Health Consultation

REVIEW OF THE PROPOSED SAMPLING PROGRAM TO DETERMINE EXTENT OF WORLD TRADE CENTER IMPACTS TO THE INDOOR ENVIRONMENT

WORLD TRADE CENTER
NEW YORK CITY, NEW YORK

MARCH 29, 2005

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

You May Contact ATSDR TOLL FREE at
1-888-42ATSDR
or
Visit our Home Page at: http://www.atsdr.cdc.gov

HEALTH CONSULTATION

REVIEW OF THE PROPOSED SAMPLING PROGRAM TO DETERMINE EXTENT OF WORLD TRADE CENTER IMPACTS TO THE INDOOR ENVIRONMENT

WORLD TRADE CENTER
NEW YORK CITY, NEW YORK

Prepared by:

Superfund and Program Assessment Branch
Division of Health Assessment and Consultation
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

Health Consultation

Review of the Draft Proposed Sampling Program to Determine Extent of World Trade Center Impacts to the Indoor Environment

World Trade Center
New York City, New York

March 29, 2005

Prepared by:

Superfund and Program Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry
U.S. Department of Health and Human Services

Statement of Issues and Background

At approximately 8:45 AM Eastern Daylight Time on Tuesday, September 11, 2001, a commercial airplane crashed into the north tower of the World Trade Center (WTC) complex in New York City. Initially, the severity of the incident, the numbers of people involved, and the reason for the crash were unknown. Shortly after 9:00 AM, a second plane hit the south tower of the WTC. At about 10 AM, the south tower of the WTC collapsed, followed within 30 minutes by the north tower. Reports indicated that at approximately 5:30 PM, a third tower in the WTC complex, Building Number 7, also collapsed. Wednesday evening, September 12, another building within the WTC complex collapsed.

The collapse of these structures, particularly the north and south towers, released massive amounts of dust and debris that covered lower Manhattan. In addition, fires associated with the collapse of the WTC continued to burn for several months.

Various actions (e.g., environmental and indoor sampling and cleaning) were undertaken by federal, state, city, and private agencies and organizations to help New York City recover from the collapse of the WTC towers. The Agency for Toxic Substances and Disease Registry (ATSDR) provided several types of assistance (1). Most of the U.S. Environmental Protection Agency (EPA) activities associated with the World Trade Center response are summarized on EPA's Internet site (2).

To obtain greater input concerning efforts to monitor the situation of workers and residents affected by the collapse of the WTC, EPA convened the World Trade Center Expert Technical Review Panel. ATSDR has a representative on the panel. The panel members are advising EPA on how to use available exposure and health surveillance databases and registries to characterize any remaining exposures and risks. They also are identifying unmet public health needs and recommending any steps to further minimize the risks associated with the aftermath of the WTC attacks.

To help determine the current level and geographic extent of any remaining WTC-related indoor contamination, EPA has proposed to conduct additional sampling of buildings near the WTC (3). The World Trade Center Expert Technical Review Panel provided guidance to EPA during the development of the proposed sampling program. The proposed sampling program was available for public comment from October 21, 2004, through January 18, 2005.

EPA has requested that the World Trade Center Expert Technical Review Panel members provide written comments and guidance on the proposed plan (3) and the comments received during the public comment period (4). This Health Consultation is ATSDR's response to that request.

Discussion

The draft proposed sampling plan provides an overview of how buildings (residential, office, and public) south of Houston Street, in Manhattan, would be sampled to determine if any remaining WTC-related contamination is present (3). As proposed, only dust samples would be taken from buildings made available by the owners or managers. Samples would be taken from locations where exposures are likely to occur, such as in elevated horizontal surfaces (e.g., desk or table tops). Samples also would be taken from floors and locations where dust may have accumulated, but may not have been cleaned, such as behind or on top of cabinets. In addition, some dust samples will be taken from any centralized heating, ventilation, and air conditioning (HVAC) systems. All samples will be analyzed for the WTC dust signature (under development; it will likely include manmade vitreous fibers [MMVF] and perhaps minerals of concrete or wallboard), WTC fire signature (perhaps a particular polycyclic aromatic hydrocarbons ratio [PAHs]), and a specified list of *chemicals of potential concern* (asbestos, MMVF, silica, PAHs, and lead).

ATSDR has reviewed the draft proposed plan and the results of previous investigations and reports (3, 5–23). We believe that the proposed sampling plan, plus good participation, will help determine the current level and geographic extent of any remaining WTC-related indoor dust contamination. The following discussion areas are provided to help refine the draft proposed plan and to address some of the public comments received.

Participation and Selection of Buildings to be Sampled

As discussed in the draft proposed plan, poor participation will reduce the ability of this program to determine the extent of any remaining WTC-related contamination. Every effort should be undertaken to get as many appropriate buildings involved in the program as possible.

As currently written, the draft proposed plan indicates that statistical sampling of the buildings that are volunteered by owner or managers will be the “sample frame” (study population). An alternative approach would be for EPA to use the proposed statistical model to predetermine the necessary distribution of buildings needed to conduct this study (e.g., general location, distance from the WTC, and building type). Focused recruitment could then be used to obtain access to the necessary buildings.

In addition to distance from the WTC and building type, other criteria should be used, when possible, to select the buildings that will be sampled. Care should be taken to exclude buildings that are located “downwind” of taller or wider buildings. A building in that situation will likely have been shielded from the WTC dust plume to a great degree. Preference should be given to buildings that are known to have air inlets orientated toward the WTC. By using additional selection criteria (buildings with known breaches [broken windows]), the sample frame will be biased toward the worst case situation.

Sampling in Brooklyn

The draft proposed sampling plan expands the area to be sampled from that previously covered by EPA and others. The previous EPA sampling and cleaning program limited the area that could participate to lower Manhattan buildings south and west of Canal, Allen, and Pike streets—river-to-river. The proposed plan expands the area to buildings in Manhattan that are located south of Houston Street.

By limiting the proposed plan to only Manhattan; it implies that the dust associated with the collapse of the WTC towers could have only stayed on Manhattan as far north as Houston Street. The satellite imaging does not support that conclusion (22). A reasonable approach would be to extend the radius distance that was used to include Houston Street to the north to a similar boundary to the east in Brooklyn.

Dioxin and Mercury as Chemicals of Potential Concern

The purpose of the proposed sampling plan is to determine whether there are remaining areas of contamination in currently occupied buildings. Those buildings will likely have been cleaned, to varying degrees, many times over the last 3½ years. Frequent cleaning will likely remove some of the original dust/contamination. Therefore, one should consider what was found in uncleaned locations and, more importantly, what has been found in locations that have undergone cleaning, when choosing chemicals of potential concern.

Mercury

During the previous EPA-sponsored residential sampling and cleaning program, 915 pre-cleaning wipe samples were analyzed for mercury (15). Only 0.5% of the mercury results were above the EPA-derived health-based benchmark of 157 micrograms per square meter ($\mu g/m^2$) (15). The mean of all the sampling results was 4 $\mu g/m^2$. Around 61% of the sampling results were nondetects (nondetects were assumed to be half the detection limit).

Analytical results from outdoor bulk samples and bulk and wipe samples from uncleaned residential units did not detect mercury above the EPA-derived health-based benchmarks (5,6). Dust samples were taken inside the Deutsche Bank Building at 130 Liberty Street, immediately south of the WTC. One investigation reported that mercury was found at an average dust concentration of 14 $\mu g/m^2$, with a maximum detected concentration of 632 $\mu g/m^2$ (17). A separate study of the Deutsche Bank Building reported finding mercury in dust above the EPA health-based benchmark in only two of 125 samples (1.6% with a maximum of 157 $\mu g/m^2$) (19). Biomonitoring of firefighters during the response to the collapse of the towers and associated fires did not find any significant elevations of mercury (21). That would indicate that this group of highly exposed individuals did not inhale or ingest any significant amounts of mercury. This information, in addition to the results from the previous EPA-sponsored residential sampling and cleaning program, indicates that mercury was rarely detected in dust at levels of health concern.

Dioxin

A total of 859 pre-cleaning dioxin wipe sample analytical results (reported as toxicity equivalents to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin) were taken during the previous EPA-conducted residential sampling and cleaning program. Dioxin levels were only found above the EPA-derived health-based benchmark of 2 nanograms per square meter (ng/m^2) (11) six times (0.7% of the samples taken) (15). The mean dioxin levels for all the 859 samples was 0.8 ng/m^2.

Analytical results from bulk and wipe samples from uncleaned residential units shortly after 9/11 did not detect dioxin above the EPA derived health-based benchmark of 2 ng/m^2 (5). The analytical results ranged from 0.0012 to 0.088 ng/m^2.

During EPA's residential confirmation cleaning study, only one wipe sample out of 56 (1.8%) was found to contain dioxin above the health-based benchmark of 2 ng/m^2 (12).

Analytical results of wipe samples taken at the request of the New York City Board of Education did not find any dioxins above health-based guidelines (8).

The two studies available to ATSDR that have documented significant elevations of dioxin above health-based benchmarks were done in the Deutsche Bank Building (16,19). However, the diesel fuel tank in the basement of the Deutsche Bank Building ruptured and burned during 9/11 (19). Therefore, care must be used when evaluating the sampling results from the Deutsche Bank Building. A significant portion of the dioxin found in that building may have come from the diesel tank fire and not from the WTC. In addition, the Deutsche Bank Building has been unoccupied and mostly uncleaned since 9/11. Therefore, these results are not directly applicable to buildings that have not been directly associated with a fire and have been cleaned multiple times during the last 3½ years.

The weight of evidence does not appear to support the need to include dioxin in this sampling program.

World Trade Center Signature

Several studies indicate that the WTC dust was made up of primarily building materials (5, 6, 7, 9, 11, 12, 14, 15, 16). That dust appears to have a unique signature, with slag wool—an MMVF—being a primary component. Currently, the U.S. Geological Survey (USGS) and EPA are refining the dust signature. It should be a very useful tool for determining whether any remaining WTC-related dust is in a building (23).

Two consulting firms that have conducted extensive sampling of buildings in lower Manhattan provided comments that basically support the dust signature being developed by EPA and USGS (4). They only suggest adding some heavy metals to the list of components to be used in the signature. On the basis of information submitted by the two consulting firms and the extensive sampling results by EPA and others, it appears that there is a signature to WTC dust.

At this time, however, it is unclear whether it is possible to develop a signature for WTC smoke. EPA is currently conducting research to see if a smoke signature could be developed by looking for a particular ratio of PAHs.

Selection of Sampling Locations and Interpretation of Results

The draft proposed plan indicates that samples will be taken at locations where exposures are likely to occur. Samples also will be taken from floors and locations where dust may have accumulated, but which may not have been cleaned regularly. Those are appropriate areas to be sampled.

When choosing sampling locations within a building, preference should be given to locations that have the greatest potential to have been affected by WTC-contaminant migrations (e.g., rooms facing towards WTC and locations with windows broken by 9/11-related debris).

When analyzing the results of sampling efforts conducted in living and working spaces, the data should be grouped together and separately (likely exposure areas and dust accumulation areas). By grouping the sampling results in these two combinations, we should be able to see if the dust accumulation areas have any potential effects on people.

In addition, samples are proposed to be taken from inside HVAC units. Several comments indicate that more information should be provided as to where in the HVAC units the samples should be taken (e.g., dead-air spaces). It would be difficult to provide that level of detail without first knowing how each individual HVAC system is designed. In addition, some areas of a HVAC system may not be accessible without tearing out portions of walls or ceilings. Perhaps the proposed plan could be modified to indicate that wherever possible, without causing damage to the building and HVAC system, samples will be taken from dead-air spaces.

HVAC samples represent unoccupied locations, but several of the chemicals of potential concern benchmarks were developed assuming direct access to the contaminated material. Consequently, sampling results from HVAC systems should be analyzed separately from the occupied space sampling results.

Selection of Benchmarks

The draft proposed sampling plan indicates that all samples will be analyzed for the WTC-signature and the chemicals of potential concern (asbestos, MMVF, silica, PAHs, and lead). Health-based dust benchmarks were developed for PAHs and lead (11).

Health-based dust benchmarks were not developed for asbestos, MMVF, and silica. The health concerns associated with these contaminants are almost exclusively attributed to inhalation exposures. There are no reliable scientific methods to derive dust level concentrations that would predict potential inhalation health concerns. Therefore, it is not possible to derive health-based dust benchmarks for these toxicants (11).

Currently, the only way to determine whether asbestos, MMVF, or silica are present at levels of health concern is to take air samples. Because the proposed sampling plan is designed to determine whether any remaining WTC-related dust contamination is present in buildings, it is not necessary to take air samples. The sampling program will not and cannot be used to determine the public health implications of asbestos, MMVF, and silica that may be found. To decide whether any WTC-related asbestos, MMVF, or silica is present in building dust, one should compare the sampling results to normal background dust levels. That will require the collection of background samples using the same sampling and analytical techniques being used in the sampling frame buildings. Because background levels have a degree of variability, it will be necessary to choose a benchmark for asbestos, MMVF, and silica that is either two standard deviations above the background mean or three times background. This approach has commonly been used to determine whether a contaminant is discernable from normal background levels.

The Public Health Importance of Short Asbestos and MMVF Fibers

Several comments received by EPA indicate that "short" (less than 5 micrometers [µm] in length) asbestos and MMVF fibers are a major public health concern. ATSDR has reviewed this issue extensively. The agency's determination on this issue is based upon the results of an expert panel review on this topic and internal evaluations. The following is a very brief summary of ATSDR's previously documented findings.

In September 2001, ATSDR issued the *Toxicological Profile for Asbestos* (24). In that document ATSDR made the following observation: "There is strong evidence from animal inhalation studies, intrathoracic and intraperitoneal dosing studies, and in vitro studies that long fibers are more carcinogenic than short fibers."

The ATSDR *Toxicological Profile for Synthetic Vitreous Fibers* (also know as MMVF) also indicates that fiber dimensions influence several of the key determinants of toxicity (25). The profile states that mechanistic and pharmacokinetic studies indicate that greater potential for toxicity of inhaled inorganic fibers is associated with higher exposure concentrations, longer exposure durations, longer fiber lengths, greater fiber durability, and thinner fiber diameters.

In October 2002, ATSDR convened a panel of seven experts to discuss the state of the science on how fiber length related to toxicity of asbestos and synthetic vitreous fibers (SVF or MMVF) (26). Two of the key conclusions from the panel are as follows:

- For cancer effects: "Given findings from epidemiologic studies, laboratory animal studies, and in vitro genotoxicity studies, combined with the lung's ability to clear short fibers, the panelists agreed that there is strong weight of evidence that asbestos and SVF shorter than 5 µm are unlikely to cause cancer in humans."
- For noncancer effects: "The laboratory animal studies, epidemiologic studies, and in vitro studies generally suggest that asbestos and SVF pathogenicity increases with fiber length, but there are several notable exceptions. In laboratory animals, for example, short asbestos and SVFs at sufficiently high doses have been shown to cause inflammation, pulmonary interstitial fibrosis, and pleural reactions;

however, the doses needed to cause these effects in humans may not be relevant to environmental exposures."

During the previous EPA-conducted residential sampling and cleaning program, more than 23,126 asbestos air samples were taken (15). Chrysotile asbestos was detected in approximately 92% of the samples; amosite was detected in approximately 3%. Only about 0.4% of those samples were found to exceed the health-based asbestos benchmark of 0.0009 fibers per cubic centimeter. The maximum asbestos concentration detected was 0.0204 fibers per cubic centimeter. Short asbestos fibers were detected 952 times and long fibers were detected 466 times (M. Maddaloni, U.S. Environmental Protection Agency, personal communication, 2005). From the amounts detected, short fiber concentrations would not result in any significant elevation of exposure.

Indoor air samples were taken during the 2001 New York City Department of Health and Mental Hygiene and ATSDR lower Manhattan residential building investigation (7). The results of that investigation indicates that airborne levels of total fibers (asbestos, MMVF, etc.) were similar in lower and upper Manhattan.

The weight of scientific evidence indicates that extremely high exposures to short asbestos or MMVF fibers are necessary for health problems to occur. Asbestos (short and long) and MMVF fibers were not detected at extremely high levels around the WTC. Therefore, it is very doubtful that WTC-related short asbestos and MMVF fibers are of any public health concern under the current situations in occupied buildings.

Conclusions

1. ATSDR believes that the proposed sampling plan, if conducted in a representative number of appropriate buildings, will help to determine the current level and geographic extent of any remaining indoor dust contamination from the World Trade Center.

2. The method used to determine which buildings will be involved with the proposed sampling plan should be adjusted and additional criteria added so the sample frame will be biased toward the worst case situation.

3. Aerial photographic and satellite image data indicate that some dust from the World Trade Center was carried eastward into Brooklyn.

4. The weight of evidence does not support the need to include dioxin and mercury in this sampling program.

5. The World Trade Center dust appears to have a unique signature, which is made up of slag wool—a manmade vitreous fiber—and possibly minerals of concrete and wallboard.

6. At this time, it is unclear whether it is possible to develop a signature for World Trade Center smoke residual. The unique code for this document is 751968

7. There are no reliable scientific methods to derive health-based dust benchmarks for inhalation toxicants (i.e., asbestos, manmade vitreous fibers, and silica). Therefore, benchmarks for inhalation toxicants will have to be set by a comparison to normal background levels.

8. The weight of scientific evidence indicates that extremely high exposures to short asbestos or manmade vitreous fibers are necessary for health problems to occur. Asbestos (short and long fibers) and manmade vitreous fibers was not detected at extremely high levels around the World Trade Center. Therefore, it is very doubtful that short asbestos and manmade vitreous fibers from the World Trade Center are of any public health concern under the current situation in occupied buildings.

Recommendations

1. EPA should consider an alternative approach to using the proposed statistical model to predetermine the necessary distribution of buildings needed to conduct this study (e.g., general location, distance from the World Trade Center, and building type). In addition to distance from the World Trade Center and building type, other criteria should be used to select buildings for sampling. Care should be taken so that a building that is located "downwind" of a taller or wider building will not be selected for sampling. A building in that situation will likely have been shielded from the World Trade Center dust plume to a great degree. Preference also should be given to buildings that are known to have air inlets orientated toward the World Trade Center. By using additional selection criteria (buildings with known breaches [broken windows]), the sample frame will be biased toward the worst case situation.

2. EPA should consider extending the area that could be involved in the proposed sampling program. The radius distance that was used to include Houston Street to the north should be used to extend the boundary eastward into Brooklyn.

3. When choosing sampling locations within a building, EPA should give preference to locations that have the greatest potential to have been affected by World Trade Center contaminant migrations (e.g., rooms facing toward the World Trade Center and locations with windows broken by debris).

4. When analyzing the results of sampling efforts conducted in living/working spaces; the data should be grouped together and separately (likely exposure areas and dust accumulation areas). By grouping the sampling results in these two combinations, we should be able to see if the dust accumulation areas have any potential to affect people.

5. HVAC samples represent unoccupied locations, while several of the chemicals of potential concern benchmarks were developed assuming direct access to the contaminated material. Consequently, sampling results from HVAC systems should be analyzed separately from the occupied sampling results.

6. Benchmarks for asbestos, MMVF, and silica should be set by either two standard deviations above the background mean or three times background.

Author

Sven E. Rodenbeck, ScD, PE, DEE
Captain, U.S. Public Health Service
Deputy Branch Chief
Superfund Program Assessment Branch

References

1. Agency for Toxic Substances and Disease Registry. World Trade Center response activities, close-out report, September 11, 2001–April 30, 2003. Atlanta: US Department of Health and Human Services; 2002.

2. US Environmental Protection Agency. EPA response to September 11. Available at URL: http://www.epa.gov/wtc/. Accessed March 2, 2005.

3. US Environmental Protection Agency. Draft proposed sampling program to determine extent of World Trade Center impacts to the indoor environment. New York: US Environmental Protection Agency Region II; October 2004. EPA/600/R-04/169A. Available at URL: http://www.epa.gov/wtc/panel/pdfs/sampling-proposal-20041015.pdf.

4. US Environmental Protection Agency. Public comments received on external review draft entitled, "Draft proposed sampling program to determine extent of World Trade Center impacts to the indoor environment." New York: US Environmental Protection Agency Region II; January 2005. Available at URL: http://www.epa.gov/wtc/panel/pdfs/Public-Comments-draft-sampling-plan-Jan05.pdf.

5. Chatfield EJ, Kominsky JR. Summary report: Characterization of particulate found in apartments after destruction of the World Trade Center. Requested by the "Ground Zero" Elected Officials Task Force. Mississauga, Ontario, Canada: Chatfield Technical Consulting Limited; October 2001.

6. Lioy PJ, Weisel CP, Millette JR, Eisenreich S, Vallero D, Offenberg J, et. al. Characterizations of the dust/smoke aerosol that settled east of the World Trade Center (WTC) in lower Manhattan after the collapse of the WTC 11 September 2001. Environ Health Perspect 2002;110(7):703–14.

7. New York City Department of Health and Mental Hygiene and Agency for Toxic Substances and Disease Registry. Final technical report of the public health investigation to assess potential exposures to airborne and settled surface dust in residential areas of lower Manhattan. Atlanta: US Department of Health and Human Services; September 2002.

8. US Environmental Protection Agency. Exposure and human health evaluation of airborne pollution from the World Trade Center disaster (external review draft). Washington, DC: US Environmental Protection Agency; October 2002. Available through URL: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=54667.

9. Offenberg JH, Esenreich SJ, Chen LC, Cohen MD, Chee G, Prophete C, et al. Persistent organic pollutants in the dust that settled across lower Manhattan after September 11, 2001. Environ Sci Technol 2003;37(3):502–8.

10. US Environmental Protection Agency. World Trade Center background study report: interim final. New York: US Environmental Protection Agency, Region II; April 2003.

11. US Environmental Protection Agency. World Trade Center indoor air assessment: selecting contaminants of potential concern and setting health-based benchmarks. New York: US Environmental Protection Agency, Region II; May 2003.

12. US Environmental Protection Agency. Interim final WTC residential confirmation cleaning study. New York: US Environmental Protection Agency, Region II; May 2003.

13. US Environmental Protection Agency. Summary report of the US EPA technical peer review meeting on the draft document entitled: Exposure and human health evaluation of airborne pollution from the World Trade Center disaster. External review draft. Washington, DC: US Environmental Protection Agency; December 2003.

14. McGee JK, Chen LC, Cohen MD, Chee GR, Prophete CM, Haykal-Coastes N, et al. Chemical analysis of World Trade Center fine particulate matter for use in toxicological assessment. Environ Health Perspect 2003;111(7):972–80.

15. US Environmental Protection Agency. World Trade Center residential dust cleanup program: draft final report. New York: US Environmental Protection Agency, Region II; March 2004.

16. RJ Lee Group, Inc. Signature assessment, 130 Liberty Street property. Monroeville, Pennsylvania: RJ Lee Group, Inc.; May 2004.

17. RJ Lee Group, Inc. Mercury assessment, 130 Liberty Street property. Monroeville, Pennsylvania: RJ Lee Group, Inc.; May 2004.

18. Pleil JD, Vette AF, Johnson BA, Rappaport SM. Air levels of carcinogenic polycyclic aromatic hydrocarbons after the World Trade Center disaster. Proc Natl Acad Sci USA 2004;101(32):11685–8. Available at URL: http://www.pnas.org/cgi/content/full/101/32/11685.

19. The Louis Berger Group, Inc. 130 Liberty Street, New York, New York, initial building characterization study report. New York: The Louis Berger Group, Inc; September 2004.

20. Butt CM, Diamon MLD, Truong J, Ikonomou MG, Helm PA, Stern GA. Semivolatile organic compounds in window films from lower Manhattan after the September 11 World Trade Center attack. Environ Sci Technol 2004;38:3514–24.

21. Edelman P, Osterloh J, Pirkle J, Caudill SP, Grainger J, Jones R, et al. Biomonitoring of chemical exposure among New York City firefighters responding to the World Trade Center fire and collapse. Environ Health Perspect 2003;111:1906–11.

22. Jennings DB, Williams DJ, Garofalo D. Mapping the spatial extent of ground dust and debris from the collapse of the World Trade Center buildings. Reston, Virginia: US Environmental Protection Agency, 2004.

23. Meeker GP, Bern AM, Lowers HA, Brownfield IK. Determination of a diagnostic signature for World Trade Center dust using scanning electron microscopy point counting techniques. Open-file report 2005-1031. Denver, Colorado: US Geological Survey; 2005.

24. Agency for Toxic Substances and Disease Registry. Toxicological profile for asbestos. Atlanta: US Department of Health and Human Services; September 2001.

25. Agency for Toxic Substances and Disease Registry. Toxicological profile for synthetic vitreous fibers. Atlanta: US Department of Health and Human Services; September 2004.

26. Agency for Toxic Substances and Disease Registry. Report on the Expert Panel on Health Effects of Asbestos and Synthetic Vitreous Fibers: The influence of fiber length. Atlanta: US Department of Health and Human

Services; March 2003. Available through URL: http://www.atsdr.cdc.gov/HAC/asbestospanel/.