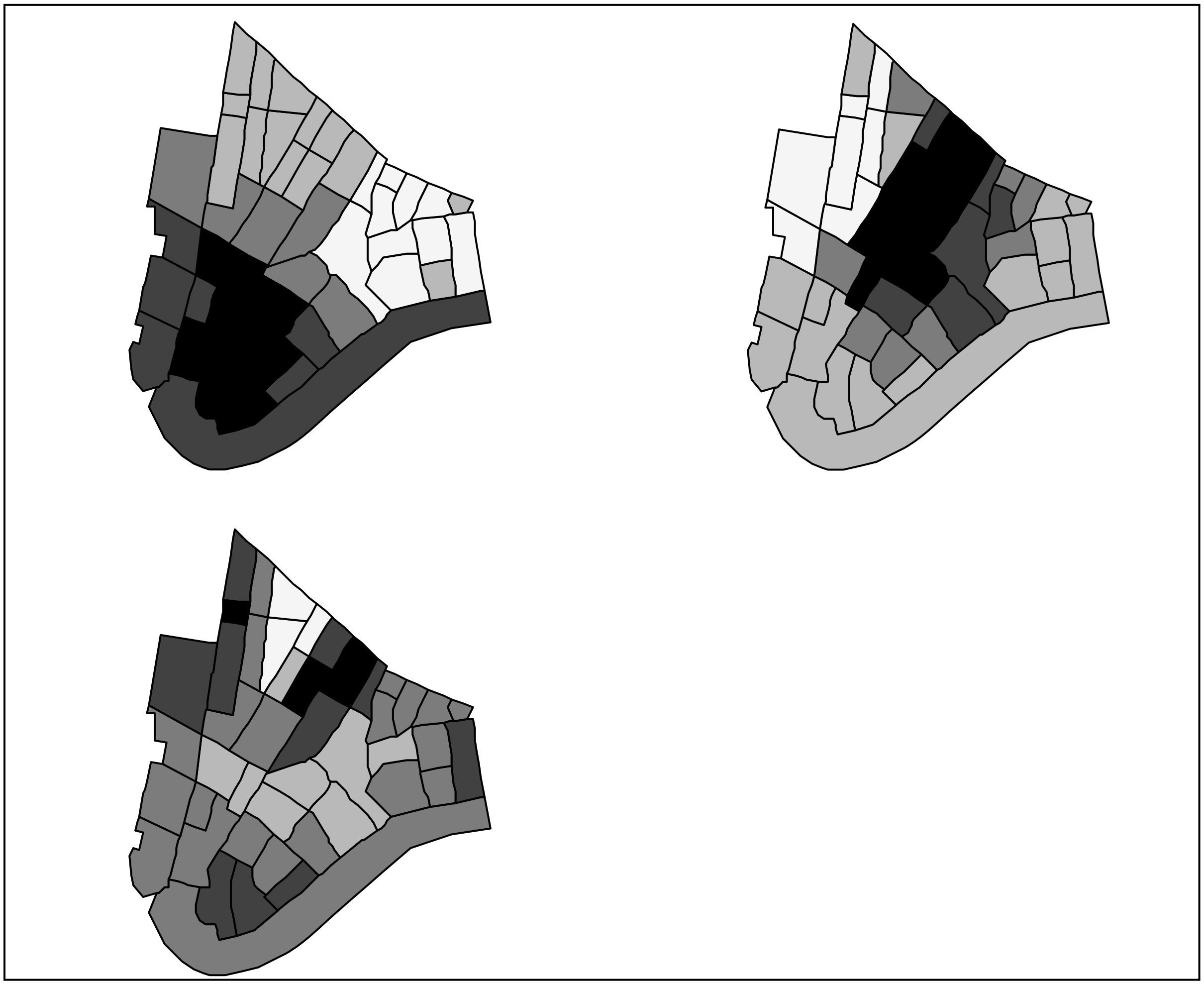


Figure H-6. Geographic distribution of relevant eigenvectors. Top left: E_2. Top right: E_3. Bottom left: E_{17}.

Pairwise Comparisons Between SSAs

Pairwise comparisons of SSA asbestos exceedance sampling results were made to assess whether or not statistically significant differences exist. Aggregate sample sizes less than 30 are considered too unreliable, and were not included in this assessment. The outcome of this sample size restriction is 32 SSAs with a sufficient number of samples, allowing ($31\times30/2=$) 465 pairwise comparison.

Differences of Exceedance Rates

The estimated spatially filtered Poisson model produces sample mean estimates for uncorrelated Poisson variables. These models include LN(# of cases) as an offset variable. Therefore, dividing both sides of the estimated equation for $\hat{\mu}_i$ (i.e., the mean rate for areal unit i) by the corresponding number of samples yields the set of estimated rates, assuming an underlying Poisson process, of $\frac{\hat{\mu}_i}{n_i}$, i=1, 2, …, 31. The accompanying set of null hypotheses becomes

$$H_o: \frac{\mu_i}{n_i} - \frac{\mu_j}{n_j} = 0 \text{ , } i \neq j\text{, } i=1, 2, \ldots, 31 \text{ and } j=i+1, i+2, \ldots, 31 \text{ .}$$

The estimated standard error for this difference of rates test is given by $\sqrt{\frac{\hat{\mu}_i}{n_i^2} + \frac{\hat{\mu}_j}{n_j^2}}$.

A simulation experiment involving 50,000 difference of means replications (total=496×50,000) was conducted using the spatially filtered Poisson model estimation results. The simulated Poisson random variable, Y, then was used in a bivariate linear regression analysis, which yielded

$$\frac{\hat{\mu}_i}{n_i} - \frac{\hat{\mu}_j}{n_j} = -0.00000 + 0.99955\overline{\frac{y_i}{n_i} - \frac{y_j}{n_j}} + e \text{ , } R^2 = 1.00\text{, and}$$

$$\sqrt{\frac{\hat{\mu}_i}{n_i^2} + \frac{\hat{\mu}_j}{n_j^2}} = 0.00001 + 0.99873\, s_{\frac{y_i}{n_i} - \frac{y_j}{n_j}} + e \text{ , } R^2 = 1.00.$$

In the second case, the intercept is significantly different from 0, and in both cases the slope is significantly different from 1. These may well be size effect results, since substantively both intercepts effectively are zero, and both slopes effectively are 1.

The model-based mean estimates range from roughly 0.10 to 32.60, implying that at least some of the difference of rates sampling distributions should be non-normal. Each simulated dataset was subjected to a diagnostic Kolmogorov-Smirnov goodness-of-fit test for a normal distribution, producing test statistics ranging from roughly 0.01 to 0.35. In other words, the simulated sampling distributions fail to conform to normal distributions. Consequently, the pairwise difference of rates assessments are based upon a Hope-type nonparametric simulation analysis, involving 99,999 replications coupled with each observed difference. The simulated distribution is based on a pair of Poisson random variables, each with the same mean of $\frac{n_1\mu_2 + n_2\mu_1}{2n_1n_2}$, which yields a null hypothesis difference of 0 and the correct theoretical variance of $\frac{\mu_1}{n_1} + \frac{\mu_2}{n_2}$. Because a two-tailed test is employed here, an observed rank of 1 or 100,000 results in a rejection of the null hypothesis for α=0.01, an observed rank of 2-5 or 99,996-99,999 results in a rejection of the null hypothesis for α=0.05, and an observed rank of 6-11 or 99,990-99,995 results in a rejection of the null hypothesis for α=0.10. Based on these criteria, six pairs of exceedance rates are significantly different at the 10% level, 14 pairs are significantly different at the 5% level, and 122 pairs are significantly different at the 1% level. Basically, roughly 33% of the extreme MCGB mean pairs tend to be significantly different. These differences arise from four clusters of mean sizes. The first is the extreme MCBG mean of nearly 33 (MCBG 10015022). The second is the third largest mean of approximately 16 (MCBG 10015012). The third is the somewhat small mean of 0.64 (MCBG 10016004) which more than likely is being amplified by its small sample size of 32. The remaining 28 MCGBs form a set whose sample-size-weighted absolute differences of means range from nearly 0 to almost 0.1. Primarily, significant differences are between the extremes within this group (see *Tables H-6a* and *6b*, and *Figure H-7*).

These results need to be moderated by keeping in mind that the estimated Poisson model accounts for only about 50% of the variance in the observed exceedances.

Table H-6a. SSAs Pairs Having Significant pairwise Comparisons of Rates[a]					
Significantly Different Means at the α = 0.10 Level					
10009002	10027001	10015011	10033002A	10027001	10317019C
10009002	10033003B	10015021	10317019C	10039004	10317019C
Significantly Different Means at the α = 0.05 Level					
10007002	10009002	10013003	10027001	10021001	10317019C
10008002	10021001	10021001	10021002	10027001	10039001A
10009001	10027001	10021001	10025001	10033003B	10317019C
10009002	10015021	10021001	10039001B	10039004	10033003B
10013003	10021001	10021001	10039004		
Significantly Different Means at the α = 0.01 Level					
10007002	10009001	10015011	10021001	10015021	10021002
10007002	10013002	10015011	10021002	10015021	10025001
10007002	10015011	10015011	10025001	10015021	10039001B
10007002	10015012	10015011	10027001	10015021	10039004
10007002	10015022	10015011	10029002	10015021	10317019A
10007002	10021002	10015011	10031001	10015021	10317019D
10007002	10039004	10015011	10033001A	10015022	10016004
10007002	10317019D	10015011	10033001B	10015022	10021001
10008002	10015011	10015011	10033002B	10015022	10021002
10008002	10015012	10015011	10033003A	10015022	10025001
10008002	10015022	10015011	10033003B	10015022	10027001
10008002	10027001	10015011	10039001A	10015022	10029002
10008003	10015012	10015011	10039001B	10015022	10031001
10008003	10015022	10015011	10039003	10015022	10033001A
10009001	10015011	10015011	10039004	10015022	10033001B
10009001	10015012	10015011	10317019A	10015022	10033002A
10009001	10015021	10015011	10317019C	10015022	10033002B
10009001	10015022	10015011	10317019D	10015022	10033003A
10009001	10021001	10015012	10015021	10015022	10033003B
10009001	10033003B	10015012	10015022	10015022	10039001A
10009001	10317019C	10015012	10016004	10015022	10039001B
10009002	10015011	10015012	10021001	10015022	10039003
10009002	10015012	10015012	10021002	10015022	10039004
10009002	10015022	10015012	10025001	10015022	10317019A
10009002	10021001	10015012	10027001	10015022	10317019C
10009002	10317019C	10015012	10029002	10015022	10317019D
10013002	10015011	10015012	10031001	10021001	10039001A
10013002	10015012	10015012	10033001A	10021001	10317019A
10013002	10015021	10015012	10033001B	10021001	10317019D
10013002	10015022	10015012	10033002A	10021002	10027001
10013002	10021001	10015012	10033002B	10021002	10033003B
10013002	10027001	10015012	10033003A	10025001	10027001
10013002	10033003B	10015012	10033003B	10027001	10039001B
10013002	10317019C	10015012	10039001A	10027001	10039004
10013003	10015011	10015012	10039001B	10027001	10317019A
10013003	10015012	10015012	10039003	10027001	10317019D
10013003	10015021	10015012	10039004	10033003B	10317019A
10013003	10015022	10015012	10317019A	10033003B	10317019D
10015011	10015012	10015012	10317019C	10039001B	10033003B
10015011	10015021	10015012	10317019D	10317019C	10317019D
10015011	10015022	10015021	10015022		

[a]See ***Figure H-7*** for a map of the statistical summary areas (SSAs).

Table H-6b. Distribution of Significant Difference of Means by MCBG, Clean & Test Data			
MCBG	**Number of Significant Differences**	**MCBG**	**Number of Significant Differences**
10007002	9	10029002	3
10008002	5	10031001	3
10008003	2	10033001A	3
10009001	9	10033001B	3
10009002	9	10033002A	3
10013002	9	10033002B	3
10013003	6	10033003A	3
10015011	28	10033003B	12
10015012	30	10039001A	5
10015021	14	10039001B	7
10015022	30	10039003	3
10016004	2	10039004	9
10021001	16	10317019A	7
10021002	8	10317019C	12
10025001	6	10317019D	9
10027001	16		

[a]See *Figure H-7* for a map of the statistical summary areas (SSAs).

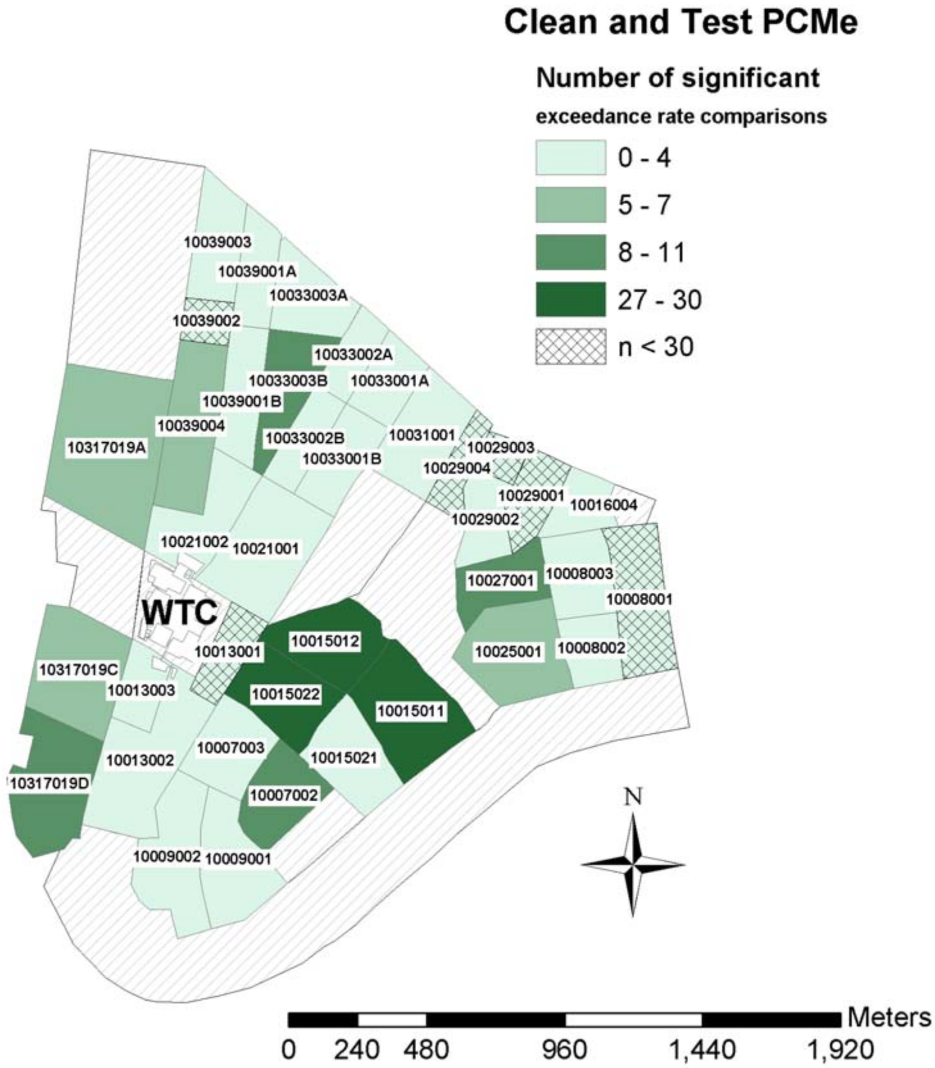


Figure H-7. Significant differences between estimated exceedance rates for clean and test data, with Statistical Summary Areas labeled. Estimates are based on the spatially-filtered Poisson model (see *Section 3.2.3.2* and *Appendix D* for details). The number of significant pairwise comparisons at an experiment-wise $\alpha = 0.01$ (with a Bonferroni adjustment) are shown for SSAs that had one or more exceedances. Comparisons with SSAs with sample sizes less than 30 (indicated in figure by cross-hatching, and in figure legend by "n<30") were deemed unreliable and were therefore not included in the analysis. Three of the SSAs that were found to have the most number of significant comparisons are located east of the WTC. The numbers of exceedances for these three SSAs range from 17 to 32; their exceedance rates range from 0.006 to 0.059. The spatial pattern exhibited above is similar to the pattern of exceedance rates that is shown in *Figure 3–14* however, 3 of the 9 SSAs with exceedance rates in the 4th quartile (*Figure 3–14*) were found to be significantly different from 4 or fewer of the other SSAs.

H.3.0 CLEAN AND TEST DATA SUBSET

Description of Sample

When sampling results for five intensively sampled buildings are removed from the *clean and test* dataset, a total of 17,905 samples remain, of which 17 have no geographic labels. The total number of samples with a value that exceeds the threshold level is 92. These sample asbestos measurements were aggregated by location into 45 modified census block groups (SSAs) for lower Manhattan. One of these SSAs is the site that housed the WTC; the modified database contains no data for this plus an additional 7 SSAs.

Initial Data Analysis

Simple estimation results for each of the four models (i.e., Poisson, negative binomial, binomial and logistic) that parallel those for the complete dataset appear in *Table H-7*. These results are very similar to those obtained with the complete dataset, too.

Table H-7. Selected Constant Mean Model Estimation Results for Rates

Model	Intercept	Equidispersion
Poisson for rates	-5.2701	NA
Negative binomial for rates	-5.1409	3.1819
Binomial	-5.2649	NA
Logistic	0.4964	NA

Note: rates were modeled by including the log of the number of cases as an offset variable.

Accounting for Spatial Autocorrelation

Identified prominent latent map patterns also are very similar (E_3, E_8, and E_{17} are common to the rates models; and again were selected using the stepwise options for PROC LOGISTIC in SAS, and SWPOIS in STATA). One of the eigenvectors identified with the complete dataset disappears here (E_2). One model difference now is that the binomial model links to eigenvector E_{22}, whereas the Poisson model links to eigenvector E_{27}. The negative binomial model yielded a dispersion parameter estimate of 0 here, making it indistinguishable from a Poisson model. As before, the same single eigenvector (E_{10}) relates to the logistic version of the variable. The Poisson model with an assumption of equidispersion appears to be reasonable here. This specification accounts for roughly 40% of the variation in the geographic distribution of rates.

Table H-8. Selected model estimation results for rates when spatial dependence is included				
Variable	**Poisson model**	**Negative binomial model**	**Binomial model**	**Logistic model**
intercept	-5.8875	Failed to be estimable	-5.8827	0.5075
equidispersion	NA		NA	NA
E_1	2.2292		2.2311	NA
E_3	4.1741		4.2493	NA
E_8	-3.4133		-3.4547	NA
E_{10}	NA		NA	-5.3629
E_{17}	-2.8619		-2.8848	NA
E_{22}	NA		NA	NA
E_{27}	-3.3557		-3.4310	NA

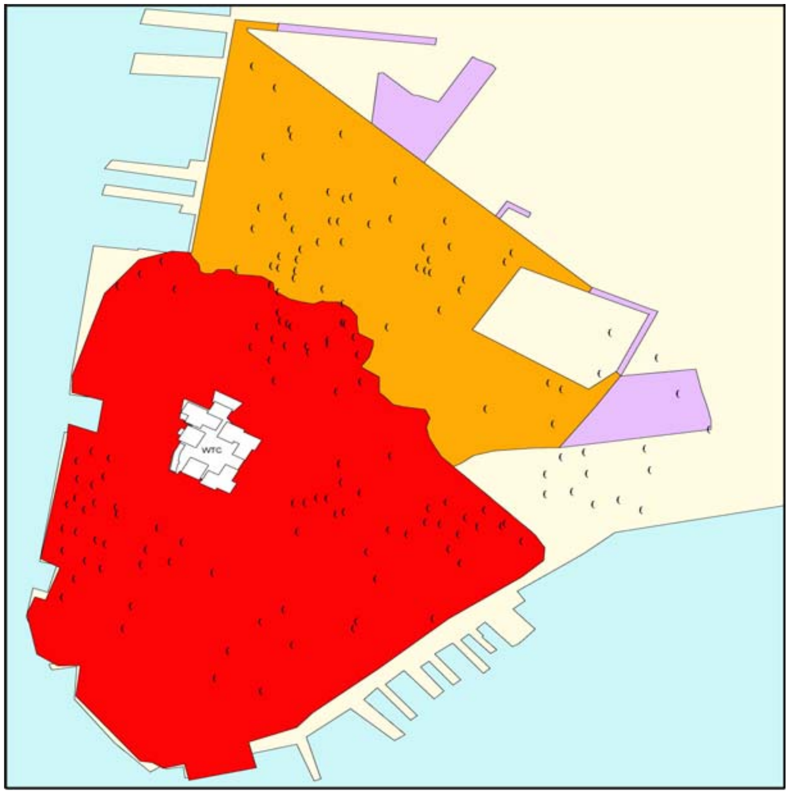
APPENDIX I.

Evaluation of Wipe Sampling Data Prepared by: U.S. Environmental Protection Agency ORD's National Center for Environmental Assessment and Region 2 for the November 15, 2004, Meeting of the World Trade Center Expert Technical Review Panel

Background

During the 2002 Region 2 Cleanup Program, over 1500 pre- and post-cleaning wipe samples were taken in a sample of 263 (out of a total of 4200) apartments in the clean up program in 165 buildings. These samples were measured for 24 contaminants, including lead and other metals, and dioxin. Wide geographic coverage was sought by attempting to identify volunteer apartments in as many buildings as possible. This evaluation focuses on the approximate 1000 pre-cleaning sample results, with an emphasis on lead.

The spatial analysis described earlier in this report was completed before EPA received a final draft photo analysis describing the distribution of visible dust resulting from the collapse of the WTC. The figure below indicates the location of sampled apartments with respect to EPIC Zones of Confirmed (Red), Probable (Orange), Possible (Violet), and No (Blank) impact by dust and debris from the collapse of the WTC Towers.



We then obtained from New York City information on the age of the buildings ~~we~~ sampled and matched this information to the sample results so that the possible relationship between building age and sample results could be assessed. A summary of the distribution of building ages by EPIC zone is provided in the *Table I-1*.

Table I-1. Building Construction Year by Zone

Date Built	**Zones**				
	N	**A**	**B**	**C**	**D**
Before 1920	60	37	22	1	0
1920 - 1950	13	0	11	0	2
After 1950	25	19	6	0	0
No date	58	35	10	1	12
Totals	156	91	49	2	14

Notes: A = confirmed dust; B = probable; C = possible; D = no dust
N= number of samples, approximately 4 samples per apartment

The public expressed continued concern that Mercury, Dioxin and Lead are contaminating indoor environments. Below is the *Table I-2*, which an overview of key results for these contaminants in relation to the health based cleaning benchmarks established for the program

Table I-2. Overview of Key Results for these Contaminants in Relation to the Health Based Cleaning Benchmarks Established for the Program

Analytes	N	Health-based benchmark	# > BM; (range)	Overall Mean
Mercury	915	157 ug/m2	5 (161-248)	4
Dioxin	859	2 ng/m2	6 (2 – 5; 75)	0.8
Lead	995	25 ug/ft2	6 (2 – 5; 75)	37
Lead *	993	25 ug/ft2	115(25 – 6790)	22

Notes: * These are lead results not including two high outliers at 6790 and 2530 ug/ft2
- 1 or 2 exceedances found for 20 other contaminants
- the high measurement of dioxin of 75 ng/m2 was found above a fireplace
- # > BM: number of measurements greater than the health benchmark. Range of the values exceeding the bench mark is shown in parentheses.

Only in the case of lead were there a significant number of measurements (12%) above the health-based benchmarks. The results were then examined as a function of three factors that may affect measured lead concentrations: floor of building where measurement was taken, age of building, and location of building: i.e., EPIC Zone and distance from WTC. Also, the proposed criteria for building cleanup includes a link to WTC dust via signature analysis and requires the 95% upper confidence limit on the building mean to be greater than the 25 ug/ft2 benchmark. An analysis was performed to determine how many buildings would meet this concentration criteria. The Lead results by EPIC zone and distance from the WTC are described in the *Tables I-3* and *I-4* below:

Table I-3. Lead Results by EPIC Zone					
	Zone				
Meters	**A**	**A1**	**B**	**C**	**D**
N	625	623	285	7	78
Mean, ug/ft2	37	22	21	26	14
Median, ug/ft2	7	7	2	17	9
Max, ug/ft2	6790	1380	1160	48	208

Notes: A = confirmed dust; A1 = confirmed with two high measurements of 2530 and 6790 ug/ft2 deleted; B = probable; C =possible; D = no dust

Table I-4. Lead Results by Distance from WTC					
Meters	**0-250**	**250-500**	**500-750**	**750-1000**	**>1000**
N	102	388	276	145	82
Mean, ug/ft2	20	29 (23)*	23	66 (18)**	20
Median, ug/ft2	7	7	6	4	9
Max, ug/ft2	861	2530	1160	6790	208

Notes: * mean for 250-500 with outlier of 2530 removed
** mean for 750-1000 with outlier of 6790 removed

The information gathered on building age was then used to evaluate whether there was any association between the lead results and the building age. The New York City records provided to us did not have the ages of every building in which samples were collected. Thus the graphs below *Figures I-1, I-2, I-3* and *I-4* report results only for buildings in zones A and B. Two sets of information were graphed: the concentration of lead in samples vs. the building age, and the number of values greater than the health screening benchmark of 25ug/ft2 vs. building age.

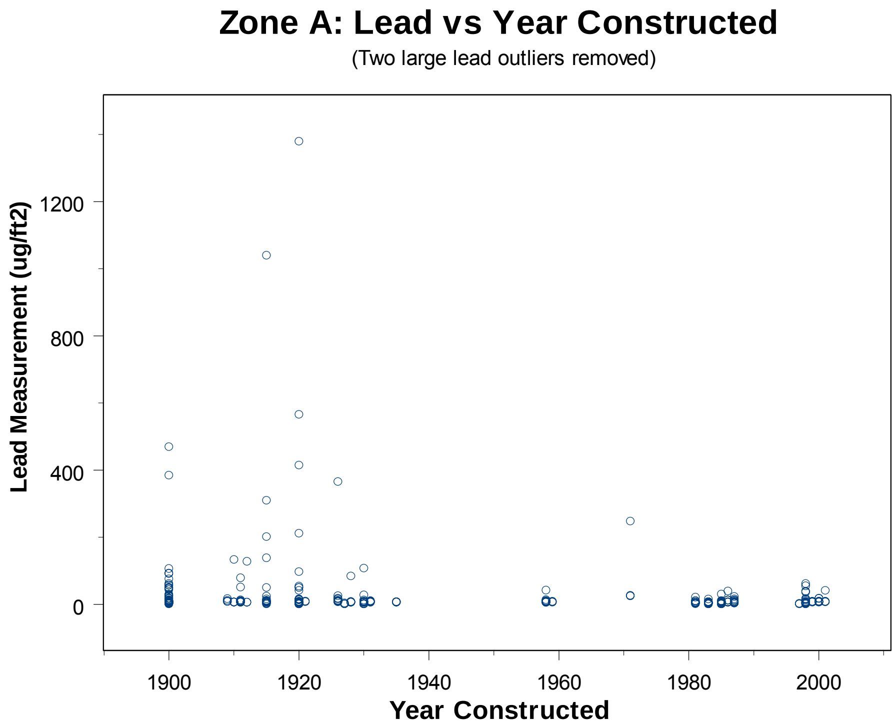


Figure I-1. Zone A: Lead vs. Year Constructed

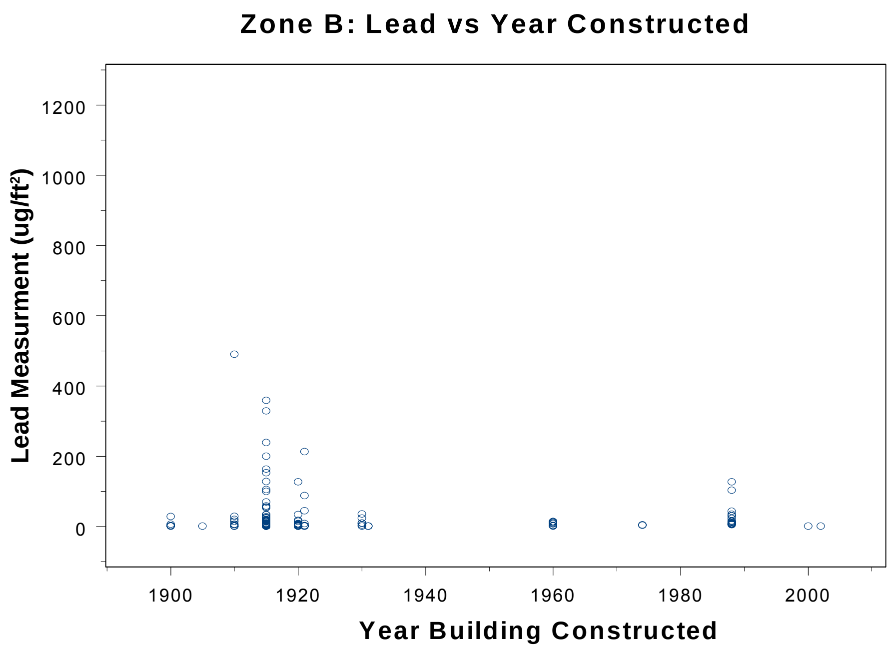


Figure I-2. Zone B: Lead vs. Year Constructed

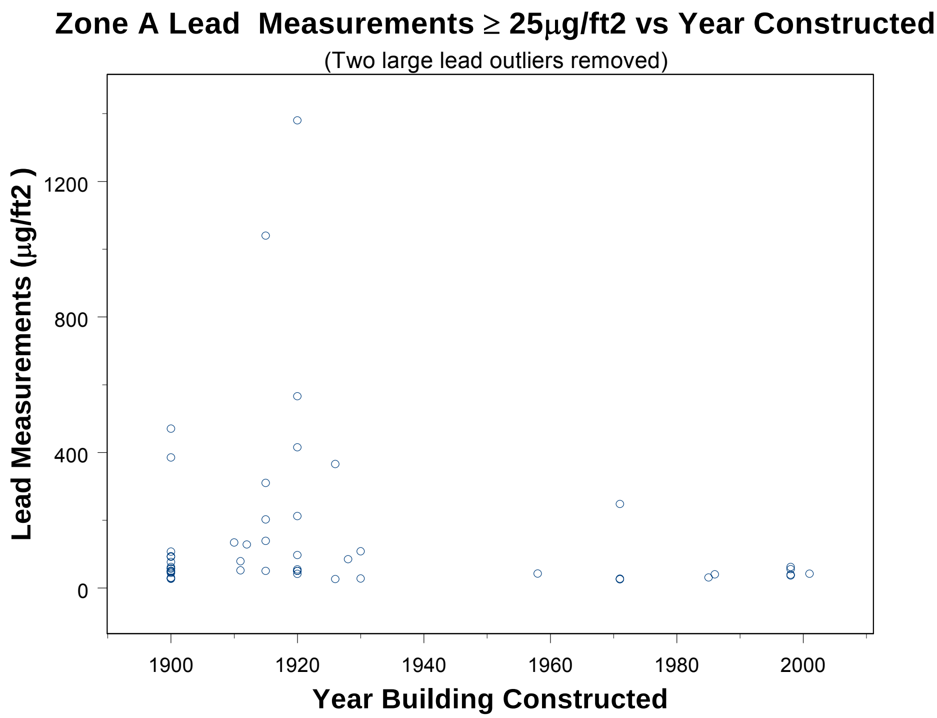


Figure I-3. Zone A: Lead Measurements >= 25 ug/ft2 vs. Year Constructed

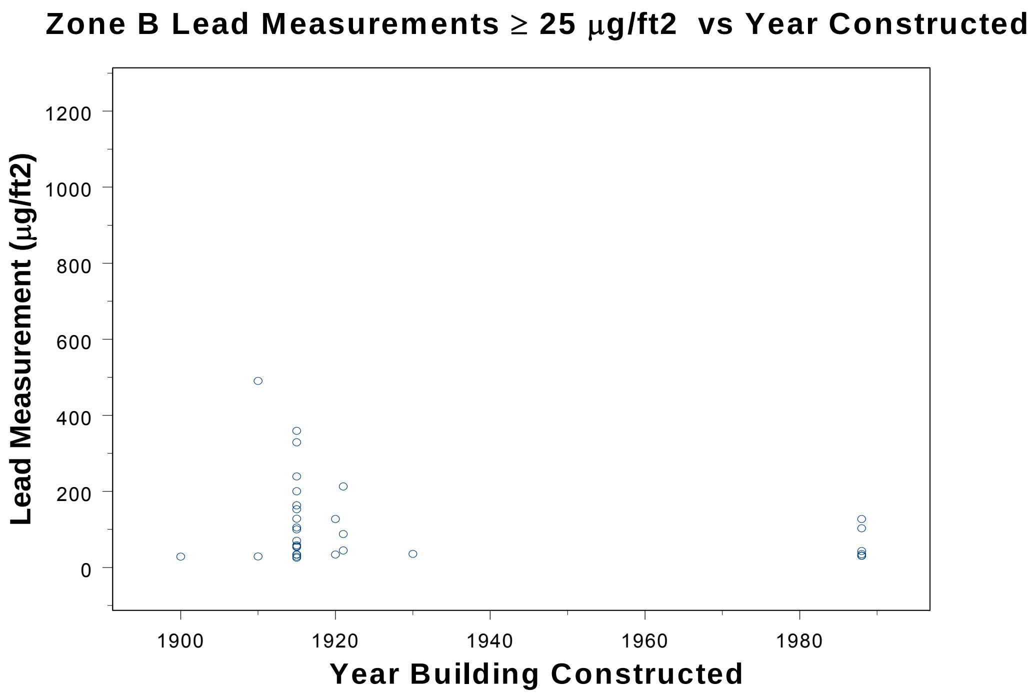


Figure I-4. Zone B: Lead Measurements >= 25 ug/ft2 vs. Year Constructed

We next looked at the relationship between the floor in the building where the samples were collected and the building age. *Table I-5* below describes the means (ug/ft2) of lead sample results by floor and EPIC Zone. *Table I-6* describes the means (ug/ft2) of lead sample results by floor and building age.

Table I-5. The Means (ug/ft2) of Lead Sample Results by Floor and EPIC Zone

		Zone				
Floor	**Overall Mean (n)**	**A**	**A1**	**B**	**C**	**D**
Basement	113 (4)	---	---	113	---	---
1st	14 (29)	5	5	26	---	--
2nd	117 (124)	168	56	9	---	9
3rd	29 (127)	38	38	42	24	6
4th	21 (114)	10	10	36	23	13
5th	25 (80)	12	12	80	---	2
6-10	14 (227)	13	13	12	---	22
11-20	21 (141)	29	29	11	---	10
>20	8 (149)	6	6	5	---	7

Notes: All results are the mean in ug/ft2
A1: Zone A mean for 2nd floor measurements calculated without two outliers

Table I-6. The Means (ug/ft2) of Lead Sample Results by Floor and Building Age

		Zone			
Floor	**Overall Mean (n)**	**<1920**	**1921-50**	**>1950**	**No Year**
Basement	113 (4)	113	---	---	---
1st	14 (29)	19	---	2	5
2nd	117 (124)	204 (41)*	34	9	8
3rd	29 (127)	53	15	5	16
4th	21 (114)	35	24	7	10
5th	25 (80)	14	7	10	45
6-10	14 (227)	17	4	14	14
11-20	21 (141)	31	1	14	25
>20	8 (149)	39	17	6	5

Notes: *mean of 41 calculated with two outliers of 6790 and 2530 ug/ft2 removed
All results are the mean in ug/ft2;

Observations on Full Data Set

When the two lead outliers are deleted, the overall results do not appear meaningfully different among the four zones, and among the five distance categories. There is a suggestion that higher concentrations are found on lower building floors, across zones although this may be confounded with the presence of older buildings across zones. The clearest relationship is between lead concentrations and age of building, i.e., older buildings tend to have the higher concentrations and older buildings have higher concentrations on lower floors. Some high lead concentrations were also observed in newer buildings.

An examination of the highest measurements for lead may suggest trends of note. There are 23 measurements higher than 200 ug/ft2:

15 of these 23 measurements are in "confirmed" zone; only 1 in "no dust" zone:
17 of the top 23 measurements are found in the 5th floor or lower:
18 of top 23 are in buildings built 1926 and earlier; 4 have no date and 1 built in 1971
11 of top 13 are in "confirmed" zone, but 9 of these 13 are in buildings built 1920 and earlier, with the remaining 4 in buildings of unknown age.

Taken together, this suggests that all three factors (zone, floor and age) may be related to the observation of the highest measurements of lead in this sampling program. Site specific factors may help to explain results from particular buildings. For example: high measurements were made in three buildings on Chambers Street that were located near a renovation project. High measurements were also made in a building on Liberty Street that was observed to have remaining WTC dust lodged outside in window ledges. The building with the highest measurement, 6790 ug/ft2, was built in 1900, the earliest year identified for building date in this sample set. (However, this measurement may be suspect because it is so much larger than the others.)

Finally we looked at the 95% UCL on building-specific results in relation to EPIC Zones, which are shown in the *Table I-7* below. To obtain an estimate of how many buildings might require a lead clean up if the HUD screening level of 25ug/ft2 were used as a clean up benchmark.

Table I-7. 95 % UCL on Building-Specific Results in Relation to EPIC Zones

	Zone			
Description	**A**	**B**	**C**	**D**
Number buildings	91	49	2	17
# blds mean > 25	18	10	1	0
# blds 95% UCL > 25	32	17	2	4
# blds max > 25	42	18	2	3

Notes: A = confirmed dust; B = probable; C = possible; D = no dust
blds mean > 25 : # of buildings with mean > 25 ug/ft2
blds 95% UCL > 25: # of buildings with 95% UCL on mean > 25 ug/ft2
blds max > 25: # of buildings with maximum observed value > 25 ug/ft2

Overall Results

Measurements of contaminants above health benchmarks were infrequent with the exception of lead. The clearest relationship is found between lead concentrations and age of building, suggesting lead paint as a cause for high lead measurements in Lower Manhattan. Proximity and floor of building seemed to be, at best, weakly related to measured lead levels. However, an examination of the highest measurements does suggest that, on a case-by-case basis, these factors as well as direct WTC impact, may be important. Building-specific results suggest that a substantial percentage of buildings may meet the partial criteria for building cleanup of 95% UCL of mean being greater than health screening benchmark of 25 ug/ft2.