

A Life-Time Mortality Risk Analysis and Cost-Benefit Analysis Associated With Asbestos Exposure From The Collapse of the World Trade Center on 9/11: Does the Cost of US-EPAs Residential Dust Clean-up in Lower Manhattan Exceed its Benefit?

By:

Benjamin M. Sallemi, PhD Candidate



A dissertation submitted to the Graduate Faculty in Earth & Environmental Science in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

2012

© 2012
Benjamin M. Sallemi
All Rights Reserved

This manuscript has been read and accepted for the Graduate Faculty in Earth & Environmental Science in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

Dr. Robert Nolan

Date

Chair of Examining Committee

Dr. Yehuda Klein

Date

Executive Officer

Dr. Robert Nolan

Dr. Arthur Langer

Dr. Yehuda Klein

Supervisory Committee

THE CITY UNIVERSITY OF NEW YORK

ABSTRACT

A Life-Time Mortality Risk Analysis and Cost-Benefit Analysis Associated With Asbestos Exposure From The Collapse of the World Trade Center on 9/11: Does the Cost of US-EPAs Residential Dust Clean-up in Lower Manhattan Exceed its Benefit?

By

Benjamin M. Sallemi

Advisor: Dr. Robert P. Nolan

Pursuant to the collapse of the World Trade Center Towers on September 11, 2001, the presence of chrysotile asbestos in the dust plume raised concern about exposure to Search and Rescue workers, Clean-up and Recovery workers, and Residential exposures that might result during the ground zero clean-up and removal efforts. Asbestos related air monitoring included Analytical Transmission Electron Microscopy (ATEM) analysis under the Asbestos Hazard Emergency Response Act (AHERA) protocol; Phase Contrast Microscopy (PCM) and ATEM measurements on the same filters; and Phase Contrast Microscopy Equivalent (PCMe) using ATEM. This study focused primarily on the exposure of emergency responders, clean-up workers, and residents to the presence of asbestos, taking asbestos fiber-type and size into consideration. The three exposure scenarios evaluated show that cumulative residential exposures ((0.02 asbestos fibers per milliliter-year (af/mL-yr)) were the greatest, followed by Clean-up and Recovery exposures (0.007 af/mL-yr), then Search and Rescue exposures (0.003 af/mL-yr), which shows that the lower residential dose over a longer period of time would result in a greater cumulative exposure than either the Search and Rescue, or Clean-up and Recovery scenarios. A risk assessment for the three cumulative exposure scenarios was conducted using the US-EPA's 1986 aggregate risk model which presumes equal potency for all asbestos fiber-types, and the 2000 Hodgson & Darnton model which considers the potency of differing asbestos fiber-types, and is more current with the historic epidemiologic literature. A marked difference between the US-EPA aggregate model and Hodgson & Darnton model exists with the later showing an approximate 240-fold decrease in risk for the lower Manhattan population when chrysotile fiber-type potency is considered. Using the calculated cumulative exposure data a cost-benefit analysis (CBA) was performed to show whether the social benefit associated with a reduction in the asbestos contaminant levels warranted the total cost of providing specialized equipment to lower

Manhattan residents and remedial cost of conducting the US-EPA Residential Dust Clean-up Program. As expected, the CBA shows that the social benefits of averting asbestos-related morbidity and mortality outweigh the costs under the US-EPA's risk assessment protocol. However, using the Hodgson and Darnton risk assessment protocol, the benefits do not outweigh the risks and the US-EPA would have been expected not to provide specialized equipment to lower Manhattan residents or conduct the residential dust cleaning program.

ACKNOWLEDGEMENTS

I would like to acknowledge the patience, guidance and overall support of my advisory committee comprised of Dr. Robert Nolan, Chairman; Dr. Arthur Langer; and Dr. Yehuda Klein whose experience and insight were invaluable in the completion of this doctoral thesis. Their encouragement during portions of this process are truly appreciated, and will never be forgotten.

A special acknowledgement to my dear wife, Maria Sallemi, who was as supportive and committed to this process as I, and to my daughters Bianna (12) and Amanda (8) who both exuded patience and understanding far beyond their years during the countless afternoons and evenings when I was dedicated to writing. This could not have been completed without their love and support.

TABLE OF CONTENTS

ABSTRACT.....	iv
ACKNOWLEDGEMENTS.....	vi
INTRODUCTION AND STATEMENT OF PROBLEM.....	1
LITERATURE REVIEW.....	4
Diseases Associated with Asbestos Exposure in the Workplace.....	4
A Synthesis of Asbestos Rulemaking in the United States to Protect Workers.....	7
Federal Laws to Protect Non-Occupationally Exposed Individuals.....	10
The National Emissions Standard for Hazardous Air Pollutants.....	11
The Asbestos Hazard Emergency Response Act of 1987.....	12
The Asbestos School Hazard Abatement Reauthorization Act (ASHARA).....	12
Summary of Historical Asbestos Risk Assessment Reports.....	12
Current Knowledge Regarding Asbestos Related Lung Cancer and Mesothelioma.....	18
Fiber-Type and Fiber-Size Effect the Biological Potential for Disease.....	27
Animal and Biopersistence Studies.....	30
Asbestos Air Monitoring Methodology.....	32
Ground Zero Related Reports.....	34
How this discussion of fiber counts and methodology relate to the clean-up efforts at Ground Zero, and with the US-EPA Residential Dust Clean-up Program.....	40
Background Information on Cost-Benefit Analysis.....	41
Cancer-Related Medical Costs.....	43
The Cost of Cancer-Related Morbidity.....	43
The Cost of Premature Asbestos-Related Cancer Deaths.....	44
METHODS.....	47
Hazard Characterization.....	47
Risk Assessment Models.....	47
Exposure Assessment.....	48
Cost Benefit Analysis.....	49
DATA.....	53
Preliminary Federal (OSHA & US-EPA).....	53
Preliminary New York State (NYSDEC & PESH).....	55
Preliminary Local (NYCSCA and NYCDEP).....	56
Residential Exposures.....	58
RESULTS AND DISCUSSION.....	59
Hazard Characterization.....	59
Asbestos Containing Material used in the Construction of the WTC.....	59

Exposure Assessment.....	61
Risk Assessment	67
Evaluating the CBA Analysis - The Go, or No-Go Decision.....	70
US-EPA-Based Data CBA Decisions.....	75
Hodgson & Darnton-Based Data CBA Decisions	80
Research behind the US-EPA Residential Dust Clean-up Program	85
US-EPA’s establishment of “Chemicals of Potential Concern”	86
Cleaning Program Too Late.....	87
Potential “Indoor” Exposures Assessment.....	87
A “new” health-based benchmark for Airborne Asbestos.....	88
 CONCLUSIONS.....	 90
 TABLES	 92
Table 1a - Historic Lung Cancer Potencies (K_L) by Assessment Report	
Table 1b - Historic Mesothelioma Potencies (KM) by Assessment Report	
Table 2 - Technical Differences in Air Monitoring Fiber Counting Methodologies	
Table 3 - Historic Values for a Statistical Life	
Table 4a - Summary of Arithmetic Mean Air Sampling Concentrations per Activity	
Table 4b - Summary of Air Sampling Results with Lifetime Exposure Calculations from WTC Dusts	
Table 5 - Summary Table for No. Excess Cancer Deaths from Asbestos Based on Risk Assessment Method	
Table 6 - US-EPA-based Exposures, Project Analysis Decision Matrix	
Table 7- Hodgson Darnton-based Exposures, Project Analysis Decision Matrix	
 APPENDIX A – FREEDOM OF INFORMATION ACT RESPONSES	 102
 APPENDIX B - COPIES OF SPREADSHEET CALCULATIONS FOR LIFETIME	 122
 ASBESTOS-RELATED CANCER RISK.....	 122
 REFERENCES	 128

INTRODUCTION AND STATEMENT OF PROBLEM

Monitoring of the air at the site of the former World Trade Center (WTC), also known as “Ground Zero”, and within residential housing units has been conducted throughout lower Manhattan. These measurements have been coordinated prior to or as part of the United States Environmental Protection Agency (US-EPA) Residential Dust Cleaning program established following the attack of 9/11/2001 on the World Trade Center Complex. The surrounding properties and housing units sampled are located around Ground Zero, the unofficially named area of collapse, and were heavily contaminated with dust and debris following the catastrophic collapse of the WTC structures.

Preliminary data (data collected immediately following the collapse of the towers) associated with Ground Zero indicate that the settled and airborne dust consisted of common construction materials, e.g., concrete dust, drywall gypsum board, as well as the inorganic silicate (asbestos) components of the fireproofing applied to the structural steel (Chatfield and Kominsky (2001), Lioy (2002), Chemical of Potential Concern Committee (COPC) (2003a), COPC (2003b), COPC (2004), Gavett, *et al.*, (2002), US-EPA (2003a), US-EP (2003b), US-EPA (2003c), US-EPA-OIG (2003), Lorber, *et al.*, (2004), US-EPA (2005). Some of the fireproofing in the north tower (Tower 1) was formulated with chrysotile asbestos (Langer & Morse, 2001). The presence of asbestos in the dust plume following the collapse of the Twin Towers raised concern about exposure to rescue workers, clean-up workers, and potential residential exposure that might result during clean-up and removal efforts. There are three exposure scenarios based on the dates of various activities performed at Ground Zero: Search and Rescue; Clean-up and Recovery, and Residential groups of individuals with potentially different exposure. Search & Rescue and Clean-up and Recovery exposures are based upon both low-volume personal air sampling, and ambient high-volume air sampling. Residential exposures were calculated based upon only high-volume air sampling data. This air sampling data represents workers removing the debris from the “Pile” at Ground Zero (including emergency rescue workers), the residences of neighboring dwellings adjacent to, or in close proximity to Ground Zero, and residents of lower Manhattan which would have resided south of Canal Street, but not necessarily adjacent to Ground Zero.

Asbestos related data following the collapse of the Towers have been obtained and evaluated for the various testing methods for asbestos in the air around Ground Zero, they include: Analytical Transmission Electron Microscopy (ATEM) analysis under the Asbestos Hazard Emergency Response Act (AHERA) protocol; Phase Contrast Microscopy (PCM) and ATEM measurements on the same filters; Polarized Light Microscopy (PLM); PCM and TEM assays of settled dust, and Phase Contrast Microscopy Equivalent (PCMe), which is a method for counting fibers using ATEM that would be found if only PCM, which has fiber resolution limits, was used. This study focused primarily on the exposure of emergency responders, clean-up workers, and residents to the presence of asbestos, taking asbestos fiber-type and size into consideration, and whether the social benefit associated with a reduction in contaminant levels, based on asbestos dose and risk, warranted the total cost of providing specialized equipment to lower Manhattan residents and remedial cost of conducting the US-EPA Residential Dust Clean-up Program. Additionally, this research delves into the various actions taken by EPA in communicating whether a clear understanding of the true asbestos-related risk was provided to the residents about airborne asbestos.

Several local environmental consulting firms have administered both Ground Zero clean-up and monitoring activities in lower Manhattan. This researcher currently has Ground Zero generated asbestos data, asbestos data generated from the cleaning activities, and data pertaining to the costs associated with the clean-up program (i.e.: abatement contractor costs and analytical laboratory costs), and the cost of providing specialized equipment to residents (i.e.: HEPA vacuums, air purifiers, etc.).

This research also includes a cost-benefit analysis, a risk analysis (calculation of asbestos exposure risk to the Ground Zero emergency responders, clean-up workers and resident population exposed prior to the residential cleaning program administered by US-EPA), and a technical commentary on the various testing methodologies used; their pros, cons, and an argument as to why certain airborne fiber testing methodologies did not provide useful information during the days immediately following the collapse of the Towers. Census data pertaining to individuals residing in lower Manhattan, and the general demographics of the lower Manhattan area have been obtained and used in conjunction with available data depicting

potential exposure, the nature of asbestos minerals and their related health effects. In addition, a comparison of air monitoring methodologies used, asbestos fiber-type and morphology, and their relevance with current asbestos-related cancer risk assessment models will be discussed. This asbestos information will be coupled to a cost benefit analyses to determine if the US-EPA policy of providing specialized equipment to the lower Manhattan residents, and the remedial policy of the clean-up program was effective at reducing the risk of asbestos-related cancer and justified the cost.

LITERATURE REVIEW

Diseases Associated with Asbestos Exposure in the Workplace

There are a number of diseases linked to occupational exposure to asbestos (HEI-AR 1991). The majority of this information has come from epidemiological studies of workers with occupational asbestos exposure. These workers had little or no respiratory protection and the airborne levels of asbestos were very high. Additionally, very little information regarding the fiber-type and morphology were available. Each of the following diseases was identified:

Asbestosis

Asbestos that escapes the nasal hair, cough, and mucous/cilia defense mechanisms reach the lung parenchyma. Once deposited there the pulmonary macrophages try to remove the asbestos fibers by translocation. However, the macrophages are not always able to engulf and remove the inhaled fibers. The macrophages have limited success, particularly as the exposure increases in concentration and fiber length. The high pulmonary burden of asbestos leads to interstitial fibrosis, thus damaging the lung's ability to exchange oxygen for carbon dioxide leading to shortness of breath. As more asbestos is inhaled, the extent of the fibrosis or scarring becomes greater and the lungs' ability to function progressively decreases.

Both long fibers and short fibers have been implicated as being the cause of this pulmonary fibrosis and carcinoma of the lungs. In addition, difference in fiber-type (e.g. serpentine from amphibole) may also influence this onset of these diseases (Langer, 2001). Chrysotile asbestos is cleared from the lung more rapidly than the amphibole asbestos fiber-types, some reports indicated that the short duration in the lung may be enough to initiate cell transformation or fibrosis (see review in Langer, *et al*, 1978, Nicholson *et al*, 1982, Nicholson, 1989). It is also possible that once the chrysotile related fibrosis begins, the ability of the lung to clear chrysotile is impaired. Alternatively, the amphibole fiber-type is not effectively cleared from the lung and subsequently accumulates (see review in Langer *et al*, 1978, Nicholson *et al*, 1982, Nicholson, 1989).

The interstitial fibrosis can progress very rapidly if the levels of airborne asbestos are very high but the process can be markedly slower at lower exposures. Asbestosis generally does not usually appear until 10-20 years after the first exposure. This period of exposure to the development of disease is known as the latency period. There is no treatment, and fibrosis may progress after exposure stops.

Lung Cancer

Asbestos related lung cancer was first identified among chrysotile asbestos textile workers (Doll, 1955). These workers also had asbestosis and initially the increase in lung cancer was thought to be a consequence of the scarring. Efforts to control asbestosis were thought to be effective at reducing or eliminating the increased risk of lung cancer.

Excess incidences of lung cancer have been found in workers occupationally exposed to asbestos. Often these workers had little or no respiratory protection (HEI-AR 1991). The risk of developing lung cancer increases if:

- An individual smokes cigarettes and can increase further if the smoker is exposed to airborne asbestos fibers;
- As exposure to airborne asbestos increases and the cohort of workers develop asbestosis increased incidence of lung cancer are more clearly demonstrated.

The risk of developing lung cancer increases significantly when one smokes and is exposed to asbestos fibers compared to a non-smoker exposed to asbestos (Hammond *et al*, 1979). This is because asbestos and smoking have a synergistic relationship. In other words, the effects of the individual exposures, when combined, are multiplicative. One reason for this is that smoking paralyzes the cilia located in the trachea and bronchi, which normally sweep some portion of the asbestos fibers upwards, which aids in clearance from the trachea and bronchi. By paralyzing the cilia in these areas, more asbestos fibers can travel deeper into the lung, thereby increasing one's risk for lung cancer and asbestosis. More importantly, cigarette smoking alone is a recognized

carcinogen to the lungs. Coupled with another carcinogen, asbestos, the increased risk of lung cancer can be significant.

Mesothelioma

Mesothelioma is a rapidly fatal but rare malignancy, causing only 2,500 deaths in the United States each year (Price and Ware, 2004). The tumors can develop either on the pleural (lung and chest) cavity linings or the peritoneal (abdominal) cavity linings. Initially, the malignancy commonly presents as pleural effusion or fluid which is drained from the chest or peritoneal cavity. Exposure to asbestos is undoubtedly responsible for the disease being 4-times more common in males than females as males are more commonly occupational exposed to asbestos. Mesothelioma often has the longest latency period (onset of exposure to the clinical appearance of the disease) of all asbestos related diseases, beginning 20 years and peaking 35 or more years from onset of exposure (HEI-AR 1991).

Mesothelioma often causes the greatest concern when assessing the dangers of asbestos exposure, as opposed to the other asbestos-related diseases, because mesothelioma has occurred in individuals with very little exposure, or exposure over a short period of time (HEI-AR 1991).

Results of research studies have demonstrated that inhalation of asbestos fibers many lead to increased risk of developing disease (see review in Langer, 2001). Exactly why some people develop a disease as a result of asbestos exposure and others do not is not yet understood. According to the Health Effects Institute, there are several factors that are important in assessing an individual's risk to develop asbestos-related disease:

- The concentration of asbestos fibers a cohort is exposed to and the number of years of exposure – the cumulative dose;
- Whether the person smokes – a lifestyle factor;
- Fiber type and size;
- The body's reaction to the fiber; and
- Age at onset of exposure (Important due to latency of disease).

A Synthesis of Asbestos Rulemaking in the United States to Protect Workers

As the risks of asbestos exposure to unprotected workers became evident, a precursor to asbestos rulemaking in the United States was initiated in the United Kingdom. In 1931, pursuant to a report depicting an increased risk of fibrosis of the lungs in persons employed within the UK asbestos industry (Merewether & Price, 1930), the asbestos industry standards for the United Kingdom were enacted, which required employers to install mechanical exhaust systems, provide a “breathing apparatus” along with other personal protective equipment including coveralls, head covers, and gloves to employees working with asbestos.

A few years later (1935), the United States Public Health service published a report by Dr. Anthony Lanza with the Metropolitan Life Insurance Company, that prolonged exposure to asbestos causes fibrosis of the lungs. Concurrently, the Walsh-Healy Public Contracts Act came into effect. This Act required that any company entering into a contract greater than \$10,000.00 with the United States Government ensure that all work conducted under the contract was not accomplished in unsanitary, hazardous or dangerous environments, which affect the health of employees (Nowinski, 1986).

It had been published that asbestosis was found to be prevalent in factory workers conducting daily routines in an asbestos textile plant in North Carolina (Dreessen, 1938). These workers were often exposed to asbestos dust concentrations greater than 5 million particles per cubic foot (mppcf), as measured by the impinger method. The impinger method of determining the number of particles per cubic foot of air preceded the current methodology of counting airborne fibers, and a direct correlation between mass impinger concentrations and airborne asbestos fiber concentrations is problematic. However, rough estimates between the impinger methodology and optical fiber counting techniques have been used in previous risk assessments (CHAP 1983, Nicholson, 1986), and include, estimates that a mass concentration of 1 mppcf is roughly equivalent to 3 fibers per milliliter (f/ml) and depends on the fiber generating industry.

In 1946 Fleischer and Drinker (as reviewed in Nowinski, 1986) reported that data comparisons between the textile industry and shipyards were not applicable because of inconsistencies between the exposures in each of the industries: textile workers were reported to have been exposed to a dust comprised of 80% asbestos, while workers employed in the shipyards were exposed to a dust with as little as 15% asbestos (Nowinski, 1986). Based on Dreessen's determinations that particles greater than 10 micrometers (μm) reach the alveoli, Fleischer and Drinker concluded that asbestosis was a result of relatively large ($>10\mu\text{m}$) asbestos fibers (Nowinski, 1986). They concerned themselves with long asbestos fibers, with an aspect (length to width) ratio of 3:1. Fleischer and Drinker calculated that 6 mppcf was equivalent to 0.7 f/mL when counting particles greater than $15\mu\text{m}$. Due to the counting protocols used in the 1940s where smaller fibers ($<10\mu\text{m}$) were not identified, Fleischer and Drinker were unable to conclude that these smaller fibers would not produce fibrosis or tumors (Nowinski, 1986).

The American Conference of Governmental Industrial Hygienists (ACGIH), in 1942, adopted 5 mppcf as a standard to which worker exposure was not to exceed. This 5 mppcf standard counted all particles, and made no determination between asbestos and non-asbestos particles. Similarly, this particulate based standard largely detected granular masses as opposed to long fibers, which Dreessen and Fleischer believed to cause a greater risk of lung fibrosis (Nowinski, 1986).

It must be pointed out that the ACGIH was not a regulatory agency and had no legal authority to establish their standard as law. Therefore, no specific penalties with regard to the failure of an employer to achieve this particulate standard could be levied (Nowinski, 1986). In an attempt to legalize a threshold standard for exposure to asbestos dusts, the ACGIH ratified allowable concentrations or Threshold Limit Values (TLVs) for asbestos to be 5 mppcf. ACGIH subsequently acknowledged, in 1946, that the TLV for asbestos (5 mppcf) was based on an eight-hour time weighted average (TWA) of worker exposure determined by optical quantification of total particulates. However, the ACGIH acknowledges that employers would circumvent this standard by allowing employees to be exposed to higher concentrations of asbestos dust over a shorter time frame, then reassign highly exposed employees to a duty with far less exposure; thereby reducing the calculated 8-hour TWA of asbestos exposure for that particular employee (Nowinski, 1986).

To regulate around this short-coming, another concept on allowable worker exposure to asbestos dust was brought forward in an attempt to further define allowable asbestos exposures; the concept for a maximum allowable concentration (MAC) was developed. The 5 mppcf TLV standard was adopted as a MAC. The MAC, however, suffered from some drawbacks with regard to a clear-cut conceptual definition. First, legislators wanted to establish a legal threshold that was as close to a concentration, that below which, a person exposed was not likely to develop asbestosis. The second drawback entailed the legislators understanding that a fraction of the MAC should be established that would require employers to implement mechanical exhaust and issuance of personal protective equipment in an attempt to guard against the synergistic effect from multiple contaminants for those employees that may be exposed to more than one contaminant. Lastly, the MAC should also provide for a work environment free from offensive odors, dust, etc. that may be in concentrations below the established standard (Nowinski, 1986).

In 1968, the ACGIH proposed to lower the asbestos exposure standard. The agency made 5 mppcf a ceiling value, which was argued as equivalent to an 8-hour TWA of approximately 2 fibers per milliliter (f/mL) greater than 5 μ m in length. This proposed change was made to “reduce to an insignificant risk” the chance of developing asbestosis in persons exposed for 30 years. The introduction of fiber length into proposed standards was beginning to take root, as longer fiber lengths were believed to be more carcinogenic. By 1968 the amphibole, crocidolite, was considered to be more hazardous than other asbestos fiber-types. However, the effect of fiber-type on the onset of disease was still poorly understood.

In 1970 the ACGIH proposed to further lower the asbestos standard to 5 f/mL for fibers greater than 5 μ m, and lowered the excursion level to 10 f/mL.

In 1971, the Occupational Safety and Health Administration (OSHA), was enacted with all the force of a law (Nowinski, 1986). The National Institute of Occupational Safety and Health (NIOSH) was established to act as the science advisor to OSHA. The ACGIH asbestos standard was adopted by OSHA and lowered from 12 f/ml for fibers greater than 5 μ m to 5 f/mL for fibers greater than 5 μ m. Concentrations were not to exceed 10 f/ml over any fifteen minute duration, as

OSHA became increasingly wary of worker asbestos exposure levels in high concentration atmospheres for short durations.

NIOSH recommended, in 1972, to lower the worker exposure standard for asbestos from 5 f/ml for fibers greater than 5 μ m to 2 f/ml for fibers greater than 5 μ m. By 1976, ACGIH adopts the OSHA exposure standard, but due to concerns with the potency of differing fiber-types, recommends lowering the exposure standard of two amphiboles to 0.5 f/ml for exposures to amosite asbestos, and 0.2 f/ml or exposures to crocidolite asbestos. To date, there exists no federal, state or local asbestos standard that takes fiber-type into consideration. However, a current movement into the consideration of including asbestos fiber-type and size into asbestos-related risk assessments has been initiated by EPA (Berman & Crump, 2003) following a previous asbestos exposure assessment conducted by Hodgson & Darnton (Hodgson & Darnton, 2000).

OSHA subsequently lowered the asbestos exposure standard to 0.2 f/ml over an 8-hour time weighted average (TWA), and introduced an “action level” of 0.1 f/ml, which was designed as the airborne concentration, above which, triggers employers to institute engineering controls (mechanical ventilation), provide personal protective equipment (PPE) to employees, and provide medical surveillance for those employees exposed to airborne asbestos (OSHA, 1988).

The final changes to date in the OSHA construction standard for asbestos were promulgated in 1994 with the establishment of the Permissible Exposure Limit (PEL) which effectively reduced the 8-hour TWA from 0.2 f/ml to 0.1 f/ml. The “action level”, was abandoned in 1988 in favor of the short term excursion limit (STEL). This STEL, which allowed for personal exposure no greater than 1 f/ml over a 30 minute time span, was subsequently renamed simply the Excursion Limit and continued to require employers to establish engineering controls, provide PPE and medical surveillance for employees exposed to asbestos.

Federal Laws to Protect Non-Occupationally Exposed Individuals

In the preceding discussion, the federal government was primarily concerned with protecting workers who were occupationally exposed to asbestos. As scientific reports continued to be published regarding these hazards, asbestos exposure entered into the public policy arena with

the understanding that even the slightest of exposures can cause an asbestos-related disease. Moving to protect a new group of employees who did not work in asbestos mines, mills, or factories, but those who may be exposed as the end users of the manufactured products that contain asbestos, the US-EPA modified three different federal Acts under two existing Laws. Under the Clean Air Act (CAA), the US-EPA, in 1973 originally enacted an asbestos provision to the National Emissions Standard for Hazardous Air Pollutants (NESHAPs), which was revised in 1990, and under the Toxic Substances Control Act (TSCA), the US-EPA, in 1986, enacted the Asbestos Hazard Emergency Response Act (AHERA), followed by the Asbestos School Hazard Abatement Reauthorization Act (ASHARA) in 1990.

The National Emissions Standard for Hazardous Air Pollutants

Under the Clean Air Act the NESHAPs (40 CFR Part 61, Subpart M) established work practices to minimize release of asbestos fibers during activities involving processing, handling and disposal of asbestos when a building, or part thereof, is being demolished or renovated. To do so, it became apparent that a material that contained asbestos must be regulated. Therefore, a regulated asbestos-containing material (ACM) was defined as any material that contained greater than one percent (1%) of the asbestiform varieties of chrysotile, amosite, crocidolite, tremolite, anthophyllite and actinolite as determined using polarized light microscopy (PLM). Different regulatory requirements exist depending on whether the ACM is friable (able to be reduced to powder using hand pressure, hence provide a greater potential risk if a worker is exposed to these materials) or non-friable (those materials that cannot readily be reduce to powder using hand pressure) . However, this distinction will not be discussed in detail as the powerful forces that fell the World Trade Towers rendered all materials friable. The owner / operator of a property is required to notify the State in which they are going to perform work that demolition or renovation activity will commence. Additionally, NESHAPs regulates asbestos waste handling, hauling, and disposal.

The Asbestos Hazard Emergency Response Act of 1987

Under the TSCA regulation, US-EPA enacted the AHERA to respond to asbestos in public and private schools. During such response actions, specific requirements are to be met by the local education agency to ensure that those end user individuals and, because of long latency, the students are not exposed to materials that contain asbestos. Specifically, the government now passed the requirements for individuals who will inspecting for asbestos, managing the asbestos materials in place, designing asbestos abatement work plans, workers and supervisors who perform actual removal activities to be appropriately trained in the potential hazards of asbestos. Furthermore, AHERA regulated the model criteria on how to perform an asbestos survey, and established the final Transmission Electron Microscopy (TEM) air clearance methodology and airborne concentration level to be achieved following asbestos abatement in schools. Through this regulation, US-EPA started the current asbestos abatement industry. However, the passing of this law was not without its detractors who claimed that in-place asbestos, in good condition, was relatively harmless (Mossman *et al*, 1990). ACM disturbed during abatement may result in school children becoming exposed to asbestos.

The Asbestos School Hazard Abatement Reauthorization Act (ASHARA)

Although the name may be misleading, the US-EPA enacted the ASHARA regulation which essentially required that all of the AHERA requirements: the use of trained and accredited inspectors, workers, supervisors, project designers, and management planners, when conducting asbestos activities at schools into all public and commercial buildings, which created for the first time, a model plan to be used in virtually any employment settings. Although far reaching, the AHERA/ASHARA requirements neither regulate residential buildings with less than ten units, nor single-family dwellings.

Summary of Historical Asbestos Risk Assessment Reports

Current literature on the risk of asbestos exposure to past cohorts examines workers who were exposed to high concentrations of asbestos fibers each working day, and became ill as a result of that exposure. In the past, these workers had little or no protection to minimize the risk of

exposure (Dreessen *et al*, 1938). More recent documents, which include the Chronic Hazard Advisory Panel (CHAP) report to the United States Consumer Product Safety Commission (CPSC) 1983, the United States Environmental Protection Agency Airborne Asbestos Health Assessment Update (Nicholson, 1986), a quantitative risk assessment report (Hodgson & Darnton, 2000), and other documents aimed at establishing a protocol to assess asbestos related risk (Berman & Crump, 2003, 2008a, 2008b) all further the asbestos literature with regard to asbestos exposure, and all assess asbestos related risks differently. **Table 1a** summarizes the lung cancer potency factors (K_L) and **Table 1b** summarizes the mesothelioma potency factors (K_M) derived from these different risk assessment reports.

Chronic Hazard Advisory Panel (CHAP) Report Summary

Following a 1981 United States Consumer Product Safety Commission (CPSC) amendment, in July of 1983, the Chronic Hazard Advisory Panel (CHAP) on Asbestos issued their report to the CPSC pertaining to the health hazards associated with asbestos exposure.

The 1983 CHAP report concluded that lung cancer and mesothelioma constituted the majority of asbestos related diseases, with other forms of cancer, (i.e.: digestive tract, oral, etc.) less prevalent as evidenced by disagreements amongst panel members as to the validity of this claim.

A clear relationship existed between the major asbestos fiber-types used during manufacturing in the United States: chrysotile, amosite and crocidolite, and the risk of developing lung cancer in occupationally exposed cohorts. The risk of developing lung cancer is determined by the cumulative asbestos exposure, and not by the age at first exposure. This lung cancer risk appeared to increase linearly with both the concentration and duration of the exposure.

Chrysotile, according to the epidemiology data studied as part of this thesis, showed a lower potential for producing peritoneal mesothelioma when compared to the other major asbestos fiber-types. The report concludes that crocidolite appears to cause a much higher risk of developing lung cancer than chrysotile, while a clear difference between asbestos fiber-types and the potential to develop plural mesothelioma did not exist. The risk of developing mesothelioma is not related to smoking or the concentration and duration of exposure. The higher the concentration, the higher

the risk of developing mesothelioma. Mesothelioma incidence increases exponentially with time. Due to the fact that the risk of developing mesothelioma is time-dependant, the likelihood of children exposed to airborne asbestos developing this disease would be greater than if exposed at adulthood.

The CHAP report concluded that fiber length and diameter are major determinants of carcinogenicity in animal studies, but chemical and physical properties of the differing fiber-types may still affect their biological activity (CHAP 1983). Furthermore, animal studies suggest that longer and thinner asbestos fibers appear to be more carcinogenic than shorter and thicker asbestos fibers. The CHAP report concluded that chrysotile asbestos has a much lower potential for causing peritoneal mesothelioma, but less evidence exists for a significant difference between fiber types and their ability to produce pleural mesothelioma and lung cancer (CHAP 1983). Evidence for this is suggested by the asbestos miners' exposed to chrysotile asbestos. However, as stated above, it is not clear as to whether the onset of disease is attributed to differences in fiber-type, or duration of exposure.

Lung cancer was determined to be dependent upon the total cumulative inhaled dose of asbestos and irrespective of age at first exposure. Non-smokers were noted to have one-tenth the risk of developing lung cancer as compared to smokers exposed to a similar cumulative asbestos dose. A figure not unlike the Center of Disease Control's (CDC) current understanding (CDC Fact sheet, accessed 11/19/11). Furthermore, a linear relationship between the relative risk (the ratio of observed over expected lung cancer cases) and the cumulative asbestos dose exists. The risk of developing mesothelioma appears to be independent of smoking habit, but time dependant; whereas the risk of developing mesothelioma increases if exposure occurred at a younger age versus an older age. The combination of these two points; the limited evidence that fiber-type affects the onset of mesothelioma as determined from chrysotile asbestos miners, and time dependence of mesothelioma development are at the forefront of public concerns regarding asbestos exposure at Ground Zero.

USEPA Airborne Asbestos Health Assessment Update, 1986 Summary, (Nicholson, 1986)

In preparing the risk assessments reflected in this update report, EPA focused on a total of forty-one cohorts as compared to the eleven studied by the CHAP committee. Additionally, cohorts of different fiber-type exposures were separated. These cohorts were grouped into the following fiber-type exposure categories: chrysotile, predominantly chrysotile, amosite, predominantly crocidolite, anthophyllite, tremolite, and a mixed fiber-type. A significant exposure to response relationship existed for lung cancer and mesothelioma, and to a lesser degree, gastrointestinal cancer, a discussion of which will henceforth be omitted because current thinking regards asbestos to be an inhalation hazard, not an ingestion hazard, and Ground Zero related concerns and risks pertain to asbestos as an inhalation hazard.

NIOSH reaffirmed their position on the 0.1 f/mL OSHA PEL. However, this standard is based largely on optical microscopy which is less sensitive than ATEM, does not differentiate between asbestos and non-asbestos fibers-types, and therefore may not protect against asbestos-related risks. Please see the discussion on analytical methodologies in the section entitled *Asbestos Air Monitoring Methodology*.

Lung cancer and mesothelioma are the two most prevalent asbestos-related causes of death among exposed individuals. Chrysotile mining and milling employees tend to have a lower unit exposure risk than chrysotile textile production, which was largely based upon a study of South Carolina textile workers (Dement *et al*, 1983b, and McDonald *et al*, 1983a – as referenced in Nicholson, 1986).

In a cohort of 1261 workers employed as textile workers (Dement *et al*, 1983 as referenced in Nicholson, 1986), 33 reported lung cancer deaths were observed, when 9.8 were expected. CHAP members argue that an underestimate of the exposure levels in this cohort may have occurred, as exposures from British textile workers (Peto, 1977 as referenced in Nicholson, 1986) are greater, arguing that 49 reported lung cancer cases were reported within a cohort of 822 persons. The CHAP members do acknowledge, however, that the exposures depicted in Peto, 1980 (as referenced in Nicholson, 1986) may also be overestimated. Additionally, workers employed in the British textile plants during similar time frames were exposed to a mixed asbestos fiber-type. The

difference in fiber-type can also affect worker exposure as the manipulation of chrysotile (Langer, 2003) and amphibole asbestos fibers in processing would produce fibers of differing sizes and diameters. This difference in fiber type and morphology would greatly influence the biologic potential for disease. Regardless of fiber-type discrepancies involved in assessing asbestos-related risk, this US-EPA protocol still does not differentiate between differing fiber-types and treats all asbestos fiber-types as equally potent, which they are not (Berman & Crump, 2003, 2008a, 2008b; Camus *et al*, 2002; Hodgson & Darnton, 2000; Nolan *et al*, 2005).

Hodgson & Darnton Assessment Report Summary

To further the literature on asbestos related malignancy, a quantitative analysis of seventeen asbestos exposed cohorts was undertaken and published in 2000 (Hodgson & Darnton, 2000). Hodgson and Darnton have specifically drawn upon recent health effect estimates that have either quantified the risk of contracting an asbestos malignancy from exposure to chrysotile alone or failed to account for the difference between different fiber-types within the amphibole group (i.e. the difference between amosite and crocidolite exposure). In conducting these estimates, earlier exposure data that had been reported in mppcf have been estimated to be equivalent to f/mL via the following conversion: 1 mppcf \sim 3 f/mL. This is equivalent to previous calculations conducted in (CHAP 1983). The authors concluded that the ratio of increased risk of developing mesothelioma between exposure to chrysotile, amosite and crocidolite asbestos exposure was 1:100:500 respectively. In other terms, with all things being equal, an individual exposed to crocidolite asbestos will have a 500-fold greater risk than an individual exposed to equivalent chrysotile levels. Similarly, an individual exposed to amosite will have a 100-fold greater risk of developing mesothelioma than an individual exposed to equivalent chrysotile levels. Lung cancer risks have been determined to be less clear, with little difference observed between the separate amphibole fiber-types. The ratio of increased risk of developing lung cancer between chrysotile exposure and the amphibole (amosite and crocidolite combined) fiber-types have been determined to be in the range of 1:10 and 1:50. The importance of this assessment is the fact that, to a reasonable extent, risks have been established for the differing fiber-types. One possible concern pertaining to this assessment is that a limited number of cohorts were used during the risk calculations, and not all available asbestos exposed cohorts. Only seventeen (17) cohorts have been studied for this estimate, while more than forty (40) were

available for study, see Berman & Crump, 2003. Another concern regarding the risk assessments presented in this report deals with the omission of the South Carolina textile worker cohort. A panelist supplying comments to the Berman & Crump asbestos exposure assessment had specific concerns relating to the omission of this cohort, which were presented as Appendix B of their report. Hodgson & Darnton omitted this cohort under the rationalization that the increased lung cancer potency depicted by the cohort was an anomaly due to the potential of crocidolite use in the manufacturing of gaskets. Hodgson and Darnton acknowledge that the South Carolina cohort used very little crocidolite as compared to chrysotile in this plant operations. However, 47% of the post-mortem lung burden fiber counts were amphiboles. Hodgson & Darnton concluded that the mesothelioma risk was primarily due to exposures to amphiboles, therefore excluded this cohort in their chrysotile calculations. However, as the panelist pointed out, this cohort does not show increased lung cancer potency when compared to other textile cohorts and that this omission may have affected the author's conclusions of lung cancer potency.

Berman & Crump's Assessment Report Summary

Drs. Berman & Crump have conducted the most exhaustive asbestos risk assessment to date including all ascertainable cohorts in their calculations. Furthering Hodgson & Darnton's work, Drs. Berman & Crump recalculated asbestos risks for not only the seventeen cohorts previously studied by Hodgson & Darnton, but included several more. Of particular note is the author's weighting of the asbestos fiber size in the relative risk associated with asbestos exposure and the development of both lung cancer and mesothelioma incidence which have been discussed in more detail in the following section.

The potency factors for both the lung cancer (K_L) risk model and the mesothelioma (K_M) risk model have been developed which take asbestos fiber-type into consideration. However, unlike Hodgson & Darnton, who separated amosite and crocidolite amphibole fibers and assigned different potencies to each fiber-type, Drs. Berman & Crump grouped the amphibole fibers together into one potency coefficient. Drs. Berman & Crump have derived that the potency of amphibole fibers increases the risk of contracting lung cancer by five times: whereas, the

potency of amphibole fibers increases the risk of contracting mesothelioma by five hundred times. Drs. Berman & Crump described their assignment of these potency factors based upon their interpretations of various exposure studies. Their asbestos fiber size criteria (discussed below) was predominately based upon animal studies, while the mineralogical component of their assessment criteria (chrysotile versus amphibole) was primarily based upon human epidemiology studies. Both of which are discussed in great detail in Chapters 6 & 7 of their 2003 assessment document respectively. Drs. Berman & Crump (2003) introduce an optimum concentration of asbestos in their risk calculation which is the weighted sum of two fiber size factions; fibers lengths greater than 10 μ m and thinner than 0.5 μ m are multiplied by 0.997, while fiber lengths between 5 & 10 μ m and thinner than 0.5 μ m are multiplied by 0.003. It is important to note that regardless of fiber-type, asbestos fibers shorter than 5 μ m hold absolutely no weight in Berman & Crump's risk assessment approach. Emphasis is clearly placed on long and thin asbestos fibers, with very long fibers (greater than 10 μ m in length) weighted significantly greater than long fibers (between 5 & 10 μ m). This strengthens the belief that short asbestos fibers, regardless of mineralogical type, pose very little health-based risk.

A more recent discussion of panel members convened to discuss the proposed modification to assessing asbestos related risk detailed in Berman & Crump 2003 with data from the South Carolina cohort, drawing various interpretations. Some panelists saw the South Carolina cohort data as an outlier in comparison to other epidemiologic studies where chrysotile exposure was predominant, and requested the authors to exclude these data from their study. Other panelists viewed the South Carolina data as flawed, with a portion of the studied cohorts exposed not only to chrysotile asbestos, which the original study alleges, but to tremolite as well, a known contaminant to the chrysotile ore which might increase the risk of developing an asbestos related disease.

Current Knowledge Regarding Asbestos Related Lung Cancer and Mesothelioma

Since the Berman & Crump, 2003 update, many additional studies have been performed (Bernstein *et al*, 2005a, 2005b; Bernstein & Hoskins, 2006b; Yarbough, 2006; Ogden, 2007; Hein *et al*, 2007; Stayner *et al*, 2007; Berman & Crump, 2008a; Berman & Crump, 2008b; Bernstein *et al*, 2008; Pierce *et al*, 2008; Berman, 2010; and McDonald, 2010). These studies

have advanced the current knowledge base regarding asbestos induced disease and are summarized below:

Bernstein *et al*, 2005a, 2005b

Building off their 1996 animal study, the authors extrapolated on their biopersistence findings with attention to Canadian chrysotile. The findings of this study confirmed previous data that inhaled chrysotile is readily removed from the lungs and amphiboles persist. This reduced biopersistence of chrysotile asbestos was suggested in part due to two reasons; 1) chrysotile, as a sheet silicate, is susceptible to surface alterations which make longer fibers unstable (Langer & Nolan, 1994a, 1994b); and 2) the ability for macrophages to phagocytize the fibers aids in clearance. These two reasons have been detailed in the section entitled "Fiber-Type and Fiber-Size Effect the Biological Potential for Disease" below. The authors suggest that the clearance half-times for amphibole fibers longer than 20µm are 50 times greater than the chrysotile clearance half-time of 11.4 days. This finding supports the chrysotile versus amphibole differentiation suggested by Hodgson & Darnton, 2000, and Berman & Crump, 2003, 2008a, 2008b.

The authors acknowledge that chrysotile certainly influences cancer; however, the induction appears to be a result of high exposures over a long duration. Suggesting that low exposures to chrysotile over a short duration appears not to be hazardous.

Bernstein & Hoskins, 2006b

The authors updated the health effects of chrysotile in this paper by looking at several factors and their role in inducing cancer. Summarizing previous pathology works by Bernstein *et al*, (2003a, 2003b, 2004, 2005a, 2005b, and 2006a) where rats were involved in short-term exposures to pure chrysotile, they concluded that exposures to pure chrysotile does not present a detectable risk.

Depending on the geographical location of the chrysotile mine, chrysotile fibers have a clearance half-time of 0.3 to 11 days. As the long chrysotile fibers break apart in the lung they behave more like an aerosol in the long term, while the amphiboles retain their fibrous morphology and remain in the lung. The ability of the chrysotile fibers to be reduced to smaller fibers and

aerosol-like particulate render them relatively harmless; whereas exposure to tremolite asbestos in as little as 5 days produced fibrosis and macrophage aggregates (Bernstein *et al*, 2005a).

Bernstein and Hoskins also stated that previous chronic inhalation studies were often conducted using very high exposure concentrations resulting the lung load, therefore their usefulness towards lower-exposure extrapolation is limited. They acknowledge that chrysotile is not unlike other particulates in that exposure to high concentrations over a prolonged period of time will produce lung cancer. In contrast, they conclude that short-term exposures, or low-level long-term exposures to chrysotile do not appear to cause cancer.

Yarborough, 2006

Furthering the topic of chrysotile and its cause of mesothelioma, Yarborough conducted an assessment of several epidemiologic studies: 18 cohort studies where amphiboles were the only source of exposure; 39 cohort studies where a mixed fiber-type was the source of exposure; and 14 cohorts where no amphibole exposure was identified, exposure was only to chrysotile. Among these cohorts, which can reviewed within the article, 404 cases of mesothelioma were identified within the 32,853 subjects where exposure was to the amphibole fiber-type (1.2%); within the mixed fiber-type cohorts, 994 cases of mesothelioma were identified within the 114,384 subjects (0.87%); and from the cohorts where no amphibole exposure was identified, 7 cases of mesothelioma were identified within the 32,039 subjects (0.02%). Upon this review it can be argued that the 0.87% incidence of mesothelioma observed in the mixed fiber-type cohort can be explained by the presence of the amphibole fibers, where the cohort that was exposed to only amphiboles shows an incidence of mesothelioma of 1.2%, markedly different from the cohort that was exposed to chrysotile only (0.02%). Yarborough concluded that chrysotile, uncontaminated by amphiboles, appeared not to cause and increased risk of mesothelioma which is comparable to other studies (Bernstein *et al*, 2005a, 2005b, Bernstein & Hoskins, 2006). Yarborough further stated that "discussions about risk of chrysotile for mesothelioma in most regulatory contexts reflect public policies, not the application of the scientific method as applied to epidemiologic cohort studies", a similar hypothesis is questioned as part of this thesis.

Ogden, 2007 - Health Canada Report

In an attempt to obtain a consensus on the current state of understanding regarding the potency of chrysotile asbestos towards inducing lung cancer and mesothelioma, the Health Environments and Consumer Safety Branch of Health Canada convened a panel of chrysotile experts to discuss the available data and studies on that topic. The panel was chaired by Dr. Trevor Ogden and convened on November 13-14, 2007 in Montreal Canada. Panelists included: Dr. David Bernstein; Dr. Kenny Crump; Dr. Nicholas de Klerk; Dr. Bice Fubini; Dr. Graham Gibbs; and Dr. Leslie Stayner. Other representatives of Health Canada along with several observers were also present. Two items that were dealt with extensively during panelist discussions were a comparison between the two major risk assessment studies performed by Berman & Crump, (2003), and Hodgson & Darnton, (2000), and the difference between observed incidence of lung cancer between the two predominately chrysotile exposed cohorts in the Quebec mining industry, and the South Carolina textile industry.

On discussions regarding the two risk studies, the panelists agreed that the two studies were generally in agreement, particularly with respect to both studies showing that the Quebec mining industry has a lower incidence of cancer when compared to other chrysotile exposed industries, while the South Carolina textile industry cohorts show a greater incidence of lung cancer than other chrysotile exposed industries. The major differences between these studies was elucidated as the following:

- Berman & Crump took into account the tremolite exposed cohort in the predominately chrysotile exposed cohort in the South Carolina textile industry, Hodgson & Darnton did not.
- Berman & Crump modeled the relationship between disease and exposure within each cohort studied, while Hodgson & Darnton used the mean result of each study. This means that the Berman & Crump study can better adjust to changes in background risk information, but becomes more susceptible to changes in exposure mischaracterizations.

- With respect to amphiboles, Berman & Crump pooled these fibers in both their lung cancer and mesothelioma risks, but Hodgson & Darnton found that crocidolite was more potent than amosite in inducing mesothelioma. Hodgson & Darnton did not make this distinction regarding lung cancer as they pooled the amphiboles.
- With respect to the two major types of mesothelioma, Berman & Crump pooled both peritoneal and pleural mesothelioma, where Hodgson & Darnton considered the effects of both crocidolite and amosite in inducing these two forms of mesothelioma.
- Berman & Crump used a linear relationship between exposure and disease to best fit the observed cohort outcomes, while Hodgson & Darnton allowed for non-linear relationships. The major effect is where low exposures are present, due to a paucity of available data, where Hodgson & Darnton's model predicted a greater risk for mesothelioma, and a lower risk of lung cancer as compared to Berman & Crump.
- Berman & Crump attempted to model the consideration whether changing the fiber length would improve the correlation of observed disease, while Hodgson & Darnton did not.

One important discussion between the panel members reflected in the Health Canada report was headed by Dr. Stayner and involved how the lung cancer potency for chrysotile is effected by the Quebec mining and South Carolina cohorts. Berman & Crump's analysis, which included both the occupationally exposed cohorts from Quebec and South Carolina estimated that amphiboles were three times more potent than chrysotile. When the Quebec cohort, which had a lower than expected lung cancer incidence as compared with other chrysotile exposed industries was removed, chrysotile was 1.6 times more potent than amphiboles. When the South Carolina cohort, which had a greater than expected lung cancer incidence as compared with other chrysotile exposed industries was omitted instead, amphiboles were more than ten times more potent than chrysotile. Dr. Stayner then elucidated about his 2007 study, a summary of which is included below.

Hein *et al.*, 2007

This study confirmed the exposure -response relationship for lung cancer from previous studies using Poisson regression models to the South Carolina cohort of textile workers through 2001.

Although not furthering the discussion regarding the potency potential of fiber length and diameter on the induction of lung cancer, this study is backed by solid statistics that confirms that heavy exposure to chrysotile produces lung cancer.

Stayner *et al*, 2007

The authors used the South Carolina textile mortality study cohort updated by Hein *et al*, 2007 to see what fiber dimension best predicted this observed cohorts' mortality. The authors used TEM and a direct transfer technique modified by NIOSH for this analysis. The benefits of TEM as the best available technique to be used in analyzing for asbestos has been described later in this thesis. The direct-transfer technique modified by NIOSH is simply a technique whereby the replacement of the membrane sample filter for analysis does not modify the longer fiber dimensions resulting in a reduction of the number of smaller fiber lengths that are generated from the indirect transfer technique.

The results of this study confirmed that exposure to thin fibers ($<0.25\mu\text{m}$) provided the strongest fit to the observable induction for both lung cancer and asbestosis. Long fibers with a length greater than $10\mu\text{m}$ provided the best fit to the observable induction of lung cancer alone. When analyzing the fiber length and diameter simultaneously, a length range between $20\text{-}40\mu\text{m}$ coupled with a diameter range of $0.25\text{-}1.0\mu\text{m}$ provided the best fit. This supports previous reports (CHAP, 1983, US-EPA, 1986, Hodgson & Darnton, 2000, and Berman & Crump, 2003) that show long, thin asbestos fibers cause lung cancer. The authors advertise the TEM technique used as in this study as the superior method for predicting lung cancer and asbestosis mortality over PCM. In previous epidemiologic studies using PCM, fiber lengths shorter than $5\mu\text{m}$ would not have been counted, and the authors argue that these short chrysotile fiber lengths provided a "highly statistically significant" prediction of lung cancer and asbestosis. Similarly, PCM would not have been able to detect fiber diameters below $0.2\mu\text{m}$, which was the fiber diameter that best fit the observable incidence of lung cancer and asbestosis in this cohort study.

Berman & Crump, 2008a

Berman & Crump updated their 2003 update of the EPA's 1986 risk assessment protocol, which as of the date of this study is now 24 years old, and seems to be outdated with respect to the

current state of knowledge regarding the incidence of asbestos related disease. In their 2008 study, the authors concluded:

- The South Carolina cohort for lung cancer potency was comparable to cohorts exposed to amphibole fibers, and not comparable to predominately chrysotile exposed miners and millers from Quebec;
- The relative risk of lung cancer is predicted to remain constant after 10 years from end of exposure;
- The relative risk of mesothelioma is predicted to increase indefinitely as the square of the time of exposure lagged by 10 years;
- That neither assumption from the EPA 1986 model that chrysotile and amphibole potencies are no different in lung cancer and mesothelioma incidence, nor that PCM data is sufficient for this prediction, is valid; and
- Lung Cancer potency factor (K_L) estimates appear to correlate well between industries as well as between fiber-types (**Table 1**).

These conclusions appear to support the growing hypothesis that short-term, low level exposure to short chrysotile fibers is relatively harmless (Hoskins, 2001).

Berman & Crump, 2008b

In support of the growing hypothesis referenced above, the authors conducted a meta-analysis of asbestos related cancer risks to include fiber size and fiber-type. The analysis was performed by applying exposure information to non-overlapping fiber categories, then applying the updated K_L and K_M obtained from their 2008a study to assign a potency for each fiber category. The authors separated fiber size categories into lengths of: $<5\mu\text{m}$, $5-10\mu\text{m}$, and $>10\mu\text{m}$; and widths of: All, $<0.4\mu\text{m}$, and $<0.2\mu\text{m}$. The major finding resulting from this study were the following:

- The assumption used in the EPA 1986 model that all fiber-types (chrysotile and amphibole) are equally potent for inducing disease was strongly rejected;

- The hypothesis that pure chrysotile, uncontaminated by amphiboles, is potent for mesothelioma was rejected by the analysis, furthering the paradigm that chrysotile asbestos may not be hazardous;
- The hypothesis that chrysotile and amphiboles are equally potent for inducing lung cancer was rejected by the fiber width categories of $<0.4\mu\text{m}$, and $<0.2\mu\text{m}$, but not for all fiber widths. This suggests that long and thin fibers are most potent;
- The hypothesis that shorter fibers ($5\text{-}10\mu\text{m}$) were potent was rejected; and
- The analysis on short fiber ($<5\mu\text{m}$) did not provide consistent evidence towards lung cancer or mesothelioma potency.

This study did not completely resolve the differences observed in past studies conducted regarding the exposure to asbestos in occupational cohorts; specifically the observed low lung cancer incidence reflected in the Quebec miner and millers, and high incidence among South Carolina textile workers.

Bernstein *et al*, 2008

As the epidemiological meta-analysis was performed on past occupationally exposed cohorts, a toxicological inhalation study was performed by Bernstein *et al*. The authors performed an inhalation biopersistence study using Wistar rats. Two groups of rats were exposed to equal amounts of chrysotile alone, or in combination with respirable particulate from joint compound material that is typically trowel-applied to gypsum wallboard seams and joints during construction. This particulate is comparable to the generated dusts released upon sanding the dried joint compound after application. The lung fiber burden comparison between the rats exposed to chrysotile alone versus the chrysotile mixed within the sanded joint compound material resulted in an order of magnitude less fibers in the rats where the chrysotile was mixed with the dusts from the sanded compound. The authors explained this finding due to increased macrophage activity in the lungs from the presence of the particulate matter (joint compound dust).

Pierce *et al*, 2008

The purpose of this study was to evaluate the reported no adverse effect levels to chrysotile exposures discussed in some of the literature. All of the past occupationally exposed cohorts involving chrysotile have been exposed to large airborne concentrations of asbestos fibers. However, past studies have been fraught with known differences in latencies, cohort size, a lack of fiber dimension data, and unknown exposures to tremolite asbestos. The authors report a no observed adverse effect level range to chrysotile exposure of approximately 25-1,000 f/mL-year for lung cancer, and 15-500 f/mL-year for mesothelioma. The authors further agree that low exposures to chrysotile are unlikely to cause adverse health effects (Liddell *et al*, 1997).

Berman, 2010

In reviewing the scientific literature, a general consensus exists that chrysotile asbestos is less carcinogenic than amphiboles. A growing faction of scientists have published articles stating that exposure to chrysotile may not be hazardous to human health (Hodgson & Darnton, 2000, Berman & Crump, 2003, Bernstein *et al*, 2005, Bernstein & Hoskins, 2006, Yarbough, 2006, and Berman & Crump, 2008). However, historical epidemiological studies of two particular cohorts, miners and millers from Quebec, and textiles workers from South Carolina, show a markedly differenced lung cancer incidence even though both cohorts were exposed to primarily chrysotile asbestos (Ogden, 2007, Hein *et al*, 2007, and Stayner *et al*, 2007). It has been surmised that beyond the potential amphibole contamination of chrysotile asbestos in these two cohorts, fiber length considerations may influence this incidence as well, but the difference in past methods for determining worker exposure have not been successful in fully categorizing these differences. This study was performed to evaluate the Modified Elutriator Method (MEM), a method that would better generate observed dust exposures comparable to a particular factory process. Analyzing the MEM-derived dusts using TEM would best predict worker exposures and an often cited limitation (Midget impinger, or PCM derived data) regarding past study would be reduced.

The analysis of the MEM-derived dust from the Quebec miners and millers, and the textiles workers from South Carolina show that each generated sample of dust compared well to actual samples of dust from each respective factory. TEM analysis of these MEM-derived dust samples show that textile dust have a considerably longer fiber length than do dust generated by mining

and milling the ore. The authors have stated that PCM sized fibers elutriated from textile dusts were 100% asbestos, meaning that the PCM and TEM data would be identical. Alternatively, 2/3 of the total dust elutriated from mining and milling operations was either non-asbestos, or non-asbestiform, while only 1/3 of the fibers were asbestos via TEM.

The authors concluded that the observable difference in lung cancer potency can now be explained by the difference in fiber-length the two cohorts were exposed.

McDonald, 2010

McDonald drafted this outline on the epidemiology of malignant mesothelioma starting with the known incidence of malignant tumors of the mesothelium reported in Cape Province, South Africa in 1960 (originally reported by Wagner *et al*, 1960; but also cited in Mossman *et al*, 1990, and Nolan, 1999, 2006). In his review of the epidemiologic literature, McDonald reiterated the overwhelming trend that a higher risk of asbestos-related disease is associated with exposure to amphibole versus chrysotile alone. In regions like Quebec, where exposure was originally thought only to be chrysotile, plural thickening and calcification was more prevalent in the Thetford mines rather than in Asbestos, existing at least twice as often in Thetford, than in Asbestos. It was later determined that exposure to fibrous tremolite greater than 5µm in length often contaminated the chrysotile, and lung fiber burden results showed an equal or greater amount of tremolite and chrysotile in affected lungs (Liddell *et al*, 1997; Roggli *et al*, 2002).

Fiber-Type and Fiber-Size Effect the Biological Potential for Disease

The aforementioned summarized studies have verified that fiber-type and fiber-size effects the biologic potential of disease. These studies have advanced our understanding regarding this issue by building off a few commonly cited ideas behind the incidence of disease observed versus what was expected. These ideas are: the clearance of chrysotile from the lung, and the amphibole hypothesis.

The Clearance of Chrysotile from the Lungs

The observed difference in the clearance rate between the amphiboles, and chrysotile have been attributed to a few items: 1) the mineralogical structure of amphiboles as a double-chain silicate, while chrysotile is a sheet silicate; 2) the effect of the macrophage on phagocytization; and 3) the dissolution rate of chrysotile in organic acids (Langer & Nolan, 1994a, 1994b). The cumulative effect of each of actions enables for the chrysotile fiber to become cleared from the lung. Often ending in the parenchyma where it may be relatively harmless towards mesothelioma incidence (as evidenced in Langer's 2001 SMR calculation between chrysotile exposure lower than amphibole or mixed exposures, and as referenced from Table 1 in Nolan *et. al*, 2006).

The mineralogical structure of amphibole asbestos, and the serpentine chrysotile are markedly different. The amphiboles are double-chained silicates with high iron content (Van Oss *et al*, 1999), while chrysotile is a sheet silicate with a layer of brucite and silicate that is wound around itself having a hollow center and magnesium on the surface of the fiber (Langer *et al*, 1978, and as reviewed in Langer, 2001). The presence of magnesium on the outer surface of the chrysotile fiber lends it to fragmentation within organic acids when the magnesium from the surface of the fiber gets dissociated within acidic lung conditions, and is quickly broken down to smaller and smaller fibers (Langer *et al*, 1978, and as reviewed in Langer, 2001). The higher relative iron content of the amphiboles may retard fiber fragmentation therefore rendering it less susceptible to macrophage engulfment (Van Oss *et al*, 1999). It has been shown that chrysotile has one of the shortest clearance half-times, shorter than some fibrous glasses, and other man-made vitreous fibers (Mossman, 1990; Van Oss, 1999; Bernstein *et al*, 2006a, 2008), thereby potentially less potent (Liddell *et al*, 1999) where the clearance of amphibole fibers is appreciably longer.

The presence of these smaller chrysotile fibers invoke a human response where macrophages attack the foreign body. It has been shown (Bernstein *et. al.*, 2008) that chrysotile exposure in the presence of nuisance dust sized particles invokes an even greater reaction producing an abundance of macrophages to clear the chrysotile and the nuisance dust from the lung. The process of phagocytization starts as the macrophage adheres to the fiber in an attempt to clear it from the lung. If the fiber is too long to be fully engulfed by the macrophage, then the process becomes "frustrated" and clearance ceases. As amphiboles do not become fragmented as readily

as chrysotile, they tend to remain in the lungs longer as larger fibers and are unable to be phagocytized, hence cleared from the lungs. The presence of these unphagocytized amphibole fibers produce inflammation and tumors.

Chrysotile has been shown to breakdown in the acidic medium resulting from phagocytization while the amphibole fibers do not (Roggli, 2002). Owing to their surface chemistry, chrysotile has been shown to dissolve in a pH of less than 10 (Langer & Nolan, 1994a).

The Amphibole Hypothesis

This hypothesis has been around since the 1960s (as referenced in Mossman *et al*, 1990) and refers to the preponderance of observed amphibole fibers within the lungs of occupationally exposed workers believed to be exposed to predominately chrysotile asbestos. The premise that the observed asbestos-related disease was less attributed to the effects of the chrysotile exposure, but mostly due to the effect from amphibole exposure, specifically tremolite contamination of mined chrysotile, has been contested ever since. There appears to be a consensus that chrysotile asbestos, free of tremolite contamination, has little effect in the induction of mesothelioma (Liddell *et al*, 1997; McDonald, 2010), but the evidence supporting that chrysotile exposure does not induce lung cancer is spurious. Of particular contention arguing against the amphibole hypothesis is the differing incidence of lung cancer and mesothelioma observed from two predominately chrysotile exposed cohorts, the South Carolina textile workers, and the miners and millers from Quebec.

Both cohorts have been exposed to predominately chrysotile, with known amphibole contamination believed to be rather minor, specifically tremolite. The total chrysotile fiber burden and the total tremolite fiber burden observed in lung tissue of the miners and millers was greater than that of the textile workers. However, the incidence of observed lung cancer in the textile cohort is markedly greater. Considering exposures worldwide, it is well documented that amphibole asbestos is more durable and biopersistent, therefore responsible for inducing mesothelioma than is chrysotile (Liddell *et al*, 1997). Opponents to the amphibole hypothesis argue that all fiber types should be regulated equally, but the literature does not bare this to be true. Most occupational and almost all environmental mesotheliomas are caused by exposure to

amphibole asbestos. Regardless of whether one is a "chrysophile" or "chrysophobe" (Tweedale & McCulloh, 2004), it seems clear that low level exposure to very short chrysotile fibers (< 5µm), free from amphibole contamination should not be treated as equally potent as amphibole asbestos, and will not induce adverse health effects (Hoskins, 2001).

Asbestos fiber sizes greater than 4µm and < 1µm diameter (i.e.: long and thin fibers) are more carcinogenic than shorter and thicker fibers (Nicholson, 1986). This conclusion has been based upon the aforementioned assessment studies coupled with various animal studies. Fibers placed into the pleura of animals showed greater carcinogenicity when they were less than .25µm in diameter, and greater than 8µm in length.

The amphibole hypothesis can arguably be said to have morphed into a discussion regarding tremolite (McDonald, 2010) whereby the differences in the observed Thetford mine incidence of asbestos-related disease has been attributed more to tremolite contamination of the chrysotile ore, than to the chrysotile itself. Coupled with data from his previous chrysotile biopersistence studies using rates, McDonald, 2010 concludes that the majority of the observed cases of mesothelioma in predominately chrysotile exposed cohorts could be explained by the presence of tremolite, and chrysotile only a few.

Regardless of the approach used to advance our understanding about chrysotile exposure; whether it is from inhalation studies, in animal experiments, or statistical analyses of observed outcomes from epidemiological studies, no clear consensus about chrysotile has been reached. Exposure to chrysotile within past occupationally exposed cohorts, where the dosage to asbestos was far greater than environmental exposures of today, causes cancer. However, as these studies show, it is becoming clearer that low-level long-term, or short-term chrysotile exposure to short (< 5µm) fibers may not increase the risk of mesothelioma.

Animal and Biopersistence Studies

In determining the referenced risk parameters for induction of an asbestos-related disease, it has been shown that for chrysotile exposed cohorts, occupational and environmental exposures to

chrysotile do not carry the same risk (Langer & Nolan, 1994a). Berman & Crump, (2003) have drawn on biopersistence information obtained largely from two animal inhalation studies; Berman *et al*, 1995 and Bernstein *et al*, 1996. These referenced studies are summarized below.

Berman *et al*, 1995

As fiber-type and size considerations continued to grow as potential reasons for the observed onset of lung cancer and mesothelioma, Berman *et al*, 1995 conducted an inhalation study using AF/HAN rats exposed to asbestos fibers. No one length provided a proper fit to the observed lung tumor incidence observed in other studies, but the authors reported that lung tumor incidence was best correlated to a long fiber length, greater than or equal to 20 μ m. When the analysis was performed using multiple variables the analysis identified a fit that described the observed lung tumor incidence. Their analysis identified a correlation between fibers that are long (>5 μ m) and thin (0.4 μ m) in diameter and increased lung cancer potency. Furthermore, as fiber length increases, so too does potency with fiber longer than 40 μ m reported as being 500 times more potent than fibers less than 40 μ m.

This analysis did not, however, find a difference between chrysotile exposure and amphibole exposure in producing lung tumors in rats.

Bernstein *et al*, 1996

Another fiber size analysis was performed by Bernstein *et al*, 1996. The authors exposed Fischer 344 male rats to different fiber sizes. Some of the fibers were not asbestos as the analysis included manufactured glass fibers with different mineralogy. Bernstein *et al*, 1996 citing other rat inhalation studies performed by Mast *et al*, 1995a, 1995b, and Hesterberg *et al*, 1993 have acknowledged an important consideration when extrapolating the conclusions from rat studies to human inhalation. Humans can inhale into their lower respiratory pathways and alveoli fibers with a diameter of approximately 3 μ m. Rats, primarily due to their more restrictive nasal passages, can only inhale fibers into their lower respiratory pathways with a diameter of approximately 1 μ m. This has been reported as the "rat respirable" difference between rat and human respiration of fibers. This consideration makes it difficult to infer any exact correlation between animal & human exposure cohorts.

This study confirmed that longer fibers, generally $> 20\mu\text{m}$ clear quicker in the lung compared to shorter fibers, which is comparable to previous studies. Of note was the observed difference between the clearance of longer fibers of crocidolite as compared to longer fibers of fibrous glass; long crocidolite fibers clear considerably slower in comparison. These longer fibers of crocidolite have been determined to take 150 to 300 times longer to get cleared from the lung. This prolonged residence time in the lung can eventually lead to inflammation and other reactions in the lung.

Asbestos Air Monitoring Methodology

The two analytical procedures utilized to determine airborne asbestos concentrations associated with activities in and around Ground Zero are phase contrast microscopy (PCM) and analytical transmission electron microscopy (ATEM). The main difference between these two analytical procedures, aside from cost, is the fact that PCM, due to the physical properties of light employed in this microscopic technique, cannot differentiate between asbestos and other fibers, where ATEM does. PCM, as mentioned in the NIOSH-7400 analytical standard, cannot resolve the internal structure of viewable fibers and certainly cannot determine mineralogy. PCM has a magnification of 400X that does not allow all fibers to be imaged. Due to this limitation, very thin fibers cannot be detected. NIOSH defines a fiber as a structure having a length equal to or greater than $5\mu\text{m}$, and a length-to-width (aspect) ratio of equal to or greater than 3:1. PCM results are reported in units of fibers per volume of air collected (f/mL). ATEM, however, can distinguish between the various asbestos fiber-types and other non-asbestos fibers by using an electron beam to image the fiber and energy dispersive x-ray spectroscopy and selected area electron diffraction to determine the elemental composition and crystal structure. ATEM results are reported in “structures” per square millimeter of filter analyzed (s/mm^2) (US-EPA-AHERA 1987). As asbestos fiber-type and fiber size affect the biologic potential for disease, the US-EPA modified the International Organization for Standardization (ISO) 10312 ATEM technique and developed was called the phase contrast microscopy equivalent (PCMe) methodology. The PCMe methodology is a technique that directly transfers the sampled fibers to the TEM filter for analysis without reducing the size of the sampled fibers. These sampled fibers will then be analyzed using ATEM, a determination made regarding whether they are asbestos, and their fiber

size determined to correspond with fiber sizes equivalent to those observable using PCM. **Table 2** summarizes the technical differences between the PCM, TEM AHERA, and PCMe methodologies.

A good correlation between the fiber levels from PCM and ATEM data is not always found due to the inherent limitations of the PCM method, as most of the health effects data on asbestos have been established based upon exposure measurements or converted to PCM fiber counts, and assuming that an asbestos “structure” is equivalent to a “fiber”. Then the following conversion can put the TEM AHERA clearance criteria of 70 s/mm² into a clearer view. Although not exact, these numbers can be correlated to a degree which can be useful in calculating asbestos-related health risks (see Nolan *et al*, 2005).

The ATEM result, in s/mm², is multiplied by the area of the membrane filter used in the sampling cassette, typically a 25mm cassette, which corresponds to a 385 mm² area, divided by the total volume of air drawn across the filter in liters or milliliters. This yields a conversion factor of 0.00031 mm²/mL using a sampling volume of 1,250 liters of air. Using this conversion factor the AHERA standard of 70 s/mm² is equivalent to 0.022 s/mL; a value much greater than the current PCM “clearance” standard utilized by Federal, State and Local agencies of 0.01 f/mL (US-EPA-AHERA 1987, NYSDOL Industrial Code Rule-56, NYCDEP Title 15). However, units of s/mL create an upper limit as some of the structures are not fibers but all the fibers are included in the s/mL count.

This leads directly to the lack of equivalency between what defines a structure, and how it relates to the definition of a fiber. AHERA defines a structure as “a microscopic bundle, cluster, fiber or matrix, which may contain asbestos”, then goes on to define a fiber differently from the NIOSH- 7400 method. According to AHERA, a fiber is defined as “a structure greater than or equal to 0.5µm in length with an aspect ratio of 5:1 or greater and having substantially parallel sides”. Therefore, by definition, structures are different from fibers, and this distinction is present throughout the literature and is an often cited limitation in gauging earlier occupational exposures to asbestos. For risk assessment evaluations the number of fibers ≥5µm in length must be determined.

Ground Zero Related Reports

Following the collapse of the World Trade Center buildings on September 11, 2001, extensive environmental sampling and analysis for the presence of asbestos (amongst other contaminants) was undertaken by several federal, state and local agencies, public and privately hired environmental testing companies, and labor unions in order to determine if asbestos exposures would increase the risks of asbestos-related disease. Asbestos analysis for airborne fibers included both the optical analysis via PCM, a form of analysis that cannot resolve asbestos and non-asbestos fibers, and the more definitive analysis for asbestos, TEM. TEM can distinguish between the various asbestos fiber-types and other non-asbestos fibers by using an electron beam to image the fiber and energy dispersive x-ray spectroscopy and selected area electron diffraction to determine the elemental composition and crystalline structure.

The issuance of the now infamous September 13, 2001 press release by then EPA Administrator, Christie Todd Whitman, where it was stated that "...no significant levels of asbestos dust in the air in New York City" was present, resulted in one of the first reports dealing directly with airborne and settled dust concerns resulting from the collapse of the world trade center buildings which was published by the American Industrial Hygiene Association (AIHA), (Granger, et. al. 2001). The AIHA report identified the presence of asbestos in eight (8) of the eleven (11) surface samples collected and subjected to PLM analysis. Of particular note, was the dominant presence of very short chrysotile asbestos fibers, believed to be the result of the immense pulverizing forces enacted on all building materials as the WTC towers collapsed (Granger *et al*, 2001). A total of eleven (11) air samples were also collected as part of the Granger *et al* investigation and subjected to analysis via EPA Level II TEM. Under this protocol, only asbestos fibers with an aspect (length to width) ratio $\geq 3:1$ are enumerated. Additionally, asbestos structures have been categorized by fiber length: either $> 5\mu\text{m}$ or between $0.5 - 5\mu\text{m}$. Airborne chrysotile asbestos structures greater than $5\mu\text{m}$ in length were only identified in three (3) of the eleven (11) samples analyzed. Alternatively, chrysotile asbestos structures were identified in all but one (1) sample subjected to enumeration in the $0.5\mu\text{m} - 5\mu\text{m}$ range. The results of the air sampling confirm those encountered in the PLM results: that a very short chrysotile asbestos fiber morphology dominates over the longer asbestos fibers in the settled dust and air associated

with the collapse of the WTC Towers. No discussion on the importance of the chrysotile asbestos fiber-type in relation to the potential increase risk of developing asbestos-related cancers was presented in this report.

As growing concern resulted from the disparity between EPA's early findings and that of AIHA, a consortium of public health groups was formed consisting of the New York City Department of Health and Mental Hygiene (NYCDOHMH), the Agency for Toxic Substances and Disease Registry (ATSDR), the U.S. Public Health Service (PHS), and WTC Environmental Assessment Working Group. These groups conducted analysis of indoor and outdoor settled surface and airborne dust in residences around Ground Zero (US-EPA, 2003b). These lower Manhattan areas were compared to areas in upper Manhattan (north of 59th Street) not believed to be impacted by the September 11, 2001 collapse. These airborne and settled dust samples were subjected to analysis for a variety of analytes, including asbestos. With regard to total airborne fiber concentrations, a little more than 5% (6 of 117) of the air samples collected in lower Manhattan showed higher results when directly compared to the upper Manhattan air samples. These six samples were further analyzed via TEM which determined that asbestos did not contribute to the total airborne fiber concentrations in the lower Manhattan area. However, asbestos was detected in the settled dust samples collected from indoor residential areas in lower Manhattan, with no asbestos fibers collected in the upper Manhattan comparison areas. This finding resulted in the consortium of groups to: 1) conclude that residents should continue to clean their residences' with High Efficiency Particulate Air Filtered vacuums, and 2) recommend that further monitoring of residential areas in lower Manhattan be conducted, and to determine a NYC background concentration for asbestos.

The recommendation by the consortium of health groups to determine the background concentration for asbestos in Manhattan resulted in the US-EPA conducting a study, the results of which have been published in a report titled "World Trade Center Background Study Report, which was issued on April, 2003. Concluded therein, the US-EPA established a NYC background asbestos concentration for settled surface dust and airborne asbestos fibers. The background concentration was determined to be 6,192 s/cm² for asbestos within settled surface dust, and 0.00024 asbestos structures per milliliter (s/mL) for airborne asbestos fibers. Both the settled

surface dust and airborne concentrations for asbestos were determined by establishing a 95% upper confidence limit on the arithmetic mean of the set of samples collected. Settled surface dusts were collected from within residences, while background airborne asbestos fibers concentrations were determined from the entire data set (indoor and outdoor samples combined).

As a result of growing political concern to the mere presence of asbestos in the air at ground zero, EPA established another group of professionals entitled the “World Trade Center Indoor Air Task Force Working Group”. This group was tasked with determining the potential health issues related to Contaminants of Potential Concern (COPC) among those residing in residences in lower Manhattan. Armed with background data from the aforementioned World Trade Center Background Study, and coupled with a growing public concern that residences around ground zero have become contaminated with potentially harmful dusts, fumes, etc.; the Indoor Air Task Force sought to commence with a remedial program instead of conducting a comprehensive investigation into the true hazards regarding World Trade Center contaminants (COPCC, 2003a, 2003b).

Before the remedial program could be initiated, EPA would enact two complimentary studies to aid in the facilitation of the WTC Residential Dust Clean-up Program. These two programs entailed the previously referenced Background Study Program, where the NYC background concentrations for various chemicals were determined by a testing area in upper Manhattan, and the WTC Residential Confirmation Cleaning Study (US-EPA, 2003c) where the effectiveness of the cleaning activities to be employed by the Residential Dust Clean-up Program could be evaluated. One result of the confirmation study was the possibility of using asbestos as a testing surrogate for other contaminants of potential concern (COPCC, 2003a, 2003b). Under this possibility, the remedial action was to be considered effective in reducing or eliminating all the chemicals of potential concern following testing for the surrogate (asbestos) analyte only. The use of asbestos as a surrogate for all chemicals of potential concern was enacted following a report by NYCDOHMH and ATSDR (NYCDOHMH/ATSDR, 2002), where it was determined that using asbestos as a testing surrogate would be effective.

A report issued by McGee *et al.*, 2003 characterized the size fractionation and chemical constituents of the dusts attributed to the collapse of the World Trade Center. Concluded therein,

the authors identified calcium sulfate (gypsum) and calcium carbonate as the major components of WTC dust, and relegate asbestos to obscurity finding only one or two possible asbestos fibers in the 2.5 micron respirable dust range.

A peer review meeting of the draft document entitled “Exposure and Human Health Evaluation of Airborne Pollution from the World Trade Center Disaster” was held in July of 2003 (US-EPA, 2003a). The document characterized potential health related concerns for the general population from the outdoor World Trade Center dust, while specifically omitting the potential exposures to emergency workers and persons exposed to potential cancer causing indoor dust. A total characterization of outdoor World Trade Center dust was conducted, with particular emphasis placed on determining the concentrations of Particulate Matter (PM) in the sizes of 2.5 and 10 μ m (PM_{2.5}) & (PM₁₀), metals, poly-chlorinated biphenyls (PCBs), dioxin, polycyclic aromatic hydrocarbons (PAHs), asbestos, and volatile organic compound (VOCs). Of note was the fact that most of the aforementioned chemicals returned to background levels in months following September 11, 2001, including asbestos, a fact that was also concluded by Nolan *et al*, 2005. It was decided during this technical meeting that the AHERA standard of 70 s/mm² would not continued to be used to test the air in residences because it was not a health-based standard. Instead, the group acknowledged that a combination of the US-EPA Integrated Risk Information System (IRIS) standard coupled with TEM analysis would best protect public health. The IRIS assessment for asbestos utilizes phased contrast microscopy (PCM) to determine airborne fiber concentrations. PCM, as previously stated, is an optical form of analysis, and cannot resolve fibers shorter than 5 μ m. Additionally, PCM cannot distinguish asbestos from non-asbestos fibers, therefore TEM would be used for these analyses.

In the immediate aftermath following the destruction of the entire World Trade Center, TEM analysis of air samples was conducted. These preliminary samples were analyzed under the AHERA protocol and compared against a limit of 70 s/mm², which as stated earlier, is considered the airborne asbestos level to be achieved in order to allow re-occupancy to a work area following asbestos abatement in schools. The 70 s/mm² standard holds little significance within the historical asbestos related literature for risk assessments, and is only a practical form of measurement used in asbestos abatement. The members of the review panel voiced concern that all units expressed as

s/mm² would have to undergo conversion into s/mL, which is the exposure index for conducting risk assessments, albeit not directly equivalent to the conventional AHERA unit expressed in s/mm². The IRIS toxicity value for asbestos (all fiber types with a 3:1 aspect ratio and greater than 5µm in length) of 4x10⁻⁵ f/mL at a target population risk value of 1:100,000 was planned to be used for EPA's assessment, but due to the conversion needed to obtain acceptable risk data, no conclusions about asbestos related risk could be determined.

The most comprehensive report dealing with EPA's environmental response to the collapse World Trade Center was issued by the Office of the Inspector General of EPA on August 21, 2003. This report details the available information at hand during the incremental steps EPA made in responding to environmental concerns associated with Ground Zero. Specific actions regarding informing the public, inconsistencies with asbestos analysis immediately following the collapse, and assessing the risk of indoor environments are dealt with in detail. Again, in haste to collect data regarding potential airborne asbestos exposures, responders responsible for collecting air samples for analysis by PCM and TEM did so without a clear understanding whether this data could be used to assess asbestos-related risk. The limitations regarding PCM and AHERA's TEM data regarding the calculation of risk have been discussed earlier. EPA acknowledges the conclusion made in the Human Health Evaluation report that the 70 s/mm² criteria used for TEM analysis is not a health-based exposure benchmark, rather it was established to reflect the background fiber load on manufactured air sampling cassettes in 1987. Since that time, the background concentration on filter cassettes has been significantly reduced, but the AHERA standard has not been altered to reflect this change (US-EPA-OIG, 2003). Additionally, in an attempt to characterize the asbestos content of the settled dust, many environmental responders collected bulk samples of dust and subjected it to analysis via polarized light microscopy (PLM). Initially, PLM samples were collected to satisfy the National Emissions Standard for Hazardous Air Pollutants (NESHAPs) standard of greater than 1% asbestos to evaluate if the settled dust was a regulated material under the standard, as building owners raced to re-open their buildings for business. The NESHAPs regulation addresses the handling, packaging and disposal of an asbestos-containing waste and offers the threshold requirement that was only used by building owners and managers to determine if the more expensive, specially trained abatement workers, or their maintenance staff would clean-up WTC accumulated dust. Due to the excessive quantity of

settled dust in and around Ground Zero environmental responders collected PLM bulk samples to satisfy the NESHAP regulation to determine if the settled dust was asbestos containing, thereby subject to the packaging and disposal requirements of that standard.

This EPA response document also briefly summarized some of the TEM asbestos air data collected. According to the report, a total of four hundred ten outdoor TEM air samples were collected during the month of September, 2001 in lower Manhattan. Of those, only eleven (3%) exceeded the AHERA 70 asbestos s/mm^2 criteria. No specific mention towards the possible different asbestos fiber-types is reflected in the report. A review of the preliminary raw data sheds little light on the type of asbestos detected in the outdoor environmental samples collected. Footnote no. 11 is the only area of the report which addresses the different asbestos fiber-types observed in World Trade Center related environmental sampling. Amosite asbestos, a once common commercially available form of amphibole asbestos was reported as being contained within some pipe insulation sampled from within the Ground Zero boundary. The amosite pipe insulation was reportedly abated in April of 2002. The footnote goes on to reference that studies suggest that exposure to amphibole asbestos causes an increased risk of asbestos-related disease than does exposure to chrysotile. Additionally, the last statement in the foot note acknowledges that chrysotile asbestos was the predominant form of asbestos detected in environmental sampling conducted at Ground Zero, not amphiboles; a fact that was reiterated in a report issued on May 2004 (Landrigan *et al*, 2004).

It was at this time when various reports dealing with, among other things, asbestos air monitoring data, began to lean towards the possibility that excess risks to asbestos may not be present. An independent report published in Environmental Health Perspectives (Landrigan *et al*, 2004) further acknowledges, that for the most part, airborne asbestos concentrations of chrysotile were low, with a predominance of short ($<5\mu m$) fibers. Furthermore, two independent reports issued by the Journal of Occupational and Environmental Hygiene (Breysse *et al*, 2005 & Nolan *et al*, 2005) note the predominance of chrysotile asbestos either airborne, or present in the settled dust attributed by the collapse of the World Trade Center towers.

Breyse *et al*, conducted personal exposure monitoring on truck drivers removing steel and other construction related debris from Ground Zero. In all, thirty-three (33) PCM and forty-five (45) TEM samples (excluding overloaded samples) were collected and subjected to analysis to determine the quantity of total fibers and asbestos fibers respectively. Due to the inherent limitation of the PCM analysis discussed earlier, no determination between asbestos and non-asbestos fibers can be made. Within those forty-five (45) TEM samples collected, seventy-three asbestos structures were detected, with only one being an amphibole. The majority of the fiber sizes collected was less than 5 μm in length, and therefore less carcinogenic, leaving the authors to conclude that the truck drivers removing debris from Ground Zero are not at an increased risk of developing an asbestos-related cancer.

As detailed in Nolan *et al*, 2005, the authors conducted an asbestos-related cancer assessment comparing EPA's current aggregate asbestos cancer risk model, a model that does not differentiate between the various types of asbestos, with a risk model developed by Hodgson & Darnton 2000. As stated earlier, the Hodgson and Darnton protocol assigns differing risks based upon various asbestos fiber-types; weighing the crocidolite and amosite fractions within the amphibole group, and chrysotile differently. Mesothelioma potencies are assigned risks of 500:100:1 for crocidolite, amosite and chrysotile respectively; distinguishing a clear difference of the biological potency between chrysotile and the amphibole fiber types. The ratio of increased risk of developing lung cancer between chrysotile exposure and amphibole exposure is in the range of 1:10 and 1:50. The results of the risk assessment conducted by Nolan *et al*, show a marked difference (12 vs. 1) of an excess risk of cancer when all fiber-types are grouped together (EPA's current aggregate asbestos cancer risk model) versus characterizing the risk to chrysotile exposure alone (The Hodgson & Darnton model).

How this discussion of fiber counts and methodology relate to the clean-up efforts at Ground Zero, and with the US-EPA Residential Dust Clean-up Program

Emergency response workers (Firefighters, Police Officers, EMTs, construction workers, etc.) immediately initiated the Search & Rescue efforts following the collapse of the World Trade Center towers. These Search & Rescue efforts lasted until September 29, 2001, until the Fire Department of the City of New York (FDNY) switched the efforts to Clean-up and Recovery,

which lasted until March 30, 2002. In performing their duties, these workers often disregarded advice from OSHA, and US-EPA representatives whom requested that respiratory protection be donned (US-EPA-OIG, 2003). Without respiratory protection, potentially carcinogenic asbestos would have certainly been inhaled. Many of the very first air samples taken to document asbestos exposure in and around Ground Zero were analyzed using the PCM fiber counting method. However, due to growing public concern, and the inability of PCM to differentiate between asbestos and non-asbestos fibers, the governing agencies involved; chiefly the US-EPA, NYCDEP, and OSHA, began to collect ATEM data. These air samples were analyzed in accordance with the AHERA protocol and reported in units of s/mm^2 , a unit that based upon the previous epidemiological studies, holds little health-based risk assessment significance.

Similarly, nearby residents would have been exposed to airborne asbestos. According to the US-EPA website for the residential clean-up efforts, a direct ATEM sample preparation clearance criterion had been enacted; the PCMe method, or PCM equivalent of 0.0009 asbestos f/mL (COPC, 2003a, COPC 2003b, COPC-Addendum, 2004), US-EPA Website http://www.epa.gov/wtc/copc_study.htm. This criterion was based on the conservative assumption that continuous exposure to a constant level of airborne asbestos fibers is combined with the US-EPA IRIS Slope Factor to yield a benchmark equaling a 10^{-4} (1 in 10,000) excess lifetime cancer risk.

Background Information on Cost-Benefit Analysis

In 1981, then President Reagan through use of Executive Order 12291, required regulatory agencies to conduct impact assessments for major rules and regulations. This Executive Order required that regulatory action not be taken unless the benefits of the proposed rule or law can be shown to exceed its cost, the action chosen must produce maximum social benefit, and any alternative approaches elected must be chosen based upon the lowest net cost to society. Through the federal Office of Management and Budget (OMB), then President Clinton under Executive Order 12866 of January 11, 1996 allowed for federal agencies to conduct economic analyses prior to enacting a federal regulation or program. Following a request under the federal Freedom of Information Act (FOIA) to the USEPA (currently unanswered), to the best of my knowledge, no cost versus benefit analysis (CBA) was conducted by EPA prior to initiating the

lower Manhattan residential dust clean-up program. It is my assertion herein that if EPA would have conducted a preliminary CBA, their findings would have been comparable with my working hypothesis, specifically, that from an asbestos-related health hazard point-of-view, the costs associated with conducting the lower Manhattan Residential Dust clean-up program exceeds its benefits. Several responses to various FOIA requests are included in **Appendix A**.

Under Executive Order 12866, the OMB provides general principles for conducting a CBA based upon “best practices”. These principals have been further elaborated upon by Cass Sunstein (Sunstein, 2001), unless clearly stated otherwise, federal agencies can:

1. Be permitted to make de minimus exemptions to a statutory requirement by exempting small risks;
2. Be permitted to balance health risks created by a regulation against its health benefits;
3. Be permitted to take the resulting costs and benefits into account when deciding to issue a regulation or program;
4. Be permitted to decline to regulate past a point where the regulation becomes economically or technologically infeasible to continue; and
5. Be expected to balance cost against benefits in issuing regulations.

The difficulty rises in answering, how to best monetize the societal benefit¹ of EPA’s residential dust clean-up program. Several methods for evaluating these benefits have been published, and can be considered as an individual's willingness-to-pay for a reduction in an adverse health outcome. The most widely used methods include: Cost of Illness (COI), Contingent Valuation (CV), and Averting Behavior (AB) methods, (Dickie & Gerking, 2002). The CV method involves obtaining individual valuation preferences to a hypothetical commodity through the use of a survey or questionnaire (Dickie & Gerking, (2002). The AB method links an individual's willingness-to-pay with specific actions aimed at reducing or eliminating and adverse health outcome. As both the CV and AB methods involve the use of surveys to collect individual preference data, they will not be used in this research. The COI method measures direct and

¹ The calculated benefits do not account for the possibility that property values in lower Manhattan may have increased due to the availability of US-EPA funds used for clean-up purposes.

indirect values of morbidity based on the cost of medical treatment for disease. Therefore, the social benefit of the USEPA's Residential Dust Clean-up program would be the price of averting; 1) asbestos-related cancer medical costs, 2) the costs of cancer-related morbidity (including pain & suffering and loss-of-work time), and 3) premature asbestos-related cancer deaths based on a Value of a Statistical Life, for the residents of lower Manhattan.

Cancer-Related Medical Costs

The mean net cost for lung cancer care as been estimated at \$35,672 per patient for the initial 12 month period following diagnoses, \$51,759 per patient for the last year of life, and \$3,926 for each continuing year between the initial diagnoses and last year of life (Yabroff *et al*, 2008). The estimates above are listed in 2004 dollars. Although the average life expectancy for a lung cancer patient depends on age, general health, the patient's tolerance to treatment, and how advanced the cancer is at the time of diagnosis, in conducting the CBA, an average life expectancy of five years has been used. Therefore, a five year, per patient, total cost aversion of \$99,209 was used.

The Cost of Cancer-Related Morbidity

The direct medical costs related to lung cancer listed above are only a portion of society's benefit for aversion. Indirect morbidity costs, such as averting loss-of-work time, and pain and suffering, which includes psychological effects, will also add to the societal benefit regarding US-EPA's electing to perform the Residential Dust Clean-up Program. The psychological effects of dealing with cancer have been shown to increase a patient's suffering (Saarino *et al*, 2011, Lethborg *et al*, 2007). Specifically, vulnerable societal influences and situations for patients have increased their suffering. Lethborg, 2007 believes that psychological distress is influenced by the physical distress of the cancer and treatments, the patient's coping style, availability of social support groups, and existential effects. The loss of life, and fear for loved ones who may have been in, or near, the collapsing towers aside, the fear for one's health from the resulting WTC debris and contamination is considered what Lethborg would consider existential effects, with 7.6 % of a mental health survey respondents reporting use of mental health services and 7.7% using psychiatric mediations within 30 days following the September 11th disaster

(Boscarino *et al*, 2004). Therefore, the avoidance of pain and suffering include a psychological stress avoidance component have been used as a societal benefit for US-EPA's Residential Dust Clean-up Program.

Monetizing loss-of-work time due to lung cancer has been estimated by Chang *et al*, (2004) at \$698 per month for cancer patients. These costs account for the higher absenteeism of the cancer patients and caregiver, and insurance deductibles and copayments. Although monetizing the indirect costs of loss-of-work time, have more tangible data behind them, monetizing pain and suffering does not. The available literature relating to monetizing pain and suffering resides in court related documents where juries determine the value of pain and suffering on a case-by-case basis. Approximately 50% of total awards in court cases involve pain and suffering due to personal injury (Avraham, 2006). Pain and suffering damages within the United States are addressed through tort law, where someone's actions or behavior have caused another some form of harm. However, predicting pain and suffering damages is more problematic as damages may be valued differently between victims. For example, knee or ankle related injuries will be valued higher for a professional distance runner, say, than for an office employee who may remain sedentary for the greater lengths of time during each day. Offering a method for use in tort law, Avraham suggests using a multiplier based on medical costs claiming that "linking the pain-and-suffering damages to the victim's health costs is the best approximation of the social nonmonetary costs of the defendant" (Avraham, 2006). This approach assumes that similar injuries would incur similar medical costs, and that higher medical costs would reflect a more serious injury resulting in greater compensation. This method, therefore, does not address how different victims may value their personal damages. Avraham does not offer binding multipliers for issuing pain and suffering damages, however, for this research, pain and suffering benefits have been calculated at twice the cost of averted medical costs.

The Cost of Premature Asbestos-Related Cancer Deaths

How much is a human life worth? Any cost attributed to the saving, or more accurately stated, the extending of a human life, as any regulation will not truly save, but only extend a human life, can be argued based on personal preference; Individuals make preference choices every day,

whether it is to purchase a more expensive automobile equipped with greater safety features, or a decision to start or restart smoking even in light of a large body of evidence linking the development of lung cancer to cigarette smoking. Persons skeptical of using a monetary value for a human life benefit associated with an environmental regulation or program often cite the appropriateness of such a valuation arguing how economists can “put a price tag on a human life?” Farrow and Toman (1998) have argued that economists engaged in assessing the reduction in a reduced mortality risk are not engaged in true monetary valuation of a human life, but are simply trying to determine what an individual is willingness-to-pay (WTP) in order to obtain a reduction in mortality risk. My intention is not to enter into this realm of debate, but utilize EPA’s current WTP estimates for the value of a statistical life (VSL) as a basis for the CBA portion of this research.

Current VSL estimates used by EPA value a human life at \$9.1 million (Sinha, *et al.*, 2010). The federal government has valued a statistical life under several instances which fall in the range of \$1.5 million in 1990 to \$9.1 million in 2008 (see summary in Sunstein 2001; Sinha, *et al.*, 2010). **Table 3** (adapted from Sunstein, 2001) includes a list of monetized statistical life valuations adjusted to year 2000 dollars for comparison with current data. Monetizing the costs of future benefits with current costs of the residential dust clean-up program require the discounting of the future benefits into present values. Discounting can be considered as the reverse of compounding interest on an investment. Where an investment of one dollar today, under 3% compounding interest, is worth \$1.03 in one year and \$1.06 in two years. Alternatively, one dollar received two years from now under a 3% discount rate is worth \$0.97 one year from now, and \$0.94 today. The choice of discount rate can have a profound effect on the values of the project, therefore the overall results of this CBA. The USEPA-OMB proposes a “default” discount rate of 7% (Sunstein, 2001, 2004; Farrow & Toman, 1998), but circumstances may require a discount rate other than 7%. In fact, the US-EPA has used different discount rates depending on the contaminant studied. US-EPA used 0% for a latent harm of cancer from arsenic to 7% with regard to drinking water, where the harms would have been more immediate (Farrow and Toman, 1998). While utilizing a 0% discount rate doesn’t seem appropriate when dealing with the 30 year latent harm from asbestos exposure, it has been argued by Sunstein (2001) that a 3% discount rate for latent harms would be appropriate.

The future benefits associated with current asbestos exposure monetized thirty years in the future can be discounted to present values utilizing the following formula:

$$PV = FV / (1+i)^n$$

Where;

PV = Present Value of the monetized item;

FV = Future Value of the monetized item;

i = the discount rate; and

n = number of iterations (years) used in the calculation.

Therefore, it would follow that the present value of one dollar received thirty years from now using a 3% discount rate would be worth: $PV = 1 / (1+0.03)^{30}$ or \$0.03 today. Similarly, \$5.1 million per person received thirty years from now discounted at 3% would be worth \$2,101,132 per person today. For this research a VSL of \$5,800,00 was used representing an US-EPA value of \$7,400,000 discounted to 2000 dollars. Additionally, a shadow price of \$4,400,000 was used representing the average monetized statistical life valuations adjusted to year 2000 dollars listed in **Table 3**.

Considerable debate pertaining to choosing an appropriate discount rate is present throughout the economic literature. As an example, Kasting *et al*, (1996) argue with the assertion of Arrow *et al*, (1996) that the "...same range of discount rates should be used in all regulatory analysis". Instead, the authors would have liked to have seen an appropriate discount rate of future benefits that takes future generations into account, arguing for a zero discount rate claiming that future generations have as much right to environmental benefits and healthcare as current generations. In response, Arrow *et al*, state, "...that an appropriate discount rate will depend on the rate at which individuals are willing to trade off present for future consumption" (1996). Justifying a zero discount rate would therefore seem difficult under the economic theory of individual time preference. Time preference studies show that individuals would rather receive \$100 today rather than \$110 tomorrow. This phenomenon, which will not be explored as part of my research, has been referred to as the time preference reversal phenomenon, and is inconsistent

with traditional discounting models (Grether & Plott, 1979). Therefore, this research will be based on a social discount rate of 3%.

METHODS

Hazard Characterization

As previously reported in the draft document entitled “Exposure and Human Health Evaluation of Airborne Pollution from the World Trade Center Disaster” (EPA, 2003). A total characterization of outdoor World Trade Center dust was conducted, with particular emphasis placed on determining the concentrations of PM_{2.5} & PM₁₀, metals, poly-chlorinated biphenyls (PCBs), dioxin, polycyclic aromatic hydrocarbons (PAHs), asbestos, and volatile organic compound (VOCs). While the main thrust of this dissertation will not account for all of the chemicals of potential concern established by EPA within the settled dust resulting from the collapse of the World Trade Center towers, nor the synergistic effect that may result from the combined effect of all the COPCs, the mere documented presence of asbestos had the media, public, and regulatory agencies categorizing World Trade Center dust as a hazard.

Risk Assessment Models

The following models incorporate cumulative dose and reasonable assumptions on the basis of available exposure information to emergency workers and residents in the lower Manhattan area, using linear, non-threshold risk models for lung cancer in order to calculate estimates of risks. The overall cancer risk was calculated by assuming that all individuals are exposed to an arithmetic mean average exposure. This average was used in risk models for lung cancer and mesothelioma to compute overall population risks for emergency workers and lower Manhattan residents. The equation below was used to estimate risk of developing Lung Cancer. The risk of lung cancer increases linearly with cumulative asbestos exposure (HEI, 1991, Hodgson & Darnton, 2000, Nolan *et al*, 2005)

$$\text{Obs}_L = \text{Exp}_L + (\text{R}_L \times \text{E}_{CA} \times \text{Exp}_L / 100)$$

Where,

Obs_L was the calculated increased number of lung cancers caused by chrysotile asbestos,

- Exp_L was the expected number of background lung cancer deaths, (equals 1 and includes smoking habits)
- E_{CA} was the cumulative exposure to chrysotile asbestos. This was assumed to be a continuous occupational exposure to chrysotile asbestos as referenced in the available air data.
- R_L is the risk of lung cancer expressed as percentage of lung cancer deaths. Modern studies utilized a R_L of 0.062 (Nolan *et al*, 2005, Hodgson and Darnton, 2000).

Validity of the Lung Cancer Model

The model for determining asbestos exposure risk is valid under the following assumptions:

1. Independent of age at the time of exposure;
2. Independent of time since stopping exposure;
3. Proportional to duration of exposure; and
4. Proportional to average level of exposure for a given duration.

The equation below was used to estimate the life-time mesothelioma risk to lower Manhattan residents from asbestos exposure following the collapse of the World Trade Center. The number of asbestos-related mesothelioma was calculated via the following equation (Nolan *et al*, 2005).

$$I_M(t) = (R_M \times E_{CA} \times T_{POP}) / 100$$

Where,

- I_M(t) is the incidence of asbestos-related mesothelioma calculated at time (t)
- R_M is the risk of mesothelioma expressed as a percentage of expected mortality (0.001)
- E_{CA} is the cumulative exposure to chrysotile asbestos. This is assumed to be a continuous occupational exposure to chrysotile asbestos as referenced in the available air data.
- T_{POP} is the total exposed population of Lower Manhattan, based on 2000 census data.

These assessments are “best estimates” in that no direct evidence exists that they are too high or too low (HEI-AR 1991). These estimates were used to generate exposure risks to airborne asbestos, and can be reported in number of excess cancer deaths greater than background (Nolan *et al*, 2005).

Exposure Assessment

The exposure assessment assumes that the residents of lower Manhattan have been exposed to asbestos following the World Trade Center collapse. Census data pertaining to individuals

residing in lower Manhattan, average family size, and the general demographics of the lower Manhattan area have been used in conjunction with available testing data to depict potential exposure.

Cost Benefit Analysis

In conducting this research, a cost-benefit analysis (CBA) was also employed. CBA is a tool used to compare desirable and undesirable impacts by proposed policies or regulations (Mazurek, 1996). Specifically, it's a technique to improve the quality of public policy decision making, using a monetary value of change in individual well-being resulting from the policy decision (Kopp *et al*, 1997). Unfortunately, individual well-being is a subjective term and is assumed to contain personal lifestyle preferences and a willingness, or not, to accept risk. In this case, a perceived increased risk due to asbestos exposure, where public fear of exposure to concentrations of airborne asbestos from the collapse of the towers was prominent in the media. Cost versus benefit analysis was employed to test the necessity for the US-EPA Residential asbestos Dust Clean-up Program especially in light of US-EPA's use of asbestos testing as a surrogate for the effectiveness of the clean-up. The majority of the preliminary data shows that asbestos structures (fiber equivalents) $>5\mu\text{m}$ in length were not detected in 98% of the air samples collected. The remaining 2% of air sample collected suggest that airborne asbestos levels were comprised of short ($<5\mu\text{m}$ in length) chrysotile fibers, that arguably may not even be biologically active (Berman & Crump, 2003). Yet an enormous amount of resources was filtered into the program where the reduction of risk related to asbestos exposure for those residing in lower Manhattan was minimal. The CBA conducted as part of this research indicates that, from an asbestos exposure standpoint, the resources used in conducting the US-EPA Residential Dust Clean-up Program had very little benefit. The justification the US-EPA used for the initial cleaning program appears to be limited and may have been impart driven by US-EPA's inability to convey to the public that the risk of contracting an asbestos-related disease was actually very low. It can be argued that US-EPA's decision to conduct this testing in residences results from the White Paper on lower Manhattan air quality prepared by U.S Congressman Jerrold Nadler (Nadler, 2002), and the work of *The WTC Community-Labor Coalition*, (WTC Community-Labor Coalition, 2005), a well-organized public interest group arguing that EPA has been covering the true cancer risks associated with the potential environmental impacts due to the

collapse of the World Trade Center Towers when, in fact, aside from post traumatic stress disorder (PTSD), these risks appear to be minimal (WTC Health Registry, 2011).

Costs associated with the US-EPA residential dust clean-up program have been determined to be the sum of all costs to the various environmental remediation and third-party air monitoring contractors utilized in each of the four quadrants, the cost of the analytical laboratories responsible for conducting analysis of the air monitoring samples collected as part of the clean-up program, and the cost of Federal Emergency Management Agency (FEMA) purchasing specialized equipment (i.e.: high efficiency filtered vacuums and air purifiers) to be provided to qualified residents.

The benefits of conducting the US-EPA residential dust clean-up program have been determined to be the social benefit of reducing the risk of asbestos exposure by conducting the clean-up program. As stated earlier, the social benefit of the US-EPA conducting the Residential Dust Clean-up program will be the price of averting; 1) asbestos-related cancer medical costs, 2) the costs of cancer-related morbidity (including pain & suffering and loss-of-work time), and 3) premature asbestos-related cancer deaths based on a Value of a Statistical Life, for the residents of lower Manhattan.

This research was based on factual public concern about the US-EPA's inability to accurately disseminate asbestos-related information to the public, and that methods based strictly on willingness-to-pay assumptions would not hold true. Public fear of exposure to concentrations of airborne asbestos from the collapse of the towers was prominent in the media and well documented in public comment meetings regarding EPA's release of their 2001 draft report entitled *Exposure and Human Health Valuation of Airborne Pollution from the World Trade Center Disaster*, where greater than 1,300 pages of concerns from various residents, interest groups, college professors, environmental consultants, and public officials regarding EPA's handling of the disaster, and their assessments of testing and cleaning are questioned. Therefore, this researcher conducted the CBA valuing the reduction in asbestos-related risks avoided by having professional remedial contractors, with oversight from environmental consultants, conduct residential dust cleaning against the total cost of the Residential Dust Clean-up Program. This method includes limited personal preference information from the COI WTP approach as

individuals have not been surveyed about their willingness to pay for an illness aversion. Instead, the social benefits to the residents of Lower Manhattan have been monetized based on the aversion of a cancer related cost from exposure to WTC dust. It must be pointed out that this research includes, by default, limited personal preference data, as residents who elected to participate in the residential dust clean-up program chose to enroll. Residents were made aware that a requirement for cleaning their residence was to include vacating the dwelling until the clean-up activities were complete. A concern regarding this approach pertains to the fact that it tends to underestimate the benefit of the investment in a reduced risk (Sunstein, 2001). When individuals avoid contracting asbestos-related diseases, their benefits are certainly greater than the value of a statistical life alone, as there is undoubtedly a benefit in psychological stresses avoided.

In conducting this cost versus benefit analysis, the social benefits are the sum of avoiding cancer-related medical costs; a reduction of lung cancer related morbidity, including loss-of-work time, and pain and suffering; and the health valuation received through the elimination of mortality interpreted from the number of lives saved. The resulting figure is not the cost of conducting the residential clean-up program, but the change in welfare based on the potential risk of mortality reduction by conducting the clean-up program versus not conducting the clean-up program.

The CBA consisted of the following:

1. Discounting of the real social benefit costs at a rate of 3% per year was used for this CBA. The rationale that drove this discounting of costs stems from the perspective that the government would have invested the money used for the WTC Residential Dust Clean-up Program into other opportunities. The argument is that the government would have received a return on the funds invested into the EPA residential dust clean-up Program at least equivalent to what the money would earn if left alone, or invested in other opportunities. This 3% rate is a standard rate for discounting social benefits supported by the Office of Management and Budget, (Kopp *et al*, 1997). This is a nominal discount rate as the future benefits of averting an asbestos-related disease have been discounted without first accounting for inflation.

2. Analysis of the distribution of the benefits, the referent group analysis shows sensitive populations in lower Manhattan, therefore, the social value of the data.
3. A sensitivity analysis that determines if the CBA result is sensitive to small changes in parameter values. A change in the real discount of the social benefit rate from 3% to 6%.
4. A determination regarding whether the clean-up program was justified. The completed CBA has been compared against the asbestos risk assessment in order to determine if the cost of conducting the clean-up program was warranted.

Conducting a cost versus benefit analysis of this nature is not without its limitations. First, the method employed to monetize benefits used average estimated values for the medical costs of lung cancer treatment, the reduction of treating cancer related morbidity, including avoiding psychological stresses, and the costs of averting a cancer-related deaths. It is unknown if these methods overestimate, or underestimated the value for the reduction of the asbestos-related risk. The social and psychological benefits of environmental protection are difficult to monetize, and will always be subject to criticism, especially from well organized residents and public interest groups that may not agree with the finding of this research. Lastly, the ethical considerations about the fairness to future generations have not been taken into account as the total benefits to the current population of lower Manhattan has been argued herein to be negligible, therefore, virtually absent from future generations.

DATA

A summary of this data, separated by the federal, state and city agency that directed this sampling is below. The total number of air sampling results is too numerous to place in tabularized form. However, **Table No. 4** was prepared to summarize the results that represent exposure concentrations to the workers at Ground Zero and the nearby residential population.

Preliminary Federal (OSHA & US-EPA)

The earliest air sample data pursuant to the collapse of the WTC was collected by OSHA. In the period representing September 13, 2001 through September 21, 2001, a total of 191 ambient and personal air samples were collected and analyzed by phase contrast microscopy. Insufficient data exists for four of the 191 (2.1%) sample results these remaining air samples were designed to represent total airborne fiber exposure to the various recovery and rescue personnel working on or near the debris pile at ground zero. Seven of these samples were collected indoors with two being additionally analyzed via ATEM analysis. Three of the seven were personal air samples with the remaining four being ambient air samples. One of the three personal air sample results returned a result greater than 0.01 f/mL (0.023 f/mL), which triggered analysis by ATEM. The ATEM analysis of those fibers observed by PCM did not confirm the presence of asbestos. Of the remaining four ambient samples collected in the same period, two were greater than 0.01 f/mL, however, the larger result of the two (0.069 f/mL) was additionally analyzed by ATEM. The ATEM results of this sample confirmed airborne asbestos fiber concentrations of 0.015 asbestos fibers per milliliter (f/mL).

One hundred seventy-eight (178) PCM samples were collected outdoors on September 15, 2001, with twenty-five (14%) of those samples additionally analyzed by ATEM. 51 of the 178 outdoor samples collected were ambient air samples with the remaining samples representing personal air samples. The outdoor ambient air sample showing the highest result was 0.034 f/mL. All of the outdoor ambient air samples were analyzed by PCM which count total fibers that meet the 3:1 aspect ratio. Outdoor personal air sample results range from none detected to 0.105 f/mL, which triggered 25 of them to be further analyzed by ATEM. The ATEM data for the outdoor personal

air samples detected asbestos in 3 of the 25 (12%). These ranged in concentration from 0.012 to 0.017 f/mL.

OSHA data also exists for the period of September 23, 2001 through April 3, 2002. In all, 548 ambient and 664 personal air samples were collected. The data is not clear as to whether they represent indoor or outdoor environments; we will assume that the majority of the data represents the outdoor environment. All but 4 of the 548 (0.7%) ambient air samples were less than 0.01 f/mL, with the elevated concentrations ranging from 0.011 f/mL to 0.028 f/mL. All but 22 of the 664 (3.3%) personal air samples were less than 0.01 f/mL, with the results ranging from 0.01 to 0.073 f/mL.

The earliest US-EPA data following the collapse of the WTC was collected during the period of September 14 to 15, 2001. In total, sixteen air samples were collected from the downtown area and analyzed using the ATEM/AHERA methodology. Seven of these samples were not analyzed due to overloading of particulate which obscures fiber determination. Six of the remaining nine air samples detected the presence of airborne asbestos, with two samples confirming greater than 70 s/mm². These two samples were located at the corner of Barclay Street and West Broadway.

US-EPA PCM air sample data exists for the period representing September 22 through 24, 2001. In total, 42 air samples were collected from various locations in the five boroughs, with all samples returning results below 0.01 f/mL.

US-EPA air samples were also collected on September 24, 2001 in lower Manhattan. Sixteen samples were collected and analyzed using the ATEM/AHERA methodology. Four of the 16 air samples detected the presence of airborne asbestos, with none greater than 70 s/mm².

Twenty-one ambient air samples were collected from the Freshkills landfill on Staten Island and analyzed using PCM and the NIOSH 7400 methodology, and ATEM using the NIOSH 7402 and AHERA methodology. These samples were collected from September 23 through 24, 2001. Two of these samples detected the presence of airborne asbestos, but in concentrations less than

0.01 f/mL and 70 s/mm² for the NIOSH and AHERA method respectively. Exact written descriptions with regard to the locations of the samples was not provided.

The US-EPA collected ambient air samples at various locations in New Jersey from period September 22-24, 2001. In total, twelve (12) ambient samples were collected and analyzed using PCM and the NIOSH 7400 methodology, and ATEM following the NIOSH 7402 and AHERA methodology. Airborne asbestos was detected in only one air sample, the concentration less than 0.01 f/mL and 70 s/mm² for the NIOSH and AHERA method respectively.

Preliminary New York State (NYSDEC & PESH)

Ambient air samples were collected by the NYS Department of Environmental Conservation and analyzed by the NYS Department of Health for the period representing September 15, 2001 through October 12, 2001. These air samples were collected from two locations throughout the sampling period; the roof level of the Canal Street Post Office and at street level of a location identified as Madison Avenue. Keep in mind that the southern portion of Madison Avenue starts at a point approximately 2.5 miles from the WTC site. In total, 86 air samples were collected from these two locations, and analyzed using the ATEM/AHERA methodology. No asbestos was detected in all 45 of the air samples collected from the roof of the Canal Street Post Office.

Three of the 41 samples collected at the street level of Madison Avenue detected airborne asbestos, however, two were reported at a concentration of 0.004 asbestos s/mL, while the third was reported at 0.01 asbestos s/mL.

The NYS Public Employee Safety & Health (PESH) Program collected asbestos air samples during four separate occasions: the period of November 25 - 29, 2001, on December 18, 2001, on January 10, 2002, and the period of March 12 through April 20, 2002. For the period ending November 29, 2001, six personal air samples were collected and analyzed using the NIOSH 7400 methodology, which counts total fibers that meet a 3:1 aspect ratio and are 5µm or greater in length. All six samples returned results greater than 0.01 f/mL, but less than 0.1 f/mL. This may have been the result of collecting an insufficient volume of air to achieve an analytical

sensitivity less than 0.1 f/mL, but the data does not provide information of each air sample volume.

On December 18, 2001, three additional personal air samples were collected and analyzed via NIOSH 7400. Two of these samples returned results greater than 0.01 f/mL, but less than 0.1 f/mL, again, perhaps a result of analytical sensitivity, with the remaining sample reported as being overloaded.

On January 30, 2002 a total of 2 personal air samples were collected by NYS PESH and analyzed via NIOSH 7400. The results of the two personal air samples were greater than 0.01 f/mL, but less than 0.1 f/mL.

The final period of sampling conducted by PESH ranges from March 12, 2002 through April 20, 2002 in which a total of 23 air samples (8 ambient samples and 15 personal samples) were collected and analyzed using PCM and the NIOSH 7400 methodology. The results of all eight of the ambient samples were reported as “not detected”, however, fourteen of the fifteen personal samples were equal to or greater than 0.014 f/mL, but less than 0.1 f/mL. Only one personal sample was reported as being “not detected”.

Preliminary Local (NYCSCA and NYCDEP)

The New York City School Construction Authority (NYCSCA) collected asbestos related air samples during the period of September 13-18, 2001. In total, 134 air samples (45 ambient air samples, 80 low volume air samples with calculated 8-hour TWA's, and 9 thirty minute short duration excursion samples) were collected and analyzed using PCM. Thirty nine of the forty-five ambient air samples were reported greater than 0.01 f/mL. Five of the eighty (6.25%) calculated 8-hour TWA's were greater than 0.1 f/mL, and zero of the nine low volume short duration samples were greater than 0.1 f/mL. A total of seven low-volume, short duration air samples exceeded 0.1 f/mL.

On September 15, 2001, NYCSCA also collected additional air samples and analyzed them for airborne asbestos using ATEM using the AHERA methodology. In total fifteen (15) samples were collected, of which nine (9) or 60% exceeded 70 s/mm².

The period of NYCDEP asbestos air sampling, mostly from NYC schools, ranges from September 14, 2001 through June 27, 2002. The results are separated by Manhattan and Outer-borough schools. Air sampling was conducted from four Manhattan-based schools: the High School for Economics and Finance located at 100 Trinity Place, Public School 234 located at 282 Greenwich Street, Stuyvesant High School located at 345 Chambers Street, and Intermediate School 89 located at 201 Warren Street. In total, forty-eight PCM air samples were collected from all four schools from October 4 through the 15, 2001, with all but one sample returning total fiber concentrations below 0.01 f/mL with a single sample from this series at 0.018 f/mL. This sample was further analyzed via TEM and the result reported as 40 s/mm². Additionally, for the period representing, October 16, 2001 through November 1, 2001, 69 air samples were analyzed via ATEM/AHERA. With regard to the ATEM data, two air samples returned results detecting 40 s/mm². The first sample was collected at Stuyvesant High School on October 7, 2001, and the second was collected at the High School for Economics and Finance on October 27, 2001.

The next period of sampling was conducted from October 19, 2001 through June 27, 2002 from the same Manhattan-based schools. In total, one thousand eight air samples were collected and analyzed using ATEM /AHERA. All air samples collected were reported as less than 70 s/mm², except for one sample, which was reported as overloaded.

The Outer-borough schools asbestos air samples were conducted from September 14 to October 16, 2001 in the following schools: Public School 314 located at 330 59th Street, Brooklyn; Intermediate School 155 located at Jackson Avenue and East 148th Street, Bronx; Public School 64 located at 600 East 6th Street, Manhattan; Public School 199 located at 30-20 48th Street, Queens; and Susan Wagner High School located at 1200 Manor Road, Staten Island. In total, four hundred seventy-three samples were collected, and analyzed by PCM. All PCM results were less than 0.01 f/mL. Additionally, six ATEM samples were collected from Public School

64 and analyzed using ATEM using the AHERA methodology. All six ATEM air samples were reported at less than 20 s/mm².

Residential Exposures

Air data representing the residential exposures using stationary high-volume sampling devices was obtained through a link at the USEPA web-site to the Columbia University Mailman School of Public Health. These data represent approximately 10,500 individual high-volume asbestos air monitoring results from September 14, 2001 through June 20, 2002. These high-volume monitoring samples were analyzed via ATEM with results expressed in fibers/mL, asbestos structures/mm², asbestos structures equivalent to fibers (s~f)/mL, asbestos structures less than 5 microns in length (<5µm), and asbestos structures greater than 5 microns or greater in length (5>µm).

In all of the above referenced asbestos air concentration data, the following conversions from asbestos structures per square millimeter (s/mm²) to asbestos fibers per milliliter (f/mL) were calculated with the following assumptions:

Assumption #1 – “Fibers” are equivalent to “structures”;

Assumption #2 – In the absence of data, sample volumes were 1,250 liters;

Assumption #3 – Samples collected on industry standard 25mm cassettes with an effective counting area of 385 mm².

$$\text{Conversion Result} = \frac{[\text{ATEM Result } (\frac{s}{mm^2})] [385 mm^2]}{\text{Volume (mL)}}$$

$$\text{Conversion Result} = \frac{[\text{ATEM Result } (\frac{s}{mm^2})] [385 mm^2]}{1,250,000 mL}$$

$$\text{Conversion Result } (\frac{s}{mL}) = [\text{ATEM Result}] (0.00031)$$

Therefore, all ATEM sample results reported in s/mm² were multiplied by 0.00031 to convert them into an equivalent s/mL unit of concentration.

RESULTS AND DISCUSSION

The asbestos sampling data was separated into three categories: 1) Preliminary emergency response data that includes PCM and TEM measurements on the same filters representing occupational exposures (personal air sampling), and environmental exposures (ambient air sampling) conducted during the search & rescue operations at Ground Zero; 2) Both PCM and TEM measurements on the same filters representing occupational exposures (personal air sampling), and environmental exposures (ambient air sampling) conducted during the clean-up and recovery operations at Ground Zero; and 3) High volume ambient asbestos air samples collected in fixed locations representative of environmental residential exposures (**Table 4a**).

Hazard Characterization

Asbestos Containing Material used in the Construction of the WTC

The properties of asbestos - high tensile strength, thermal and chemical stability, and the low cost of processing resulted in minerals such as chrysotile asbestos, being widely used in building construction, predominantly as thermal insulation and a fiber reinforcer. In the case of the buildings of the WTC complex, asbestos was used as spray-applied fireproofing on the structural steel members, and within the vinyl asbestos floor tiles (VAT) (Langer & Morse 2001).

The construction of the World Trade Center complex began with ground breaking in March of 1966 (Langer & Morse 2001). By the spring of 1972, the construction of both towers in the complex was substantially complete. However, because of growing concern about asbestos-related diseases, the use of sprayed asbestos-containing fireproofing was not uniform within the complex (Langer & Morse 2001). Its use was reported in the first thirty-eight (38) floors of the north tower (Tower 1, or Tower A), within the high speed elevators shafts from the concourse to the 44th and 78th floor Sky-Lobbies of both towers, within mechanical equipment rooms and the floors below each of these rooms in both towers, and in portions of the ceilings of the 32nd and 33rd floors of Tower 2 (Port Authority of New York and New Jersey (PANYNJ), 1988, as reviewed in Langer & Morse, 2001).

In addition, chrysotile asbestos was used in the manufacturing of VAT, used primarily throughout the complex within vinyl flooring (PANYNJ 1988, as reviewed in Langer & Morse, 2001). Following the collapse of the World Trade Center complex these asbestos materials undoubtedly became a component of the dust cloud and plume of smoke emanating from Ground Zero, which were transported to residential and commercial areas.

The hazard characterization involved linking asbestos to an environmental affect, which in this case was the dust cloud that emanated from the collapse of the World Trade Center towers. A similar approach was conducted by Nolan *et al*, 2005. Described herein, several documents establish that asbestos has been determined to exist within both World Trade Center towers prior to its collapse, and within the settled dust and ambient air around “Ground Zero” following the collapse of the World Trade Center Towers. In conducting the hazard characterization; sampling size, the analyte sampled, and the duration of the sampling was studied to justify a causal link.

Visual observations following the collapse of the World Trade Center Towers confirmed that a thick gray cloud of dust emanated from the physical forces produced by the collapsing structures. Accumulations of this dust has been determined to be visible in portions of Lower Manhattan, Brooklyn and beyond (Landrigan *et al*, 2004) resulting in significant media coverage as to the potential health consequences from breathing air laden with this WTC dust. Analytical research confirmed that the dust was comprised of silica from the pulverized cement, fiberglass, asbestos, lead, polycyclic aromatic hydrocarbons, (PAHs), poly chlorinated biphenyls (PCBs), pesticides, dioxins, furans, volatile organic compounds (VOCs), and semi-volatile organic compounds (SVOCs) (COPCC, 2003; Lioy, 2002). US-EPA all but established a chemical signature of the constituents of WTC derived the dust to include six agents of potential concern: Asbestos, Lead, Man-made vitreous fibers (fiberglass), Dioxin, PAH, and Silica (COPCC, 2003; Lioy, 2002). However, as stated earlier, the intent of this thesis is not to undertake a complete hazard analysis and risk assessment for all chemicals of potential concern. Rather this research is aimed at analyzing whether the costs incurred by US-EPA for conducting the residential dust clean-up program, from purely an asbestos exposure standpoint exceed their benefits. The preliminary asbestos exposure air data would suggest that these costs do, in fact, exceed their benefits as the preponderance of chrysotile, and not amphibole, asbestos is reflected in the air data.

Exposure Assessment

Table 4b lists the exposures for each group using the arithmetic mean and worst case readings; and environmental versus occupational exposures as discussed in detail below.

The above referenced preliminary air data has been examined, and synthesized into three main potential exposure groups: an 18-day exposure group for emergency workers that conducted Search & Rescue activities, and who arrived onsite on September 12, 2001, the day following the collapse of the WTC as the National Guard slowly allowed additional workers around Ground Zero which formally ended on September 29, 2001; a 182-day exposure group for Clean-up and Recovery workers, which formally ended on March 30, 2002; and a 280-day potential residential exposure group which is based solely upon high-volume ambient air sample data collected from September 14, 2001 and ended on June 20, 2002. Separate exposures for the 18-day group of emergency workers, and the 182-day clean-up and recovery workers were calculated based the availability of low-volume, personal air sampling and ambient, high-volume sampling at fixed locations conducted by various agencies.

Personal air sampling was conducted through the use of a low-volume personal air sampler worn by the worker. The air sampling cassette/filter attached to the sampling pump was attached to the workers clothing and representative of their personal breathing zone. This low-volume form of sampling is representative of a worker's occupational exposures to asbestos. Occupational exposures are defined as 8-hour per day working exposure over 250 work days per year. The main objective of OSHA since its inception in 1971 is to protect workers. Understanding that a workers cumulative exposure for an eight-hour work-day may constitute high concentrations of asbestos over a short duration and low concentrations over a longer duration, OSHA's eight-hour TWA is therefore calculated using both short and longer duration personal air sampling results. The OSHA TWA, in f/mL, is calculated using the following formula:

$$[(C_1 * T_1) + (C_2 * T_2) \dots + (C_n * T_n)] / 480$$

where,

C_n = Airborne fiber concentration for a given air sample in f/mL,

T_n = Duration of time for a given air sample in minutes,
480 = Total minutes worked in a standard 8-hour work day.

The high-volume ambient air sampling is representative of environmental exposures. These exposures are calculated differently than occupational exposures and based on the duration of exposure. Environmental exposures are continuous 24 hour exposures for 365 days per year. The calculations for the occupational exposures versus the environmental exposures for the available Ground Zero data are discussed below.

Potential residential exposures were calculated using available ambient, high volume air sample data collected at fixed locations near Ground Zero regardless of whether it was collected during the Search & Rescue, or Clean-up & Recovery phase of the remediation. For each exposure group, the cumulative exposure assessment has been calculated using the arithmetic mean exposure, and the worst-case environmental exposure using the highest air sample result collected from that particular exposure group. Results have been expressed in units of asbestos fibers per milliliter (af/mL) of air to make the distinction that asbestos fibers have been determined. This approach is similar to a previous World Trade Center collapse asbestos-related exposure conducted by Nolan *et al*, (2005).

Environmental Versus Occupational Exposures

The previous asbestos-related disease and exposure studies discussed in the preceding chapters, and the resulting risk assessment models have been developed based on occupational exposures. The environmental exposures calculated above will therefore need to be converted into their occupational equivalent for use in these models. Environmental exposures are calculated based upon a 24-hour per day, 365 day per year exposure. Occupational exposures, however, occur over an 8-hour work shift for 250 work shifts per year. Multiplying the above calculated environmental exposures by the ratio of 24-hour/365 day exposures to 8-hour/250 day exposures produces the equivalent (4.38) occupational exposures (Nolan *et al*, 2005).

Search & Rescue Exposures

The arithmetic mean of personal asbestos exposure to Search & Rescue worker's was calculated to be 0.009 af/mL. In conducting this calculation airborne asbestos fiber determinations using ATEM were used instead of total fiber counts by PCM. These calculations also used zero where no asbestos was detected using ATEM. The worst-case Search & Rescue worker asbestos exposure was evaluated at 0.2 f/mL collected from an ironworker on September 28, 2001, just one day before the Search & Rescue operations would cease. However this result was downgraded by ATEM analysis as the majority of the fibers counted using PCM analysis were not asbestos. The true worst-case asbestos related exposure was determined to be 0.07 af/mL after conversion. This sample represented a personal air sample collected by OSHA on a laborer on September 25, 2001.

The arithmetic mean of ambient asbestos air sampling conducted during the Search & Rescue operations was 0.015 af/mL. In conducting this calculation, similar to the personal exposures above, airborne asbestos fiber determinations using ATEM were used instead of total fiber counts by PCM. These calculations also used zero where no asbestos was detected using ATEM. The worst-case ambient air concentration collected during the Search & Rescue operations was 0.2 f/mL (total fibers) and was collected by the NYCSCA on the intersection of Murray & West Streets on September 15, 2001. The greatest airborne asbestos determination was also made on September 15, 2001 and was 0.1 af/mL. This determination, that is specific for asbestos was used in the exposure calculations to follow.

For the 18-day period of Search & Rescue work, the arithmetic mean cumulative environmental exposure calculated from ambient air data is 0.0008 af/mL-years, and cumulative exposure to workers based on personal air sampling data is 0.0006 af/mL-years. The arithmetic mean of both personal and ambient asbestos air samples was determined using ATEM which can determine asbestos from non-asbestos fibers. The same group of workers were exposed to a cumulative worst-case environmental asbestos exposure of 0.006 af/mL-years based on ambient air data, and 0.005 af/mL-years based on personal air data respectively. These cumulative environmental exposures assume that the Search & Rescue workers were exposed 24-hours per day for the

entire 18-day Search & Rescue operation, and not exposed to airborne asbestos after March 30, 2002. Personal air sampling exposures, however, are calculated as an 8-hour TWA, therefore representative of occupational exposures as discussed above.

Clean-up & Recovery Exposures

Site Clean-up and Recovery activities were initiated on September 30, 2001, and lasted through March 30, 2002. The arithmetic mean of personal asbestos exposure to the Clean-up & Recovery workers was 0.0007 af/mL. Similarly, in conducting this calculation, airborne asbestos fiber determinations using ATEM were used instead of total fiber counts by PCM. This calculation also used zero where no asbestos was detected using ATEM. The worst-case personal air concentration collected during the Clean-up and Recovery activities was 0.8 f/mL, which was downgraded to zero by ATEM as none of the fibers counted using PCM were asbestos. The true worst case asbestos-related personal exposure to any Clean-up and Recovery worker was 0.05 af/mL on an air sample collected by OSHA on March 27, 2002.

The arithmetic mean of ambient air sampling conducted during the clean-up and recovery activities were 0.003 af/mL. In conducting this calculation, similar to the personal exposures above, airborne asbestos fiber determinations using ATEM were used instead of total fiber counts by PCM. These calculations also used zero where no asbestos was detected using ATEM. The worst-case ambient air concentration collected during the Search & Rescue operation was 0.9 f/mL, which was downgraded by ATEM to zero as none of the fibers counted using PCM were asbestos. The true worst-case ambient exposure was evaluated at 0.03 af/mL collected by OSHA on October 5, 2001.

For the 182-day period of clean-up & recovery work, the arithmetic mean cumulative environmental asbestos exposure of 0.002 af/mL-years. The cumulative exposure based on personal air samples was 0.0007 af/mL-years. The arithmetic mean of both personal and ambient asbestos air samples was determined using ATEM which can determine asbestos from non-asbestos fibers. The same group of workers were exposed to a cumulative worst-case

environmental asbestos exposure of 0.01 af/mL-years based on ambient air data, and 0.05 af/mL-years based on personal air data .

Residential Exposures to Ambient Air

The ambient cumulative residential environmental exposures for the 280-day period from September 14, 2001 through June 20, 2002 based on fixed high-volume air sampling locations in lower Manhattan was 0.004 af/mL-years, which was calculated using the arithmetic mean of 0.005 af/mL. The worst case airborne asbestos exposure during this sampling period was 0.1 af/mL, which was collected at the corner of Barclay Street & West Street on October 31, 2001. On five other occasions, environmental high-volume asbestos ambient air sample results returned results greater than 0.1 af/mL. However, each contained a notation that the reported result was influenced by the extremely low sample volume which raised the limit of detection, hence the reported analytical result. The worst-case ambient environmental exposure during that 280-day period resulted in a worst-case cumulative environmental airborne asbestos exposure for the residents of lower Manhattan of 0.09 af/mL-years.

The equivalent occupational exposures for the 18-day Search & Rescue, 180-day Clean-up & Recovery, and 280-day Residential exposures based on ambient air sampling data are therefore as follows:

- Search & Rescue workers exposed to the arithmetic mean cumulative concentration of 0.0008 af/mL-yr have an equivalent occupational exposures of 0.003 af/mL-yr. The worst-case cumulative concentration of 0.006 af/mL-yr have an equivalent occupational exposures of 0.02 af/mL-yr.
- Clean-up and Recovery workers exposed to the arithmetic mean cumulative concentration of 0.002 af/mL-yr have an equivalent occupational exposure of 0.007 af/mL-yr. The worst-case cumulative concentration of 0.01 af/mL-yr have an equivalent occupational exposure of 0.06 af/mL-yr.
- Residents in lower Manhattan exposed to the arithmetic mean cumulative concentration of 0.004 af/mL-yr have an equivalent occupational exposure of 0.02 af/mL-yr. The

worst-case concentration of 0.09 af/mL-yr have an equivalent occupational exposure of 0.4 af/mL-yr.

Alternatively, personal air sampling data are, by definition, representative of occupational exposures, and calculated as an 8-hour TWA. The cumulative personal air sampling data therefore was not multiplied by 4.38, but rather calculated based on 8-hour / day, 250 working days / year exposure. The occupational exposures for the 18-day Search & Rescue, and 182-day Clean-up & Recovery personal air sampling data are therefore as follows:

- Search & Rescue workers exposed to the arithmetic mean concentration of 0.009 af/mL-yr have a cumulative exposure of 0.0002 af/mL-yr. The worst-case concentration of 0.07 af/mL-yr have a cumulative exposure of 0.005 af/mL-yr.
- Clean-up and Recovery workers exposed to the arithmetic mean concentration of 0.0007 af/mL-yr have a cumulative exposure of 0.00002 af/mL-yr. The worst-case concentration of 0.05 af/mL-yr have a cumulative exposure of 0.0342 af/mL-yr.

Table 4b summarizes the cumulative lifetime exposure to asbestos based on Ground Zero activity. The available data for the ambient high volume fixed locations are not representative of personal occupational exposures, therefore none were reported as such.

The cumulative exposures were calculated using the arithmetic mean exposure obtained from the environmental exposure air sample data provided above, multiplied by the duration of exposure. The earliest air sample data was collected during the Search & Rescue activities on September 13, 2001, and ended once the work at Ground Zero was downgraded to Clean-up and Recovery on September 30, 2001; an 18-day exposure. Search and Rescue environmental data was multiplied by 4.38 to obtain the equivalent occupational cumulative exposure.

The Clean-up and Recovery activities conducted at Ground Zero lasted until March 30, 2002; an 182-day exposure. Clean-up and Recovery environmental data was also multiplied by 4.38 to obtain the equivalent occupational cumulative exposure.

Ambient air sample data reflective of residential exposures was collected from September 14, 2001 through June 20, 2002; a 280-day exposure. Ambient air environmental data was multiplied by $(280\text{days})/(365\text{ days/yr})$, to obtain the cumulative exposures.

Risk Assessment

Based on the above exposure assessments, this risk assessment for a lifetime exposure to asbestos from the collapse of the World Trade Center Towers on September 11, 2001 has been conducted. The approach used was similar to that employed by Nolan *et al*, 2005 where the asbestos-specific risk assessment protocol used by Hodgson & Darnton, 2000 was compared to the US-EPA's all-cause asbestos-related risk protocol. The Hodgson & Darnton, 2000 protocol separates the incidence of mesothelioma and Lung Cancer, and is fiber-type specific, while the US-EPA's protocol does not separate the incidence of mesothelioma or lung cancer, and is not fiber-type specific.

These cumulative environmental exposures were then converted into equivalent occupational exposures for use in the various risk assessment protocols as these protocols were developed using occupationally exposed cohort data (Nolan *et al*, 2005). Environmental exposures result from a continuous exposure 24 hour per day 365 days per year. Occupational exposures occur, on average, 8-hours per day, 250 working days per year. Therefore, to obtain equivalent occupational exposures, the environmental exposure data must be multiplied by the product of $(365\text{ days/yr} \times 24\text{ hours/day})/(250\text{ working days/yr} \times 8\text{-hrs/day})$; or 4.38. Occupational asbestos exposures in f/mL, that are 4.38 times greater than environmental exposures, in f/mL, lead to equivalent cumulative asbestos exposures (Nolan *et. al.* 2005).

The Lifetime Average Daily Exposure (LADE) used in EPA's all-inclusive asbestos related cancer risk assessment protocol uses 24-hour per day, 365 days per year, or environmental exposures instead of occupational exposures, as a basis for measurement. This allowed for the generation of another column of data in **Table 4b**. Substituting the various environmental exposures referenced in adjacent columns in **Table 4b** into the referenced Search & Rescue (18-

Day), Clean-up & Recovery (182-Day), and Residential ambient (280-Day) exposure groups reveals the following LADEs:

- Search & Rescue Workers (mean) = 0.00001 af/mL; Search & Rescue Workers (worst case) = 0.0001 af/mL;
- Clean-up & Recovery Workers (mean) = 0.00002 af/mL; Clean-up & Recovery Workers (worst case) = 0.0002 af/mL;
- Residential exposures (mean) = 0.0001 af/mL; Residential exposures (worst case) = 0.001 af/mL.

As determined from the data above, the worst-case LADE is one order of magnitude higher than the arithmetic mean for each exposure group. Substituting these LADEs into the all-cause lifetime asbestos-related risk assessment model used by US-EPA reveals the following (**Table 5**):

- *Search & Rescue* workers exposed to the cumulative concentration of airborne asbestos based on ambient air data results in 10 excess asbestos-related cancer deaths;
- *Search & Rescue* workers exposed to the cumulative concentration of airborne asbestos based on personal air data results in 26 excess asbestos-related cancer deaths;
- *Clean-up and Recovery* workers exposed to cumulative concentrations of airborne asbestos based on ambient air data results in 25 excess asbestos-related cancer deaths;
- *Clean-up and Recovery* workers exposed to cumulative concentrations of airborne asbestos based on personal air data results in 2 excess asbestos-related cancer deaths;
- *Residents* in lower Manhattan exposed to the arithmetic mean concentration of airborne asbestos results in 50 excess asbestos-related cancer deaths;

These calculations were based on the Risk Assessment models previously discussed. However, as the current USEPA model has not been updated since 1986, and is neither current with risk assessments conducted by Hodgson & Darnton, 2000, nor Berman & Crump, 2010, substituting these cumulative exposures into a similar risk assessment model used by Nolan et. al., 2005 that

considers the effects of chrysotile asbestos, the type of asbestos workers and residents would be exposed to from the collapse of the World Trade Center, and separates lung cancer from mesothelioma risks, reveals the following:

- Search & Rescue workers exposed to the arithmetic mean concentration of ambient airborne chrysotile results in 0.001 excess mesothelioma cancer deaths, and 0.04 excess lung cancer deaths. Summing the two yields 0.04 excess asbestos-related cancer deaths;
- Clean-up and Recovery workers exposed to the arithmetic mean concentration of ambient airborne chrysotile results in 0.002 excess mesothelioma cancer deaths, and 0.09 excess lung cancer deaths. Summing the two yields 0.09 excess asbestos-related cancer deaths;
- Residents in lower Manhattan exposed to the arithmetic mean concentration of ambient airborne chrysotile results in 0.006 excess mesothelioma cancer deaths, and 0.3 excess lung cancer deaths; Summing the two yields 0.3 excess asbestos-related cancer deaths;

Table 5 represents a summary of the above referenced asbestos-related excess cancer death estimates for each exposure group. As expected, EPA's all-cause asbestos-related cancer death risk estimate is considerably higher, often two orders of magnitude, than the Hodgson & Darnton Risk estimate. This will have a profound effect on the calculated benefits of asbestos-related cancer death aversion in the CBA calculations in the section to follow. Copies of the various calculation spreadsheets used for generating **Table 5** have been presented as **Appendix B**.

The estimated number of excess asbestos-related cancer deaths from the arithmetic mean cumulative asbestos exposure are highest for the 280-day residential exposure group. Worst case asbestos exposure risk calculations were performed as an extremely conservative upper boundary for potential excess asbestos-related cancer death. The excess asbestos-related cancer death calculations for the arithmetic mean was used in the series of CBA calculations below as an estimate on whether the costs of EPA's residential dust clean-up program exceeded its benefits.

Evaluating the CBA Analysis - The Go, or No-Go Decision

The investment decision to execute a given project, or stand-down and choose not to follow through with a project, can be evaluated following the CBA using one, or any combination of the following three decision-making criteria.

1. The benefit/cost ratio (BCR) criterion;
2. The net present value (NPV) criterion; or
3. The internal rate of return (IRR) criterion.

This Go, or No-Go decision-making process is based on the premise that either the overall money spent for a given project will provide benefits (now or in the future) in excess of the expended capital, or it will not. Instead, the capital would be expected to be reinvested into a conservative holding, say, government bonds; or into another project where an appropriate return on this investment would be received.

The Benefit/Cost Ratio Criterion

The BCR is another decision-making tool that can be used to determine if a project is worth undertaking. The BCR also compares the present value of a project's cost with the present value of its benefits, but instead of subtracting the two, the two are divided. If the quotient is greater than 1, then the benefits of the project exceed its costs and the project should be initiated, a Go. If the quotient is less than 1, then the costs of the project exceed its benefits and the project should not be initiated, a no-go. If the quotient is at 1, then other methods, such as the NPV or IRR where used in the decision making process. The BCR ratio is expressed mathematically as:

$$\text{BCR} = \frac{\text{PV (benefits)}}{\text{PV (costs)}}$$

Other methods used in the decision-making process included the net present value (NPV) criterion, and the internal rate of return (IRR) criterion. These methods were only used to determine if a BCR of 1 should be swayed either for “Go” or against “No Go” decision. The

NPV and IRR did not alter the BCR, therefore were not included in the CBA summary tables, **Tables 6 & 7**. The NPV calculation is simply the difference between the discounted present value of future benefits and the discounted present value of future costs (Campbell & Brown, 2003). If the NPV is a positive number, then the project benefits exceed the project costs. If the NPV is a negative number, then the project costs exceed the benefits and the project should not be initiated. The NPV is expressed mathematically as $NPV = PV(\text{benefits}) - PV(\text{costs})$. The IRR decision criterion is expressed mathematically as:

Accept Project, if $IRR \geq \text{interest rate}$

Reject Project, if $IRR \leq \text{interest rate}$

When it comes to using the IRR as a decision making tool and considering whether the residential clean-up is accepted, or rejected, the IRR and NPV criteria would yield the same result. That is, they both would either accept, or reject the project based on the rate of return for an investment. As shown in the NPV criterion above, if the discounted costs exceed the discounted benefits, then a project should not be accepted. Similarly, if the cost of borrowing capital (interest rate) is greater than the projects IRR, then the project should be rejected.

The CBA was conducted using a multiple account framework spreadsheet as detailed in Campbell & Brown, 2003. The multiple account framework approach allows for transparency throughout the CBA process by viewing the project from three project perspectives: the project analysis; the private analysis; and the efficiency analysis.

The Project Analysis

The project analysis views the project from a social "with or without" approach, where the benefit of the project is valued against the opportunity cost [the value of allocating resources to another project, or towards nothing at all (keeping those resources in an interest bearing account)]. Under this approach, taxes are not factored into the valuation process. This perspective assumes that all project benefits and costs are valued at fair market prices, and does not consider how the benefits and cost are distributed.

The Private Analysis

The private analysis views the project from a private shareholder's point of view. The private entity would not be expected to undertake a project if that project would not be profitable. Payment of government taxes would be required under this approach and have been factored into this valuation process. However, the privatized costs associated with USEPA's residential dust clean-up program have been parceled out to various environmental contractors, environmental consultants, and analytical laboratories; each with a specific technical specialization involving a portion of the affected lower Manhattan area, and often none monetizing the social benefits of the program as a whole. It is for this reason that an analysis from a purely private market perspective is important for a public decision-maker when trying to decide the viability of a project. The public decision-maker can view the project from a pure private-market perspective while keeping focus on the social benefits of the project as a whole.

The Efficiency Analysis

The efficiency analysis is used to determine if the project is an economic efficient use of resources; regardless of who gains or loses. Where the project analysis values the benefits of the project against its opportunity cost in a fair market system; the efficiency analysis accounts for inequities in the fair market systems by introducing shadow prices that adjust market prices to reflect social benefits or costs. The efficiency analysis can be viewed as a re-calculation of the Project Analysis using opportunity costs rather than market prices, and calculates the value of the project to the economy as a whole (Campbell & Brown, 2003).

I argue herein that chrysotile exposure of the fiber size and duration of exposure to emergency workers, individuals working adjacent to Ground Zero, and individuals residing adjacent to Ground Zero was, in fact, quite low; thereby reducing the overall risk of developing an asbestos-related disease. Under this situation, the USEPA would have been expected not to include asbestos as a chemical of potential concern and possibly not expend the resources to conduct the lower Manhattan Residential Dust Clean-up program.

Three scenarios have been developed to calculate whether the EPA Residential dust clean-up program was worth the rather exorbitant cost. These scenarios were developed to account for the potential of differing viewpoints regarding the true cost of the clean-up program. For example, the costs associated with the clean-up program may, or may not, include the FEMA purchases of specialized, or replacement equipment. Or the costs associated with the program may only include actual residential clean-up labor and analytical costs. The following three scenarios were developed, and an individual CBA analysis was performed to account for these varying costs, they are:

Scenario 1 - Do everything. The "Do Everything" approach accounts for all costs associated with Scenario #2, and #3 below. That is, all costs associated with the FEMA purchases of specialized / replacement equipment for residents and providing specialty contractors to conduct the surface dust clean-up with environmental consultants performing clearance air sampling with subsequent ATEM analysis from an analytical laboratory that documents the effectiveness of the clean-up.

Scenario 2 - Supply only specialized equipment to the residents of lower Manhattan to aid in effectively cleaning their residences. No other services would be provided.

Scenario 3 - Do not supply specialized equipment to the residents of lower Manhattan, rather, have specialty contractors perform this cleaning with oversight from environmental consultants who will then conduct visual inspections and conduct ATEM clearance air monitoring to confirm the efficiency of the cleaning.

Balancing costs versus benefits is a highly controversial endeavor, especially when dealing with the public perception of asbestos exposure. Even if the public agreed overall that exposure and the associated risks to asbestos exposure at Ground Zero were low, the valuation process needed to conduct the CBA could be controversial. The "cost" side of the CBA is rather straightforward and often uncontested. In the example of the EPA residential dust clean-up program it has been reported that the cumulative cost of supplying specialized equipment (Scenario #2) to lower Manhattan residents was rounded to \$130 million (NYS DOL FOIA Response dated August 8,

2007). The above costs do not include Scenario #3 costs for additional laboratory analytical work (\$4.1 million), data validation (\$293 thousand), environmental consultant labor (\$5 million), and abatement contractor material and labor (\$8.5 million). Summing the above costs yields a Scenario #1 cost of \$148 million. The clean-up program was performed from September, 2002 through September, 2003. Costs associated with the clean-up reported in FOIA Request #02-RIN-01328-07 therefore representative of fair market values in those years. As it is essential to balance all costs and benefits in the CBA endeavor, these costs have been adjusted to year 2000 dollars. This year 2003 cost adjustment to year 2000 dollars was conducted by dividing by the Consumer Price Index conversion factor of 1.066 calculated from the September, 2003 to September 2000 United States Department of Labor, Bureau of Labor and Statistics reported annual average for all cities (US-DOL, 2011). The adjusted costs from year 2003 dollars to year 2000 dollars for conducting each of the referenced three scenarios is presented below by dividing each cost by 1.066 (US-DOL, BLS web accessed December 6, 2011) and were used in the CBA:

- EPA-supplied Specialized Equipment - \$122 million adjusted;
- Laboratory Analytical Work and Data Validation - \$4.1 adjusted;
- Environmental Consultant Material Labor - \$5 million adjusted;
- Environmental Contractor materials and Labor - \$8.5 million adjusted.

Estimating the benefits in conducting this CBA were based on the health valuation received by eliminating the asbestos-related risk of mortality interpreted through the number of lives saved. The resulting figure from the CBA is not solely the cost of conducting the residential clean-up program, but the change in welfare based on the potential risk of mortality reduction by conducting the clean-up program versus not conducting the clean-up program.

A current value for a statistical life used by US-EPA is \$7.4 million in 2006 dollars (<http://yosemite.epa.gov/ee/epa/eed.nsf/pages/MortalityRiskValuation.html>, accessed Sept. 13, 2011). Using this cost adjusted to year 2000 dollars according to consumer price index data (US-DOL, 2011) reveals that the same \$7.4 million would be worth \$5.8 million. This \$5.8 million value for a statistical life was used in the series of CBA scenarios discussed above.

Each of the aforementioned scenarios have been analyzed in detail under the three differing CBA perspectives using the excess cancer death risk assessment estimates obtained from the 280-day residential arithmetic mean, and worst-case scenarios as a very conservative CBA estimate based on excess asbestos-related cancer risk reflected in **Table 5**, and the static project details discussed below. The project details that would not be changed in the CBA included a corporate tax rate of 25%; a VSL of \$5.8 million and VSL shadow price of \$4.4 million which represents the VSL averages listed in **Table 3** adjusted to year 2000 dollars; using discount rates of 3% and 6%.

US-EPA-Based Data CBA Decisions

Tables 6 summarizes the USEPA-based asbestos-related risk decision criteria to show whether the cost of each of the CBA analyses: the Project Analysis; Private Analysis; and Efficiency Analysis exceeded their benefits. Each analysis details the BCA decision-making criteria which could have been used by USEPA to aid in making a decision presented along with a "Go", or "No Go" project decision. The USEPA would have been expected to follow a similar analysis under Executive Order 12866 to determine if valuable public resources could have been instead invested into another program, or prior to initiating the Residential Dust Clean-up Project. Each of the scenarios are discussed below. The benefits used for these USEPA CBA calculations will remain static for each scenario and reflect the cost of averting asbestos-related cancer mortality and morbidity based on the various arithmetic mean airborne asbestos exposures, and the worst-case airborne asbestos exposures respectively.

The Project Analysis

Table 6 summarizes this Project Analysis.

Scenario #1

Under the "Do Everything" scenario the adjusted total costs for purchasing specialized equipment and conducting residential cleaning for the residents of lower Manhattan was \$138 million. The benefits were viewed as the lifetime asbestos-related cancer risk aversion for 50

individuals by conducting these actions from risk calculation conducted using the USEPA's all-cause cancer risk assessment protocol which does not separate mesothelioma from lung cancer and is not asbestos fiber-type specific.

Based on the arithmetic mean air sample exposure to the residents of lower Manhattan, and with total expenditure of \$138 million. The calculated BCR was greater than 1.0 (70). According to this decision criteria, the USEPA would have been expected to have chosen to spend tax-payer money on this project, instead it could have been used elsewhere. The worst-case air monitoring data would have shown an even greater BCR, and would not have altered this decision.

Scenario #2

Under the "Specialized Equipment" scenario the total adjusted cost for purchasing specialized equipment for use by the residents of lower Manhattan would be \$122 million. The benefits were viewed as the lifetime asbestos-related cancer risk aversion for conducting these actions from risk calculation conducted using the USEPA's all cause cancer risk assessment protocol which does not separate mesothelioma from lung cancer and is not asbestos fiber-type specific.

Based on the arithmetic mean air sample exposure to the residents of lower Manhattan, and the total expenditure of \$122 million, the calculated BCR was greater than 1.0 (80). According to this decision criteria, the USEPA would have been expected to have chosen to spend tax-payer money on this project. The worst-case air monitoring data would have shown an even greater BCR, and would not have altered this decision.

Scenario #3

Under the "Cleaning" scenario the total adjusted cost for purchasing specialized equipment for use by the residents of lower Manhattan would be \$17 million. The benefits were viewed as the lifetime asbestos-related cancer risk aversion for conducting these actions from risk calculation conducted using the USEPA's all cause cancer risk assessment which does not separate mesothelioma from lung cancer and is not asbestos fiber-type specific.

Based on the arithmetic mean air sample exposure to the residents of lower Manhattan, and with total expenditure of \$17 million, the calculated BCR was also greater than 1.0 (586). According to this decision criteria, the USEPA would have been expected to have chosen to spend tax-payer money on this project. The worst-case air monitoring data would have shown an even greater BCR, and would not have altered this decision.

The Private Analysis

The Private Market Analysis **Table 6** used herein calculates the BCR following the payment of taxes (25%). Again, the benefits used for this USEPA CBA calculation will remain static for each scenario and reflect 50 excess cancer deaths avoided for the arithmetic mean airborne asbestos exposure.

Scenario #1

Under the "Do Everything" scenario the total costs for purchasing specialized equipment and conducting residential cleaning for the residents of lower Manhattan was \$138 million. The benefits were viewed as the lifetime asbestos-related cancer risk aversion for conducting these actions from risk calculation conducted using the USEPA's all-cause cancer risk assessment protocol which does not separate mesothelioma from lung cancer and is not asbestos fiber-type specific.

Based on the arithmetic mean air sample exposure to the residents of lower Manhattan, and with total expenditure of \$138 million, the calculated BCR was greater than 1.0 (52). According to this decision criteria, the USEPA would have been expected to have chosen to spend tax-payer money on this project. The worst-case air monitoring data would have shown an even greater BCR, and would not have altered this decision.

Scenario #2

Under the "Specialized Equipment" scenario the total costs for purchasing specialized equipment for use by the residents of lower Manhattan would be \$122 million. The benefits were viewed as the lifetime asbestos-related cancer risk aversion for conducting these actions from risk

calculation conducted using the US-EPA's all cause cancer risk assessment protocol which does not separate mesothelioma from lung cancer and is not asbestos fiber-type specific.

Based on the arithmetic mean air sample exposure to the residents of lower Manhattan, and the total expenditure of \$122 million, the calculated BCR was greater than 1.0 (60). According to this decision criteria, the USEPA would have been expected to have chosen to spend tax-payer money on this project. The worst-case air monitoring data would have shown an even greater BCR, and would not have altered this decision.

Scenario #3

Under the "Cleaning" scenario the total costs for purchasing specialized equipment for use by the residents of lower Manhattan would be \$17 million. The benefits were viewed as the lifetime asbestos-related cancer risk aversion for conducting these actions from risk calculation conducted using the USEPA's all cause cancer risk assessment which does not separate mesothelioma from lung cancer and is not asbestos fiber-type specific.

Based on the arithmetic mean air sample exposure to the residents of lower Manhattan, and with total expenditure of \$17 million, the calculated BCR was greater than 1.0 (439). According to this decision criteria, the USEPA would have been expected to have chosen to spend tax-payer money on this project. The worst-case air monitoring data would have shown an even greater BCR, and would not have altered this decision.

The Efficiency Analysis

The Efficiency Analysis, summarized as **Table 6** used herein also calculates the BCR. However, instead of using the standard VSL as used in the Project Analysis, the shadow price VSL of \$4.4 million was used to account for inequities in the fair market system. Again, the benefits used for this USEPA CBA calculation will remain static for each scenario and reflect 50 excess cancer deaths avoided.

Scenario #1

Under the "Do Everything" scenario the total costs for purchasing specialized equipment and conducting residential cleaning for the residents of lower Manhattan was \$138 million. The benefits were viewed as the lifetime asbestos-related cancer risk aversion for conducting these actions from risk calculation conducted using the USEPA's all-cause cancer risk assessment protocol which does not separate mesothelioma from lung cancer and is not asbestos fiber-type specific.

Based on the arithmetic mean air sample exposure to the residents of lower Manhattan, and with total expenditure of \$138 million, the calculated BCR was greater than 1.0 (53). According to this decision criteria, the USEPA would have been expected to have chosen to spend tax-payer money on this project. The worst-case air monitoring data would have shown an even greater BCR, and would not have altered this decision.

Scenario #2

Under the "Specialized Equipment" scenario the total costs for purchasing specialized equipment for use by the residents of lower Manhattan would be \$122 million. The benefits were viewed as the lifetime asbestos-related cancer risk aversion for conducting these actions from risk calculation conducted using the USEPA's all cause cancer risk assessment protocol which does not separate mesothelioma from lung cancer and is not asbestos fiber-type specific.

Based on the arithmetic mean air sample exposure to the residents of lower Manhattan, and the total expenditure of \$122 million the calculated BCR was greater than 1.0 (66). According to this decision criteria, the USEPA would have been expected to have chosen to spend tax-payer money on this project. The worst-case air monitoring data would have shown an even greater BCR, and would not have altered this decision.

Scenario #3

Under the "Cleaning" scenario the total costs for purchasing specialized equipment for use by the residents of lower Manhattan would be \$17 million. The benefits were viewed as the lifetime asbestos-related cancer risk aversion for conducting these actions from risk calculation conducted using the USEPA's all cause cancer risk assessment which does not separate mesothelioma from lung cancer and is not asbestos fiber-type specific.

Based on the arithmetic mean air sample exposure to the residents of lower Manhattan, and with total expenditure of \$17 million the calculated BCR was greater than 1.0 (488). According to this decision criteria, the USEPA would have been expected to have chosen to spend tax-payer money on this project. The worst-case air monitoring data would have shown an even greater BCR, and would not have altered this decision.

Hodgson & Darnton-Based Data CBA Decisions

Table 7 summarizes the Hodgson & Darnton-Based CBA Decision Matrix that show whether the cost of each of the CBA-Scenarios exceed their benefits. These results will then be compared with that of the outdated USEPA all-inclusive risk assessment protocol that does not distinguish between asbestos fiber-types, and does not separates lung cancer and mesothelioma risks. The BCR is presented along with a "Go", or "No Go" project decision, which is what the USEPA would have been expected to follow if a CBA were performed prior to initiating the Residential Dust Clean-up Project. Each of the scenarios is discussed below. The benefits used for these Hodgson & Darnton CBA calculations will remain static for each scenario and reflect avoiding one asbestos-related cancer morbidity and mortality based on the arithmetic mean airborne asbestos exposures.

Project Analysis

Scenario #1

Under the "Do Everything" scenario, refer to **Table 7**, the total adjusted costs for purchasing specialized equipment and conducting residential cleaning for the residents of lower Manhattan would be \$138 million. The benefits were viewed as the lifetime asbestos-related cancer risk aversion for conducting these actions from risk calculation conducted using the Hodgson & Darnton's cancer risk assessment which separates mesothelioma from lung cancer and is asbestos fiber-type specific, which for these calculations reflects exposure to chrysotile asbestos.

Based on the arithmetic mean air sample exposure to the residents of lower Manhattan, and with a total expenditure of \$138 million, the calculated BCR was at 1.0. According to the BCR decision criteria, the NPV at 3% was used in the Go/No Go decision process. The NPV was determined to be negative. Therefore, according to this determination, the USEPA would have been expected not to have chosen to spend tax-payer money on this project.

Scenario #2

Under the "Specialized Equipment" scenario the total adjusted costs for purchasing specialized equipment for use by the residents of lower Manhattan would be \$122 million. The benefits were viewed as the lifetime asbestos-related cancer risk aversion for conducting these actions from risk calculation conducted using Hodgson & Darnton's cancer risk assessment which separates mesothelioma from lung cancer and is asbestos fiber-type specific.

Based on the arithmetic mean air sample exposure to the residents of lower Manhattan, and with total expenditure of \$122 million, the calculated BCR was at 1.0. According to the BCR decision criteria, the NPV at 3% was used in the Go/No Go decision process. The NPV was determined to be negative. Therefore, according to this determination, the USEPA would have been expected not to have chosen to spend tax-payer money on this project.

Scenario #3

Under the "Cleaning" scenario the total adjusted costs for cleaning and testing individual residences use by the residents of lower Manhattan would be \$17 million. The benefits were viewed as the lifetime asbestos-related cancer risk aversion for conducting these actions from risk calculation conducted using Hodgson & Darnton's cancer risk assessment protocol that separate mesothelioma from lung cancer and is asbestos fiber-type specific.

Based on the arithmetic mean air sample exposure to the residents of lower Manhattan, and with total expenditure of \$17 million, the calculated BCR was less than 1.0 (0.8). According to the BCR decision criteria, the USEPA would have been expected *not* to have chosen to spend taxpayer money on this project.

Private Analysis

Scenario #1

Under the "Do Everything" scenario, refer to **Table 7**, the total adjusted costs for purchasing specialized equipment and conducting residential cleaning for the residents of lower Manhattan would be \$138 million. The benefits were viewed as the lifetime asbestos-related cancer risk aversion for conducting these actions from risk calculation conducted using the Hodgson & Darnton's cancer risk assessment which separates mesothelioma from lung cancer and is asbestos fiber-type specific, which for these calculations reflects exposure to chrysotile asbestos.

Based on the arithmetic mean air sample exposure to the residents of lower Manhattan, and with total expenditure of \$138 million, the calculated BCR was at 1.0. According to the BCR decision criteria, the NPV at 3% was used in the Go/No Go decision process. The NPV was determined to be negative. Therefore, according to this determination, the USEPA would have been expected *not* to have chosen to spend tax-payer money on this project.

Scenario #2

Under the "Specialized Equipment" scenario, the total costs for purchasing specialized equipment for use by the residents of lower Manhattan would be \$122 million. The benefits were viewed as the lifetime asbestos-related cancer risk aversion for conducting these actions from risk calculation conducted using Hodgson & Darnton's cancer risk assessment which separates mesothelioma from lung cancer and is asbestos fiber-type specific.

Based on the arithmetic mean air sample exposure to the residents of lower Manhattan, and with total expenditure of \$122 million, the calculated BCR was at 1.0. According to the BCR decision criteria, the NPV at 3% was used in the Go/No Go decision process. The NPV was determined to be negative. Therefore, according to this determination, the USEPA would have been expected *not* to have chosen to spend tax-payer money on this project.

Scenario #3

Under the "Cleaning" scenario the total adjusted cost for cleaning and testing individual residences use by the residents of lower Manhattan would be \$17 million. The benefits were viewed as the lifetime asbestos-related cancer risk aversion for conducting these actions from risk calculation conducted using Hodgson & Darnton's cancer risk assessment protocol that separate mesothelioma from lung cancer and is asbestos fiber-type specific.

Based on the arithmetic mean air sample exposure to the residents of lower Manhattan, and with total expenditure of \$17 million, the calculated BCR was less than 1.0 (0.8). According to the BCR decision criteria, the USEPA would have been expected *not* to have chosen to spend tax-payer money on this project.

Efficiency Analysis

Scenario #1

Under the "Do Everything" scenario, refer to **Table 7**, the total adjusted cost for purchasing specialized equipment and conducting residential cleaning for the residents of lower Manhattan

would be \$138 million. The benefits were viewed as the lifetime asbestos-related cancer risk aversion for conducting these actions from risk calculation conducted using the Hodgson & Darnton's cancer risk assessment which separates mesothelioma from lung cancer and is asbestos fiber-type specific, which for these calculations reflects exposure to chrysotile asbestos.

Based on the arithmetic mean air sample exposure to the residents of lower Manhattan, and with total expenditure of \$138 million, the calculated BCR was at 1.0. According to the BCR decision criteria, the NPV at 3% was used in the Go/No Go decision process. The NPV was determined to be negative. Therefore, according to this determination, the USEPA would have been expected not to have chosen to spend tax-payer money on this project.

Scenario #2

Under the "Specialized Equipment" scenario the total costs for purchasing specialized equipment for use by the residents of lower Manhattan would be \$122 million. The benefits were viewed as the lifetime asbestos-related cancer risk aversion for conducting these actions from risk calculation conducted using Hodgson & Darnton's cancer risk assessment which separates mesothelioma from lung cancer and is asbestos fiber-type specific.

Based on the arithmetic mean air sample exposure to the residents of lower Manhattan, and with total expenditure of \$122 million, the calculated BCR was at 1.0. According to the BCR decision criteria, the NPV at 3% was used in the Go/No Go decision process. The NPV was determined to be negative. Therefore, according to this determination, the USEPA would have been expected not to have chosen to spend tax-payer money on this project.

Scenario #3

Under the "Cleaning" scenario the total adjusted cost for cleaning and testing individual residences use by the residents of lower Manhattan would be \$17 million. The benefits were viewed as the lifetime asbestos-related cancer risk aversion for conducting these actions from risk calculation conducted using Hodgson & Darnton's cancer risk assessment protocol that separate mesothelioma from lung cancer and is asbestos fiber-type specific.

Based on the arithmetic mean air sample exposure to the residents of lower Manhattan, and with total expenditure of \$138 million, the calculated BCR was less than 1.0 (0.8). According to the BCR decision criteria, the USEPA would have been expected not to have chosen to spend taxpayer money on this project.

If, however, the residents of lower Manhattan were instead continuously exposed to the worst-case air sample concentration during each of the three scenarios discussed, which would be an extremely conservative upper boundary for asbestos-related exposure, the calculated BCR using the Hodgson & Darnton protocol would have been greater than 1.0. Accordingly, the USEPA would have been expected not to have chosen to spend tax-payer money on this project.

Research behind the US-EPA Residential Dust Clean-up Program

It was the NESHAPs definition of ACM that first governed the earliest remedial responses following the collapse of the World Trade Center Towers. Preliminary bulk samples of the settled dust and debris were collected to establish whether or not this material was regulated. A majority of the initial results were analyzed using polarized light microscopy, and returned results showing that the asbestos content of the settled dust and debris was less than 1% asbestos by weight. Therefore, the clean-up efforts, and resulting disposal of the generated waste did not fall within the current federal, state or local rules and regulations regarding personal protection, handling, and disposal of ACM. The potential for asbestos exposure to unqualified persons handling and disposing this unregulated material became media fodder; resulting in increased public perception of the risk of asbestos exposure, even with the growing epidemiological evidence in support of short-term, low-level exposure to short (<5µm) chrysotile asbestos fibers is unlikely to induce an

asbestos-related disease. Nevertheless, as the media continuously reported on asbestos being detected in lower Manhattan, this perception became a reality and USEPA was under an obligation to react.

In addition to the Risk Assessment and Cost Benefit Analysis, this research focused on the policies, procedures, and potential reasoning behind the choice of the USEPA to conduct the Residential Dust Clean-up Program. Items addressed include: US-EPA's establishment of "Chemicals of Potential Concern" (COPC, 2003a); utilizing asbestos as a surrogate contaminant for verifying acceptable cleaning (US-EPA Draft Report EPA/600/R-04/169A (2004)); public distrust issues including press release concerns, and a general breakdown to swiftly respond to indoor cleaning practices; US-EPA's establishment health-based asbestos clearance criteria, along with a discussion pertaining to the findings of the risk assessment and CBA.

US-EPA's establishment of "Chemicals of Potential Concern"

In May 2003, US-EPA produced a document entitled "World Trade Center Indoor Environment Assessment: Selecting Contaminants of Potential Concern and Setting Health-Based Benchmarks" (COPC, 2003a), a document that was issued under the direction of the COPC/Benchmarks Committee of US-EPA's Indoor Air Task Force. The purpose of the document was to select, and set health-based benchmarks for contaminants of potential concern within indoor environments resulting from the WTC disaster. Pursuant to a two-tiered screening process, the Task Force established the following six contaminants as "Chemicals of Potential Concern", they are: Fibrous glass, silica, dioxin, lead, poly-cyclic aromatic hydrocarbons (PAHs), and asbestos.

Additionally, US-EPA conducted a cleaning study to verify if asbestos could be used as a surrogate to cleaning efforts. The theory behind this surrogate study is simple: US-EPA maintained that the cleaning activities utilized as standard practice in the asbestos abatement industry (i.e.: wet cleaning methods utilizing amended water, HEPA filtered vacuuming, etc.) will not only remove asbestos from the environment, but also the other harmful *Chemicals of Potential Concern* (US-EPA Draft Report EPA/600/R-04/169A (2004)).

However, due to the fact that more than half of US-EPA's Region 2 database for environmental sampling contains asbestos data, this research has primarily focused on asbestos. This researcher believes that the aforementioned approach argues against asbestos being a *Chemical of Potential Concern*, because of the negligible risk of morbidity and mortality based upon available asbestos fiber-type and fiber size present in lower Manhattan following the collapse of the WTC towers.

Cleaning Program Too Late

2000 Census data is currently available for households eligible for US-EPA's Residential Clean-up Program. This data will be compared to the number of households that registered for the free clean-up. An alarming disparity in the number of households eligible versus the number of households that registered for the free cleaning exists. According to the 2000 Census data reflected in Nolan *et al*, 2005; 57,514 people reside in lower Manhattan. Additionally, the average number of persons per household for New York State is 2.61 (US-DOC, 2001). Yet 4,167 households registered for the US-EPA Residential Dust Clean-up Program (Kalton, *et al.*, 2004), which extrapolates to approximately 10,876 (18.9%) of the people eligible for the clean-up program actually registered. US-EPA enacted this cleaning program over one year following the events of 9/11, and initially started to interview eligible residents to inform them of the cleaning process and expectations. If there was such public concern and outcry for US-EPA to step forward and help minimize public exposure to asbestos, why did less than 20% of the eligible public participate in the program? Perhaps the answer lies in what has been called the "objective-perceived risk dichotomy" (Bostrom, 1997). The dichotomy is the disconnect between an expert assessment and observed lay persons actions of risk; either resulting in the publics' risk-taking towards what an expert would perceive to be risky, or the publics' perception, or fear, of a risk where experts feel there is little risk.

Potential "Indoor" Exposures Assessment

U.S. Congressman, Nadler has expressed concern over US-EPA's handling of their response regarding whether the air in lower Manhattan was "safe" to breath following the collapse of the World Trade Center towers. Although the available data of the time pertained solely to exterior air samples, and was certainly not sufficient to proclaim absolute safety, a review of the worst-

case “indoor” air sample data as reported by Dr. Jenkins (2001) was used in the exposure assessment to follow and shows that the total lifetime asbestos-related risk to a resident who may have cleaned their own apartment was quite low. In fact, comparable to other environmental risks presented in Table 4b. Dr. Jenkins has reported an indoor “high” exposure concentration of 10,620 s/mm² within the building located at 250 South End Avenue (Jenkins, 2001).

Placing this potential exposure concentration in another context, under the assumption that an individual was exposed to airborne asbestos fibers 24 hours per day, for 7 days was used as they cleaned their own apartment, then not exposed following the cleaning. Using the previously reported conversion factor of 0.00031, the unit of s/mm² was converted to an equivalent f/mL unit: 10,620 s/mm² ~ 3.29 f/mL. 3.29 f/mL was then multiplied by the exposure duration of 7/365 representing a 7-day exposure, yielding an environmental exposure of 0.06 f/mL-yr. Multiplying by 4.38 converts to an equivalent occupational exposure of 0.26 f/mL-yr.

This exposure is one order of magnitude greater than the residential exposure (0.02 f/mL-yr) listed in Table 4b. In comparing this result with the Hodgson & Darnton-based CBA data, US-EPA would also would have been expected to conduct the residential dust clean-up program. However, expending the amount of resources required to undertake the clean-up program would seem unethical based on the data of one air sample. Hence, the arithmetic mean average would most likely seem to be more accurate as the overall risk associated with long-term exposure to asbestos from WTC dust appears to be low (Ilgren, 2001).

A “new” health-based benchmark for Airborne Asbestos

Since being specified in the AHERA protocol, the 70 s/mm² via TEM criteria has been the benchmark to be reached in clearing regulated areas following asbestos abatement in schools prior to re-occupancy (US-EPA AHERA, 1987). However, as mentioned earlier, this criterion holds little, if any, health-based merit. ATEM assays analyzed in accordance with the AHERA protocol and reported in units of s/mm² or s/mL, a unit that based upon the previous epidemiological studies, holds no health-based risk assessment significance, so why was it used? Additionally, why is this analytical protocol still used to “clear” work areas following asbestos abatement in schools, commercial buildings, etc.?

The asbestos abatement work area clearance criterion for the US-EPA Residential Dust Cleaning Program is, for the first time in the asbestos abatement industry, a health-based clearance criterion. Unfortunately, United States public policy has been slow in establishing this criterion throughout the asbestos abatement industry, and this may be attributed to the difficulty in achieving a consensus regarding the potency of differing asbestos fiber-types and fiber sizes. US-EPA maintains that the health based criterion of 0.0009 f/mL PCMe was established through a conservative assumption that continuous exposure to a constant level of airborne asbestos fibers, combined with the IRIS Slope Factor, yields a benchmark equaling a 10^{-4} excess lifetime cancer risk (US-EPA, *IRIS*). Time and equipment constraints, as calculated above, made dealing with the effective gathering of air monitoring data ineffective for US-EPA to establish a benchmark equaling a 10^{-6} excess lifetime cancer risk. While the merits of whether chrysotile exposure should be treated like other amphiboles in the realm of airborne asbestos fiber exposure, which it clearly should not; the US-EPA nevertheless has established a new precedence towards a safe level of asbestos exposure. This safe level should be adopted by AHERA as the threshold to be achieved following asbestos abatement projects in schools. Through ASHARA's far reaching providence, this new level will then be the new industry standard for acceptable airborne asbestos fiber re-occupancy levels throughout the county. This author just cannot see why this cannot be accomplished.

CONCLUSIONS

The three exposure scenarios evaluated show that cumulative residential exposures ((0.02 asbestos fibers per milliliter-year (af/mL-yr)) were the greatest, followed by Clean-up and Recovery exposures (0.007 af/mL-yr), then Search and Rescue exposures (0.003 af/mL-yr), which show that the lower residential dose over a longer period of time would result in a greater cumulative exposure than either the Search and Rescue, or Clean-up and Recovery scenarios. A risk assessment for the three cumulative exposure scenarios was conducted using the US-EPA's 1986 aggregate risk model, which presumes equal potency for all asbestos fiber-types, and the 2000 Hodgson & Darnton model which considers the potency of differing asbestos fiber-types, and is more current with the historic epidemiologic literature. A marked difference between the US-EPA aggregate model and Hodgson & Darnton model exists with the later showing an approximate 240-fold decrease in risk for the lower Manhattan population when chrysotile fiber-type potency is considered. Using the calculated cumulative exposure data a cost-benefit analysis (CBA) was performed to show whether the social benefit associated with a reduction in the asbestos contaminant levels warranted the total cost of providing specialized equipment to lower Manhattan residents and the remedial cost of conducting the US-EPA Residential Dust Clean-up Program. As expected, the CBA shows that the social benefits of averting asbestos-related morbidity and mortality outweigh the costs under the US-EPA's risk assessment protocol. However, using the Hodgson and Darnton risk assessment protocol, the societal benefits do not outweigh the risks and the US-EPA would have been expected not to provide specialized equipment to lower Manhattan residents or conduct the residential dust cleaning program. Since the Hodgson & Darnton protocol does not differentiate between fiber-types, it therefore does not accurately portray lower Manhattan exposures where a predominately short ($< 5\mu\text{m}$), chrysotile asbestos fiber-type was detected. Under this circumstance using the Hodgson and Darnton risk assessment protocol would be more accurate. Again, using the Hodgson & Darnton protocol, the benefits do not outweigh the risks and the US-EPA would have been expected *not* to provide specialized equipment to lower Manhattan residents or conduct the residential dust cleaning program.

I argue that the US-EPA residential dust clean-up program conducted pursuant the collapse of the world trade center, based on available asbestos data, was an exercise in public policy rather than based on the available scientific literature, which shows that the health risks to low level exposure to short ($< 5\mu\text{m}$) chrysotile asbestos was relatively low.

Additionally, for the first time in the asbestos abatement industry, a health-based clearance criterion of 0.0009 f/mL PCMe was used by the US-EPA for the Residential Dust Cleaning Program. However, and this may be attributed to the difficulty in achieving a consensus regarding the potency of differing asbestos fiber-types and fiber sizes, but public policy has been slow in establishing this criterion throughout the rest of the asbestos abatement industry.

TABLES

TABLE 1a

Historic Lung Cancer Potencies (K_L) by Assessment Report

Fiber Type	Operation	Cohort	K_L					
			CPSC, 1983	EPA (1986)	HEL, 1991	H&D, 2000	B&C 2003	B&C 2008
Chrysotile	Mining and Milling	Quebec Mines & Mills		0.06	0.06	0.037	0.029	0.029
		Italian Mines & Mills	0.17	0.081			0.051	0.051
	Friction Products		0.01			0	0	
	Cement Manufacture		N/A			0.25	0.25	
Crocidolite	Textiles	New Orleans Plants			2.3	2	2.1	1.8
		South Carolina Plant				3.4	0.47	1.1
Amosite	Mining and Milling	Wittenoon						
		Paterson, NJ	6.8	4.3	6.8	2.7	1.1	2.4
Tremolite	Insulation	Tyler, Texas		N/A			0.13	0.28
		Libby, MT		N/A			0.39	0.36
Mixed	Vermiculite Mills	British Factory	0.06	0.058	0.06		0.058	0.058
		Ontario, Canada	4.82	4.8			0.29	1.9
	Friction Products	New Orleans Plants		0.53	0.31	0.395	0.25	0.25
		Swedish Plant		N/A			0.067	0.067
	Cement Manufacture	Belgium Factory		N/A			0.0068	0.0068
		Retired Workers		0.49	0.5	0.18	0.11	0.11
Insulation Application	Textiles	US Insulation Workers	1.01	0.75	1		0.18	0.28
		Pennsylvania Plant		1.4			1.8	1.8
		Rochdale Plant	1	1.1	1	0.51	0.41	0.41

TABLE 1b

Historic Mesothelioma Potencies (K_M) by Assessment Report

Fiber Type	Operation	Cohort	K _M					
			CPSC, 1983	EPA (1986)	HEL, 1991	H&D, 2000	B&C 2003	B&C 2008
Chrysotile	Mining	Asbestos, Quebec					0.013	0.012
	Milling	Thetford, Mines					0.021	0.021
	Friction Products	Connecticut Plant			0		0	0
	Cement Manufacture	New Orleans Plants				.245*	0.2	0.2
Crocidolite	Textiles	South Carolina Plant					0.25	0.15
	Mining and Milling	Wittenoon				12	7.9	12
Amosite	Insulation	Paterson, NJ	5.7	3.2	3.2	4.8	3.9	3.9
	Cement Manufacture	Ontario, Canada	12	12	12	27	18	18
		New Orleans Plants				.415*	0.3	0.3
Mixed	Factory Workers	Asbestos, Quebec					0.092	0.095
	Insulation Application	US Insulation Workers	1.5	1.5	1.5	1	1.3	1.3
	Textiles	Pennsylvania Plant				1.7	1.1	1.4
		Rochdale Plant		0.7	1	1.7	1.3	1.3

Table 2 Technical Differences in Air Monitoring Fiber Counting Methodologies

Counting Method	Fiber Type	Method of Preparation	Fiber size (µ)		Aspect Ratio	Magnification
			Length	Width		
NIOSH Method 7400	Non specific	Indirect Transfer	> 5	n/a	> or = 3:1	400X
Asbestos, AHERA (ATEM)	Asbestos specific	Indirect Transfer	≥0.5	UD	> or = 5:1	15,000X-20,000X
Yamate (ATEM)	Asbestos specific	Direct Transfer	UD	UD	> or = 3:1	20000X
PCMe* (ATEM)	Asbestos specific	Direct Transfer	> 0.5 - 5.0	< 3	> or = 3:1	10,000X

* Modified from the ISO 10312 technique.

UD= Undefined

Modified from Table 4-2, EPA Superfund Website accessed 20111204

Table 3

Historical Values of a Statistical Life

Historical Values of a Statistical Life		
Agency	Value (\$ Mil.)	Adj. \$2000 (\$ Mil.)
DOT, 1990	1.5	2.0
DOA, 1996a	1.6	1.8
DOH, 1996	2.5	2.7
DOT, 1996a	2.7	3.0
EPA, 1988	3.0	4.4
DOH, 1991	3.0	3.8
DOT, 1996b	3.0	3.3
DOA, 1994	1.5	1.7
DOA, 1994	3.0	3.5
EPA, 1997	4.8	5.1
EPA, 1996a	4.8	5.3
DOH, 1996b	5.0	5.5
DOH, 1997	5.0	5.3
EPA, 1996b	5.5	6.0
EPA, 1998	5.6	5.8
EPA, 1999a	5.8	6.0
EPA, 2001	6.1	5.9
EPA, 1999b	5.8	6.0
EPA, 2010 <i>Draft</i>	7.4	5.8
	<i>Avg.</i>	4.4

*Adapted from Sunstein, 2001a

Table 4a**Summary of Arithmetic Mean Air Sampling Concentrations per Activity**

	Personal Data		Ambient Data		Residential
	S&R	C&R	S&R	C&R	
OSHA	0.0087	0.0007	0.0039	0.0001	
Early US-EPA	0.0017		0.0154		
NYCSCA-TEM	0.016		0.0465		
US-EPA 914-915			0.018		
US-EPA 924			0.004		
US-EPA 922-924				0.005	
NYCSCA-Lower Mn. Schools				0.0045	
NYCSCA-Outer Boro Schools				0.0022	
NYSDEC			0.004	0.004	
Ambient Residential Data					
Arithmetic Mean	0.0088	0.0007	0.0153	0.0032	0.0053

S&R=Search & Rescue Operations; C&R=Clean-up & Recovery Operations

- 1) Data includes ATEM air sample results where asbestos has been confirmed. Personal samples, representative of occupational exposures, were collected from the breathing zone of workers using low air volumes.
- 2) Clean & Recovery Operations conducted from September 30, 2001 through March 30, 2002.
- 3) Search & Rescue operations conducted from September 12, 2001 through September 29, 2001.

Table 4b**Summary of Air Sampling Results with Lifetime Exposure Calculations from WTC Dusts**

	Ambient Data				Personal Data	
	Exposure (af/mL)	Cum. Env. Exp. (af/mL- vrs)	Cum. Occ. Exp. (af/mL- vrs)	LADE (af/mL- yrs)	Occ. Exposure (af/mL)	Cum. Occ. Exp. (af/mL- vrs)
Search & Rescue - Mean	0.015	0.0008	0.003	0.00001	0.009	0.0002
Clean-up & Recovery - Mean	0.003	0.002	0.007	0.00002	0.0007	0.00002
Residential - Mean	0.005	0.004	0.02	0.0001		

- 1) Search & Rescue and Clean-up & Recovery data includes both personal and high volume samples. Personal samples collected from the breathing zone of workers using low air volumes. When provided the 8-Hr TWA was used.
- 2) Residential ambient samples collected from fixed locations in and around Ground Zero using higher air volumes through June 30, 2002.
- 3) Search & Rescue operations conducted from September 12, 2001 through September 29, 2001.
- 4) Clean & Recovery Operations conducted from September 30, 2001 through March 30, 2002.
- 5) LADE calculated using the cumulative environmental exposure divided by 70 years per EPA.
- 6) ATEM data was used, and identified asbestos fibers were considered equivalent to asbestos structures.

Table 5

Summary Table for No. Excess Cancer Deaths from Asbestos Based on Risk Assessment Method

	Ambient Data				Personal Data			
	H&D, 2000			EPA	H&D, 2000			EPA
	Meso	LC	Sum	All	Meso	LC	Sum	All
18-Day Search & Rescue - Mean	0.001	0.04	0.04	10	0.0001	0.003	0.003	26
182-Day Clean-up & Recovery - Mean	0.002	0.09	0.09	25	0.00001	0.0003	0.0003	2
280-Day Residential - Mean	0.006	0.3	0.3	50				

1) Search & Rescue and Clean-up & Recovery data includes both personal and high volume samples. Personal samples collected from the breathing zone of workers using low air volumes. When provided the 8-Hr TWA was used.

2) Residential ambient samples collected from fixed locations in and around Ground Zero using higher air volumes through June 30, 2002.

3) Search & Rescue operations conducted from September 12, 2001 through September 29, 2001.

4) Clean & Recovery Operations conducted from September 30, 2001 through March 30, 2002.

5) ATEM data was used, and identified asbestos fibers were considered equivalent to asbestos structures.

6) Cumulative exposures based on worst-case (highest air monitoring data) can be up to 23-times greater.

Table 6

**US-EPA based Exposure
Project Analysis Decision Matrix**

PROJECT ANALYSIS*			
Scenarios	Cost (\$ Million)	BCR⁺	Comments
(Do everything) Scenario #1 (Avg.) [50]	\$ 138	70	Go Decision. BCR > 1
(Sp. Equip.) Scenario #2 (Avg.) [50]	\$ 122	80	Go Decision. BCR > 1
(Cleaning) Scenario #3 (Avg.) [50]	\$ 17	586	Go Decision. BCR > 1

PRIVATE ANALYSIS*			
Scenarios	Cost (\$ Million)	BCR⁺	Comments
(Do everything) Scenario #1 (Avg.) [50]	\$ 138	52	Go Decision. BCR > 1
(Sp. Equip.) Scenario #2 (Avg.) [50]	\$ 122	60	Go Decision. BCR > 1
(Cleaning) Scenario #3 (Avg.) [50]	\$ 17	439	Go Decision. BCR > 1

EFFICIENCY ANALYSIS*			
Scenarios	Cost (\$ Million)	BCR⁺	Comments
(Do everything) Scenario #1 (Avg.) [50]	\$ 138	53	Go Decision. BCR > 1
(Sp. Equip.) Scenario #2 (Avg.) [50]	\$ 122	66	Go Decision. BCR > 1
(Cleaning) Scenario #3 (Avg.) [50]	\$ 17	488	Go Decision. BCR > 1

* Based on 280-Day Residential Exposures.

[#] denote number of excess asbestos-related cancer deaths calculated.

Scenario #1-Included are all costs associated with the FEMA purchases of specialized / replacement equipment for residents and providing specialty contractors to conduct the surface dust clean-up with environmental consultants performing clearance air sampling.

Scenario #2-Included are costs to supply only specialized / replacement equipment to the residents of lower Manhattan to aid in effectively cleaning their residences. No other services provided.

Scenario #3-Costs include having specialty contractors perform cleaning with oversight from environmental consultants.

+ Other indecies calculated include Net Present Value, and Internal Rate of Return. All decissions from these calculations were comparable to the BCR.

Cumulative exposures based on worst-case (highest air monitoring data) can be up to 23-times greater.

Table 7

**Hodgson Darnton based Exposure
Project Analysis Decision Matrix**

PROJECT ANALYSIS				
Scenarios	Cost (\$ Million)	BCR+	Go/No Go	Comments
(Do everything) Scenario #1 (Avg.) [1]	\$ 138	1.0	No Go	No Go decision. Negative NPV at 3%
(Sp. Equip.) Scenario #2 (Avg.) [1]	\$ 122	1.0	No Go	No Go decision. Negative NPV at 3%
(Cleaning) Scenario #3 (Avg.) [1]	\$ 17	0.8	No Go	No Go decision. BCR < 1.

PRIVATE ANALYSIS				
Scenarios	Cost (\$ Million)	BCR+	Go/No Go	Comments
(Do everything) Scenario #1 (Avg.) [1]	\$ 138	1.0	No Go	No Go decision. Negative NPV at 3%
(Sp. Equip.) Scenario #2 (Avg.) [1]	\$ 122	1.0	No Go	No Go decision. Negative NPV at 3%
(Cleaning) Scenario #3 (Avg.) [1]	\$ 17	0.8	No Go	No Go decision. BCR < 1.

EFFICIENCY ANALYSIS				
Scenarios	Cost (\$ Million)	BCR+	Go/No Go	Comments
(Do everything) Scenario #1 (Avg.) [1]	\$ 138	1.0	No Go	No Go decision. Negative NPV at 3%
(Sp. Equip.) Scenario #2 (Avg.) [1]	\$ 122	1.0	No Go	No Go decision. Negative NPV at 3%
(Cleaning) Scenario #3 (Avg.) [1]	\$ 17	0.8	No Go	No Go decision. BCR < 1.

* Based on 280-Day Residential Exposures.

[#] denote number of excess asbestos-related cancer deaths calculated.

Scenario #1-Included are all costs associated with the FEMA purchases of specialized / replacement equipment for residents and providing specialty contractors to conduct the surface dust clean-up with environmental consultants performing clearance air sampling.

Scenario #2-Included are costs to supply only specialized / replacement equipment to the residents of lower Manhattan to aid in effectively cleaning their residences. No other services provided.

Scenario #3-Costs include having specialty contractors perform cleaning with oversight from environmental consultants.

+Other indecies used for a BCR equal to 1 was the Net Present Values, and Internal Rates of Return. Both of these decision parameters confirm a No-Go decision.

Cumulative exposures based on worst-case (highest air monitoring data) can be up to 23-times greater.

APPENDIX A – FREEDOM OF INFORMATION ACT RESPONSES

New York State Department of Environmental Conservation
Division of Environmental Remediation
Bureau of Spill Prevention & Response, 11th Floor
625 Broadway, Albany, New York 12233-7020
Phone: (518) 402-9543 • **FAX:** (518) 402-9577
Website: www.dec.state.ny.us



Erin M. Crotty
Commissioner

August 30, 2002

Mr. Benjamin M. Sallemi
253 Lincoln Blvd.
Emerson, New Jersey 07630

Dear Mr. Sallemi:

Enclosed you will find two copies of the World Trade Center Data set that you requested on CD-ROM.

The data is contained within individual files. You should be aware that some of the data in these files had not undergone final QA/QC at the time the file was received by this office (in most cases it is annotated in the file). In some cases we did not receive final copies from the originating agency.

If you have any questions regarding the data on the enclosed CD-ROMs please contact myself or the originating agency who is responsible for the data. I will help you in any manner that I can.

Sincerely,

Matt Darcangelo
Environmental Engineer I



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
EPA Region 2, 290 Broadway, 26th Floor (PAD)
NEW YORK, NY 10007

Request Acknowledgment

March 12, 2003

Mr. Benjamin Sallemi
GSUC - CUNY
253 Lincoln Blvd.
Emerson, NJ 07630

RE: Freedom of Information Act (FOIA), 5 U.S.C. 552
Request No. **02-RIN-00975-03**

Dear Mr. Sallemi:

Thank you for your FOIA request, dated March 11, 2003, and received in this office on March 11, 2003, for records related to RESIDENTIAL DUST CLEAN-UP PROGRAM LOWER MANHATTAN, NY. The Agency has twenty (20) working days to respond to your request, except when you have agreed to an alternate due date or unusual circumstances exist that would require an extension of time under 5 U.S.C. 552(a)(6)(B). Please be advised that in accordance with the EPA's revised FOIA regulations (40 CFR 2.100, et. seq.), effective November 5, 2002, the Agency's fees for processing requests have changed. The new fee schedule is as follows:

- Clerical staff time billed at \$4.00 per 15 minutes of search and/or review
- Professional staff time billed at \$7.00 per 15 minutes of search and/or review
- Managers' time billed at \$10.25 per 15 minutes of search and/or review
- No fee will be charged for services at or below \$14.00
- Assurance of payment of fees above \$25.00 will be obtained from the requester before commencing any work
- Advance payment of fees above \$250 may be required by the Agency before commencing any work

We hope to respond to you soon. In the interim, please contact us if you have any questions about your request. Please cite your FOIA request number in all communications.

Sincerely,

A handwritten signature in black ink, appearing to read "Wanda Caldwell".

Freedom of Information Officer - Public Affairs
Division
Office: (212)637-3668
Fax: (212)637-5046



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION 2
290 BROADWAY
NEW YORK, NY 10007-1866

MAR 25 2003

Benjamin Sallemi
253 Lincoln Boulevard
Emerson, NJ 07630

RE: Freedom of Information Act Request (02-RIN-00975-03)

This is in response to the above-referenced Freedom of Information Act request. You requested the following information specific to the Environmental Protection Agency's (EPA) Indoor Air Residential Assistance Program that the EPA is jointly conducting with the City of New York's Department of Environmental Protection (DEP):

- Formula, development documents, and derivation of the 0.0009 f/cc clearance criteria utilized in the cleanup program and why this criteria was used
 - ▶ The derivation of this value is contained in the draft "Contaminants of Potential Concern" document which is available electronically on the following website: www.tera.org
- Any maps or database information to date
 - ▶ Maps and downloadable information on ambient sampling are available on EPA's website: www.epa.gov/wtc.
- Access to PCMe air sampling results to date
 - ▶ This information is contained on the enclosed CD - one file (FOIA_Residential) is apartment data although specific locations have been redacted to protect residents privacy. The second file contains results from common spaces (e.g., hallways and stairways).

If there are any questions I can be contacted at 212 637-3450.

Sincerely,

A handwritten signature in blue ink that reads "A. Carpenter".

Angela Carpenter
New York City

Response & Recovery Operations Team



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
EPA Region 2, 290 Broadway, 26th Floor (PAD)
NEW YORK, NY 10007

Request Acknowledgment

September 11, 2003

Mr. BENJAMIN SALLEMI
GSUC - CUNY
253 LINCOLN BLVD
Emerson, NJ 07630

RE: Freedom of Information Act (FOIA), 5 U.S.C. 552
Request No. **02-RIN-02100-03**

Dear Mr. SALLEMI:

Thank you for your FOIA request, dated September 3, 2003, and received in this office on September 8, 2003, for records related to WTC. The Agency has twenty (20) working days to respond to your request, except when you have agreed to an alternate due date or unusual circumstances exist that would require an extension of time under 5 U.S.C. 552(a)(6)(B). Please be advised that in accordance with the EPA's revised FOIA regulations (40 CFR 2.100, et. seq.), effective November 5, 2002, the Agency's fees for processing requests have changed. The new fee schedule is as follows:

- Clerical staff time billed at \$4.00 per 15 minutes of search and/or review
- Professional staff time billed at \$7.00 per 15 minutes of search and/or review
- Managers' time billed at \$10.25 per 15 minutes of search and/or review
- No fee will be charged for services at or below \$14.00
- Assurance of payment of fees above \$25.00 will be obtained from the requester before commencing any work
- Advance payment of fees above \$250 may be required by the Agency before commencing any work

We hope to respond to you soon. In the interim, please contact us if you have any questions about your request. Please cite your FOIA request number in all communications.

Freedom of Information Officer - Public Affairs
Division
Office: (212)637-3668
Fax: (212)637-5046



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION 2
290 BROADWAY
NEW YORK, NY 10007-1866

OCT 21 2003

Mr. Benjamin M. Sallemi
GSUC - CUNY
253 Lincoln Boulevard
Emerson, New Jersey 07630

Re: FOIA 02-RIN-2100-03

Dear Mr. Sallemi:

This is in response to your request for information under the Freedom of Information Act, dated September 3, 2003, requesting all asbestos information pertaining to the Residential Dust Clean-up Program in Lower Manhattan. Enclosed is a cd-rom disk containing the asbestos sampling information we have collected. The sampling locations are reported by the zip code and census tract information associated with each sample result. The data is provided in a pipe delimited text format. If you need assistance in retrieving data from this disk you may contact me at 212 637 3559. Your request has been classified as an educational request and there is no fee for the information.

Sincerely,

A handwritten signature in purple ink that reads "D. Santella".

Dennis Santella
Data and Risk Assessment Team
New York City Response and Recovery Operations



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 2
290 BROADWAY
NEW YORK, NY 10007-1866

FEB 26 2004

Mr. Benjamin M. Sallemi
GSUC - CUNY
253 Lincoln Boulevard
Emerson, New Jersey 07630

Dear Mr. Sallemi:

This is in response to your letter, dated February 5, 2004, requesting ArcView or ArcGIS shape files related to the Residential Dust Clean-up Program in Lower Manhattan, New York. Specifically you requested shapefiles for all roads, buildings, parks, clean-up quadrants, former WTC buildings, etc.; and indicated that you understood that certain proprietary information would be withheld.

In response to your request we have enclosed a CD with shapefiles and documentation for the following themes: Cleanup Quadrants, Census Tracts and Statistical Summary Areas. A number of the shapefile layers you requested (buildings, parks, and roads) do not belong to EPA, but are proprietary information licensed to EPA by New York City. Under that license, EPA is required to direct requests to the data to the city agency responsible for maintenance and access to the information. You should contact the New York City directly to request these data sets:

Marcia D. Kaunitz
Director of City-Wide Geographic Information Systems
NYC Department of Information Technology and Telecommunications
11 MetroTech Center
Brooklyn, NY 11201
212-232-1114
MKaunitz@doitt.nyc.gov

Sincerely,

A handwritten signature in purple ink that reads "D. Santella".

Dennis Santella
Data and Risk Assessment Team
New York City Response and Recovery Operations

Enclosure (CD)



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Region 2, 290 Broadway, 26th Floor
New York, NY 10007
212-637-3668
212-637-5046 (fax)
Calderon.Wanda@epa.gov

May 08, 2007

Mr. Benjamin Sallemi
GSUC - CUNY
253 Lincoln Blvd.
Emerson, NJ, 07630
United States

RE: Request No: 02-RIN-01328-07

Dear Mr. Sallemi,

This is to acknowledge receipt of your Freedom of Information Act (FOIA), 5 U.S.C. 552, request dated April 30, 2007 and received in this office on May 04, 2007, for records related to:

WTC residential dust clean-up

The program(s) office(s) that have been assigned this request will be responding to you directly. The Agency has twenty (20) working days to respond to your request, except when you have agreed to an alternate due date or unusual circumstances exist that would require an extension of time under 5 U.S.C. 552 (a) (6) (B).

Include your FOIA request number in all subsequent communications with respect to this assignment. Additionally, for faster processing you may provide your email address.

Thank you.

Respectfully,


Wanda Calderon
FOIA Specialist

Counsel's Office

Re: Freedom of Information Law Request

Our File No. 2007-0372 Your File No. _____

Receipt is acknowledged of the Freedom of Information Law request contained in your correspondence dated 6/21/07 and received in this office on 7/3/07.

We are in the process of obtaining and reviewing the materials to which you have requested access. We will advise as to those documents to which access can be granted and the cost for same as soon as possible.

It is estimated that it will take approximately 20 business days to process this request.

JAC

CO 40 (5-07)

Very truly yours,

Maria L. Colavito

Maria L. Colavito
Records Access Officer

Counsel's Office
New York State
Department of Labor
Albany - (518) 457-4380



Benjamin Sallemi
GSUC - CUNY
253 Lincoln Rd.
Emerson, NJ 07630

38750





New York State Department of Labor

Elliot Spitzer, Governor

M. Patricia Smith, Commissioner

August 8, 2007

Benjamin Sallemi
GSUC-CUNY
253 Lincoln Blvd.
Emerson, NJ 07630

Re: Freedom of Information
Law Request/Sallemi
Our File No.: FL 07-0372

Dear Mr. Sallemi:

Receipt is acknowledged of the Freedom of Information Law request contained in your correspondence dated June 21, 2007 received at this office July 5, 2007 .

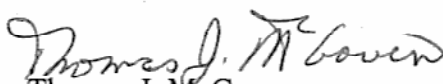
In response to your request our records show the following information:

<u>Item.</u>	<u>Units</u>	<u>Cost</u>
Air Purifiers	119, 872	\$43,027,220
Air Filters	96, 609	\$18,324,258
HEPA Vacuums	122, 791	\$26,804,335
Wet/Dry Vacuums	42, 003	\$ 3,892,926
Air Conditioners	83, 655	\$37,648,534

The statutory charge of \$.25 per page for copying is waived due to the minimal number of copies.

Very truly yours,

Maria L. Colavito
Records Access Officer

By: 
Thomas J. McGovern
Legal Assistant II

MLC:TJM:

Analytical Contracts

EMSL	\$1,988,283.30
Paradigm	\$1,418,920.00
Scientific Laboratories	\$280,608.00
Enviroscience Consultants	\$83,250.00
Eastern Analytical Services	\$255,652.38
ATC Associates	<u>\$47,200.00</u>
	\$4,073,913.68

Data Validation Contract (QATS)

Shaw Environmental	\$293,698.10
--------------------	---------------------

112

\$4,367,611.78 Total



THE CITY OF NEW YORK DEPARTMENT OF ENVIRONMENTAL PROTECTION
Emily Lloyd, Commissioner

Robert C. Avallroni
Deputy Commissioner

Bureau of
Environmental Compliance

PHONE (718) 595-3677
FAX (718) 595-3648

December 12, 2007

Benjamin Sallemi
253 Lincoln Blvd
Emerson, NJ 07630

Re: Ground Zero Remediation Costs

Dear Mr. Sallemi:

In response to your Freedom of Information Law request, dated 12-6-07, the
Asbestos Control Program has searched its files and has located the requested documents.

There are 8 pages, which required photocopying at a charge of \$.25 per page. Please remit a
check or money order in the amount of \$ 2.00 payable to the Department of Environmental
Protection.

- Violations: _____
- Sample Results: _____
- Inspection Reports: _____
- ACP7: _____
- ACP5: _____
- Other: _____

If you have any questions, please do not hesitate to contact me at (718) 595-3677.

Sincerely,

Josianne Dieudonné
Josianne Dieudonné

Open Agreement Header by Document Inquiry

Agreement ID: CT 826 20030010730 Payee/Vendor Number: 000185588E PIN: 82603WTCIARD

Name: TERMON CONSTRUCTION INC. Contract Title: WTC INDOOR DUST CLEAN ARD Contract Status: Active

Contact: TOM HEAVEY Phone: 718 694-0900 Mod Number: 0008 Buyer: / /

Contract Desc: CLEANING OF APTS IN VICINITY OF WORLD TRADE CENTER Transaction Date: 10 / 25 / 02

Resp Person: Resp Org: 826 Resp Org: 826 Last Modification Date: 08 / 21 / 05

Submitting Div Agcy: 826 Submitting Org: Total Amount of Changes: 279,298.00 OCA Number: 0000417789

Vendor: Contract 1 | Contract 2 | Amount Details | Controls | Renewal |

Total Quantity	2.000	Encumbered Amount	2,219,789.96	Original Max Contract Amount	4,199,499.40
Freight Indicator	None	Received Amount	0.00	Revised Max Contract Amount	4,478,797.40
Freight Amount	0.00	Inspection Amount	0.00	SI Drawdown Amount	0.00
FOB Point	Destination	Invoiced Amount	0.00	Retainage Outstanding	0.00
Discount Off List %	0.00000	Outstanding Amount	0.00	Req Contract Usage	0.00
Discount Amount	0.00	Expended Amount	2,219,789.96		
Trade Discount %	0.00000	Closed Amount	2,219,789.96	Closed Date	08 / 21 / 05
Trade Discount Amount	0.00				

Estimated Encumbrance					
Fiscal Year 1	2,279,298.00	Fiscal Year 2	2,199,499.40	Fiscal Year 3	0.00
Fiscal Year 4	0.00	Fiscal Year 5	0.00	Fiscal Year 6	0.00
Fiscal Year 7	0.00	Fiscal Year 8	0.00	Fiscal Year 9	0.00
Fiscal Year 10	0.00				

Open Agreement Header by Document Inquiry

Agreement ID	CT 826	20030010446	Payee/Vendor Number	0000545107	PIN	82603WTCIARA
Name	TRIO ASBESTOS REMOVAL CORP			Contract Title		
Contact	CHRIS HORAN			Phone		
Contract Desc	CLEANING OF APTS IN VICINITY OF WTC					
Resp Person	Transaction Date					
Resp Div Agency	826	Resp Org	Last Modification Date			
Submitting Div Agency	826	Submitting Org	Total Amount of Changes			
Vendor	Contract 1	Contract 2	Amount Details	Controls	Renewal	
Total Quantity	2.000		Encumbered Amount	2,406,219.43	Original Max Contract Amount	3,976,104.00
Freight Indicator	None		Received Amount	0.00	Revised Max Contract Amount	4,723,930.00
Freight Amount	0.00		Inspection Amount	0.00	SI Drawdown Amount	0.00
FOB Point	Destination		Invoiced Amount	0.00	Retainage Outstanding	0.00
Discount Off List %	0.00000		Outstanding Amount	0.00	Req Contract Usage	0.00
Discount Amount	0.00		Expended Amount	2,406,219.43		
Trade Discount %	0.00000		Closed Amount	2,406,219.43	Closed Date	06 / 25 / 04
Trade Discount Amount	0.00					

Estimated Encumbrance	
Fiscal Year 1	0.00
Fiscal Year 2	1,976,104.00
Fiscal Year 3	0.00
Fiscal Year 4	0.00
Fiscal Year 5	0.00
Fiscal Year 6	0.00
Fiscal Year 7	0.00
Fiscal Year 8	0.00
Fiscal Year 9	0.00
Fiscal Year 10	0.00

Open Agreement Header by Document Inquiry

Agreement ID: CT 826 20030010468 Payee/Vendor Number 0000569587 PIN 82603WTCIARB

Name: JBH ENVIRONMENTAL INC. Contract Title: WTC INDOOR DUST ARB

Contact: BORIS MERCKIN Phone: Contract Status: Active

Contract Desc: CLEANING OF APTS IN VICINITY OF WTC

Resp Person: Transaction Date: 10 / 22 / 02

Resp Dtl Agency: 826 Resp Org: Last Modification Date: 06 / 28 / 04

Submitting Dtl Agency: 826 Submitting Org: Total Amount of Changes: 629,127.00

Vendor: Contract 1 | Contract 2 | Amount Details | Controls | Renewal |

Total Quantity	2.000	Encumbered Amount	1,966,732.50	Original Max Contract Amount	4,595,600.00
Freight Indicator	None	Received Amount	0.00	Revised Max Contract Amount	5,224,727.00
Freight Amount	0.00	Inspection Amount	0.00	SI Drawdown Amount	0.00
FOB Point	Destination	Invoiced Amount	0.00	Retainage Outstanding	0.00
Discount Off List %	0.00000	Outstanding Amount	0.00	Req Contract Usage	0.00
Discount Amount	0.00	Expended Amount	1,966,732.50		
Trade Discount %	0.00000	Closed Amount	1,966,732.50	Closed Date	06 / 25 / 04
Trade Discount Amount	0.00				

Estimated Encumbrance	
Fiscal Year 1	2,629,127.00
Fiscal Year 2	2,595,600.00
Fiscal Year 3	0.00
Fiscal Year 4	0.00
Fiscal Year 5	0.00
Fiscal Year 6	0.00
Fiscal Year 7	0.00
Fiscal Year 8	0.00
Fiscal Year 9	0.00
Fiscal Year 10	0.00

Open Agreement Header by Document Inquiry

Agreement ID: CT 826 20030010705 Payee/Vendor Number: 000131588E PIN: 826WTCIARC

Name: KISS CONSTRUCTION, INC. Contract Title: WTC INDOOR DUST CLEAN ARC

Contact: GARRETT MEAGAN Phone: 718 366-2090 Contract Status: Active

Contract Desc: CLEANING OF APTS IN VICINITY OF WTC Mod Number: 0008

Resp Person: Transaction Date: 10 / 25 / 02 Buyer:

Resp Dtl Agency: 826 Resp Org: Last Modification Date: 06 / 28 / 04 Last Print Date: / /

Submitting Dtl Agency: 826 Submitting Org: Total Amount of Charges: 431,104.00 OCA Number: 0000473374

Vendor: Contract 1 | Contract 2 Amount Details | Controls | Renewal |

Total Quantity	2.000	Encumbered Amount	1,894,116.70	Original Max Contract Amount	4,333,734.00
Freight Indicator	None	Received Amount	0.00	Revised Max Contract Amount	4,764,838.00
Freight Amount	0.00	Inspection Amount	0.00	SI Drawdown Amount	0.00
FOB Point	Destination	Invoiced Amount	0.00	Retainage Outstanding	0.00
Discount Off List %	0.00000	Outstanding Amount	0.00	Req Contract Usage	0.00
Discount Amount	0.00	Expended Amount	1,894,116.70		
Trade Discount %	0.00000	Closed Amount	1,894,116.70	Closed Date	06 / 25 / 04
Trade Discount Amount	0.00				

Estimated Encumbrance					
Fiscal Year 1	2,431,104.00	Fiscal Year 2	2,333,734.00	Fiscal Year 3	0.00
Fiscal Year 4	0.00	Fiscal Year 5	0.00	Fiscal Year 6	0.00
Fiscal Year 7	0.00	Fiscal Year 8	0.00	Fiscal Year 9	0.00
Fiscal Year 10	0.00				

Open Agreement Header by Document Inquiry

Agreement ID: CT 826 20030010717 Payee/Vendor Number: 0001019247 PIN: 82603WTCIAMD

Name: ATHENICA ENV. SERV. INC. Contract Title: WTC INDOOR DUST MON.AMD Contract Status: Active

Contact: _____ Phone: _____ Mod Number: 0007 Buyer: _____

Contract Desc: MONITORING OF APTS IN VICINITY OF WTC Transaction Date: 10 / 25 / 02

Resp Person: _____ Last Modification Date: 06 / 28 / 04

Resp Dist Agency: 826 Resp Org: _____ Total Amount of Changes: 178,752.00

Submitting Dist Agency: 826 Submitting Org: _____

Vendor: Contract 1 | Contract 2 | Amount Details | Controls | Renewal | OCA Number: 0000421711

Total Quantity	2.000	Encumbered Amount	1,232,302.00	Original Max Contract Amount	2,367,600.00
Freight Indicator	None	Received Amount	0.00	Revised Max Contract Amount	2,546,352.00
Freight Amount	0.00	Inspection Amount	0.00	SI Drawdown Amount	0.00
FOB Point	Destination	Invoiced Amount	0.00	Retainage Outstanding	0.00
Discount Off List %	0.00000	Outstanding Amount	0.00	Req Contract Usage	0.00
Discount Amount	0.00	Expended Amount	1,232,302.00		
Trade Discount %	0.00000	Closed Amount	1,232,302.00	Closed Date	06 / 25 / 04
Trade Discount Amount	0.00				

Estimated Encumbrance					
Fiscal Year 1	2,178,752.00	Fiscal Year 2	367,600.00	Fiscal Year 3	0.00
Fiscal Year 4	0.00	Fiscal Year 5	0.00	Fiscal Year 6	0.00
Fiscal Year 7	0.00	Fiscal Year 8	0.00	Fiscal Year 9	0.00
Fiscal Year 10	0.00				

Open Agreement Header by Document Inquiry

Agreement ID: CT 826 20030010692 Payee/Vendor Number: 000085516E PIN: 82603WTCIAMC

Name: WARREN & PANZER ENGINEERS, PC Contract Title: WTC INDOOR AIR DUST MON AMC Contract Status: Active

Contact: JEFFERY TERHUNE Phone: 212 922-0077 Mod Number: 0007 Buyer: / /

Contract Desc: MONITORING OF APTS IN VICINITY OF WTC Transaction Date: 10 / 25 / 02 Last Print Date: / /

Resp Person: 826 Resp Org: 826 Last Modification Date: 06 / 28 / 04 OCA Number: 0000473409

Submitting Div Agcy: 826 Submitting Org: Contract 1 | Contract 2 | Controls | Renewal |

Total Amount of Changes: 214,887.00

Amount Details: Encumbered Amount: 2,000 Received Amount: 1,179,750.59 Original Max Contract Amount: 2,720,675.00

None Inspection Amount: 0.00 Revised Max Contract Amount: 2,935,562.00

Destination Invoiced Amount: 0.00 SI Drawdown Amount: 0.00

0.00000 Outstanding Amount: 0.00 Retainage Outstanding: 0.00

0.00000 Expended Amount: 1,179,750.59 Req Contract Usage: 0.00

0.00000 Closed Amount: 1,179,750.59 Closed Date: 06 / 25 / 04

Trade Discount Amount: 0.00

Estimated Encumbrance

Fiscal Year 1: 2,214,887.00 Fiscal Year 2: 720,675.00 Fiscal Year 3: 0.00

Fiscal Year 4: 0.00 Fiscal Year 5: 0.00 Fiscal Year 6: 0.00

Fiscal Year 7: 0.00 Fiscal Year 8: 0.00 Fiscal Year 9: 0.00

Fiscal Year 10: 0.00

Open Agreement Header by Document Inquiry

Agreement ID	CT 826	20030010736	Payee/Vendor Number	0000884560	PIN	82603WTCIAMB
Name	COLE CONSULTING CORP.		Contract Title	WTC INDOOR DUST MON AMB		
Contact			Phone			
Contract Desc	MONITORING OF APTS IN VICINITY OF WTC					
Resp Person						
Resp Div Agency	826	Resp Org	Transaction Date			
Submitting Div Agency	826	Submitting Org	Last Modification Date			
			Total Amount of Changes			
Vendor	Contract 1	Contract 2	Amount Details	Controls	Renewal	
Total Quantity	2.000	Encumbered Amount	1,247,200.75	Original Max Contract Amount	2,358,375.00	
Flight Indicator	None	Received Amount	0.00	Revised Max Contract Amount	2,519,250.00	
Flight Amount	0.00	Inspection Amount	0.00	SI Drawdown Amount	0.00	
FOB Point	Destination	Invoiced Amount	0.00	Retainage Outstanding	0.00	
Discount Off List %	0.00000	Outstanding Amount	0.00	Req Contract Usage	0.00	
Discount Amount	0.00	Expended Amount	1,247,200.75			
Trade Discount %	0.00000	Closed Amount	1,247,200.75	Closed Date	06 / 25 / 04	
Trade Discount Amount	0.00					
Estimated Encumbrance						
Fiscal Year 1	2,160,875.00	Fiscal Year 2	358,375.00	Fiscal Year 3	0.00	
Fiscal Year 4	0.00	Fiscal Year 5	0.00	Fiscal Year 6	0.00	
Fiscal Year 7	0.00	Fiscal Year 8	0.00	Fiscal Year 9	0.00	
Fiscal Year 10	0.00					

Open Agreement Header by Document Inquiry

Agreement ID: CT 826 20030010463 Payee/Vendor Number: 0001113379 PIN: 82603WTCAMA

Name: ATC ASSOCIATES INC. Contract Title: WTC INDOOR AIR DUST -AMA Contract Status: Active

Contact: Phone: Mod Number: 0013

Contract Desc: MONITORING OF APTS IN VICINITY OF WTC Buyer: / /

Resp Person: Transaction Date: 10 / 22 / 02 Last Print Date: / /

Resp Div Agency: 826 Resp Org: Last Modification Date: 10 / 16 / 06

Submitting Div Agency: 826 Submitting Org: Total Amount of Changes: 325,824.00 OCA Number: 0000421705

Vendor: Contract 1 | Contract 2 | Amount Details | Controls | Renewal |

Total Quantity	2.000	Encumbered Amount	1,315,899.60	Original Max Contract Amount	2,996,750.00
Freight Indicator	None	Received Amount	0.00	Revised Max Contract Amount	3,322,574.00
Freight Amount	0.00	Inspection Amount	0.00	SI Drawdown Amount	0.00
FOB Point	Destination	Invoiced Amount	0.00	Retainage Outstanding	0.00
Discount Off List %	0.0000	Outstanding Amount	0.00	Req Contract Usage	0.00
Discount Amount	0.00	Expended Amount	1,315,899.60		
Trade Discount %	0.0000	Closed Amount	1,315,899.60	Closed Date	10 / 16 / 06
Trade Discount Amount	0.00				

Estimated Encumbrance

Fiscal Year 1	2,325,824.00	Fiscal Year 2	996,750.00	Fiscal Year 3	0.00
Fiscal Year 4	0.00	Fiscal Year 5	0.00	Fiscal Year 6	0.00
Fiscal Year 7	0.00	Fiscal Year 8	0.00	Fiscal Year 9	0.00
Fiscal Year 10	0.00				

**APPENDIX B - COPIES OF SPREADSHEET CALCULATIONS FOR LIFETIME
ASBESTOS-RELATED CANCER RISK**

Ground Zero Cumulative Occupational 18-Day Mean Ambient Exposure During Search & Rescue Operations

<p align="center">Hodson & Darnton, 2000</p> $O_M = \frac{R_M * E_{CA} * T_{POP}}{100}$ <p>Assumptions: Cumulative Occ. Exp.= 0.003 f/mL-yr $E_{CA} = 0.003$ f/mL-yr $R_M = 0.001$ $T_{POP} = 27,697$ Pop.= 54,308</p> <p>$O_M = 0.001$ No. of Mesothelioma Cases Lower Manhattan for Chrysotile</p> <p>$O_M / O_{POP} = 0.00000002$</p>	<p align="center">EPA's All-Cause Asbestos Related Risk Calculations</p> <p>EPA Unit Risk = 0.23 f/mL</p> <p>Assumptions: No asbestos fiber type considerations Cumulative Asbestos related risk (lung cancer & Meso) No consideration for smokers Occupational exposures are 4.38 times greater than environmental exposures</p> <p>Exposure Estimates: LADE AVG= f/mL Working Exposure= N/A f/mL Cum. Env. Exposure= 0.0008 f/mL</p> <p>All cause asbestos related risk= Unit Risk * Env. Exposure * Population</p> <p>All cause asbestos related risk= 10 in Lower Manhattan based on environmental exposures</p>
<p>Assumptions: 8% of smokers develop LC 90% of LC found in smokers 1/5 of Lower Manhattan Residents smoke (NYC DHMH)</p> <p>$Obs_L = \frac{R_L * E_{CA} * Exp_L}{100}$</p> <p>30 Yr. Working Exposure= 0.081 f/mL-yr $R_L = 0.062$ $Exp_L = 782$</p> <p>No. of expected LC Deaths</p> <p>$Obs_L = 782$ $Obs_L - Exp_L = 0.04$</p>	

Ground Zero Cumulative Occupational 182-Day Mean Ambient Exposure During Clean-up & Recovery Operations

<p align="center">Hodson & Darnton, 2000</p> $O_M = \frac{R_M * E_{CA} * T_{POP}}{100}$ <p>Assumptions: Cumulative Occ. Exp.= 0.007 f/mL-yr $E_{CA} = 0.007$ f/mL-yr $R_M = 0.001$ $T_{POP} = 27,697$ Pop.= 54,308</p> <p>$O_M = 0.002$ No. of Mesothelioma Cases Lower Manhattan for Chrysotile</p> <p>$O_M / O_{POP} = 0.00000004$</p>	<p align="center">EPA's All-Cause Asbestos Related Risk Calculations</p> <p>EPA Unit Risk = 0.23 f/mL</p> <p>Assumptions: No asbestos fiber type considerations Cumulative Asbestos related risk (lung cancer & Meso) No consideration for smokers Occupational exposures are 4.38 times greater than environmental exposures</p> <p>Exposure Estimates: LADE AVG= f/mL Working Exposure= N/A f/mL Cum. Env. Exposure= 0.002 f/mL</p> <p>All cause asbestos related risk= Unit Risk * Env. Exposure * Population</p> <p>All cause asbestos related risk= 25 in Lower Manhattan based on environmental exposures</p>
<p>Assumptions: 8% of smokers develop LC 90% of LC found in smokers 1/5 of Lower Manhattan Residents smoke (NYC DHMH)</p> <p>$Obs_L = \frac{R_L * E_{CA} * Exp_L}{100}$</p> <p>30 Yr. Working Exposure= 0.189 f/mL-yr $R_L = 0.062$ $Exp_L = 782$</p> <p>No. of expected LC Deaths</p> <p>$Obs_L = 782$ $Obs_L - Exp_L = \mathbf{0.09}$</p>	

Ground Zero Cumulative Occupational 280-Day Mean Ambient Residential Exposure

<p align="center">Hodson & Darnton, 2000</p> $O_M = \frac{R_M * E_{CA} * T_{POP}}{100}$ <p>Assumptions: Cumulative Occ. Exp.= 0.02 f/mL-yr E_{CA}= 0.02 f/mL-yr R_M= 0.001 T_{POP}= 27,697 Pop.= 54,308</p> <p>O_M= 0.006 No. of Mesothelioma Cases Lower Manhattan for Chrysotile</p> <p>O_M/O_{POP}= 0.0000001</p>	<p align="center">EPA's All-Cause Asbestos Related Risk Calculations</p> <p>EPA Unit Risk = 0.23 f/mL</p> <p>Assumptions: No asbestos fiber type considerations Cumulative Asbestos related risk (lung cancer & Meso) No consideration for smokers Occupational exposures are 4.38 times greater than environmental exposures</p> <p>Exposure Estimates: LADE AVG= f/mL Working Exposure= N/A f/mL Cum. Env. Exposure= 0.004 f/mL</p> <p>All cause asbestos related risk= Unit Risk * Env. Exposure * Population</p> <p>All cause asbestos related risk= 50 in Lower Manhattan based on environmental exposures</p>
<p>Assumptions: 8% of smokers develop LC 90% of LC found in smokers 1/5 of Lower Manhattan Residents smoke (NYC DHMH)</p> <p>$Obs_L = \frac{R_L * E_{CA} * Exp_L}{100}$</p> <p>30 Yr. Working Exposure= 0.54 f/mL-yr R_L= 0.062 Exp_L= 782</p> <p>No. of expected LC Deaths</p> <p>Obs_L= 782 $Obs_L - Exp_L$= 0.3</p>	

Ground Zero Cumulative Occupational 18-Day Mean Personal Exposure During Search & Rescue Operations

Hodson & Darnton, 2000	
$O_M = \frac{R_M * E_{CA} * T_{POP}}{100}$	EPA's All-Cause Asbestos Related Risk Calculations
Assumptions: Cumulative Occ. Exp.= 0.0002 f/mL-yr $E_{CA} = 0.0002$ f/mL-yr $R_M = 0.001$ $T_{POP} = 27,697$ Pop.= 54,308	EPA Unit Risk = 0.23 f/mL Assumptions: No asbestos fiber type considerations Cumulative Asbestos related risk (lung cancer & Meso) No consideration for smokers Occupational exposures are 4.38 times greater than environmental exposures
$O_M = 0.0001$ No. of Mesothelioma Cases Lower Manhattan for Chrysotile $O_M / O_{Pop} = 0.000000001$	Exposure Estimates: LADE AVG= f/mL Working Exposure= N/A f/mL Cum. Env. Exposure= 0.002 f/mL
Assumptions: 8% of smokers develop LC 90% of LC found in smokers 1/5 of Lower Manhattan Residents smoke (NYC DHMH)	All cause asbestos related risk= Unit Risk * Env. Exposure * Population All cause asbestos related risk= 26 in Lower Manhattan based on environmental exposures

$O_M = \frac{R_M * E_{CA} * T_{POP}}{100}$	EPA's All-Cause Asbestos Related Risk Calculations
Assumptions: Cumulative Occ. Exp.= 0.0002 f/mL-yr $E_{CA} = 0.0002$ f/mL-yr $R_M = 0.001$ $T_{POP} = 27,697$ Pop.= 54,308	EPA Unit Risk = 0.23 f/mL Assumptions: No asbestos fiber type considerations Cumulative Asbestos related risk (lung cancer & Meso) No consideration for smokers Occupational exposures are 4.38 times greater than environmental exposures
$O_M = 0.0001$ No. of Mesothelioma Cases Lower Manhattan for Chrysotile $O_M / O_{Pop} = 0.000000001$	Exposure Estimates: LADE AVG= f/mL Working Exposure= N/A f/mL Cum. Env. Exposure= 0.002 f/mL
Assumptions: 8% of smokers develop LC 90% of LC found in smokers 1/5 of Lower Manhattan Residents smoke (NYC DHMH)	All cause asbestos related risk= Unit Risk * Env. Exposure * Population All cause asbestos related risk= 26 in Lower Manhattan based on environmental exposures

Ground Zero Cumulative Occupational 182-Day Mean Personal Exposure During Clean-up & Recovery Operations

<p align="center">Hodson & Darnton, 2000</p> $O_M = \frac{R_M * E_{CA} * T_{POP}}{100}$ <p>Assumptions: Cumulative Occ. Exp.= 0.00002 f/mL-yr $E_{CA} = 0.00002$ f/mL-yr $R_M = 0.001$ $T_{POP} = 27,697$ $Pop. = 54,308$</p> <p>$O_M = 0.00001$ No. of Mesothelioma Cases Lower Manhattan for Chrysotile</p> <p>$O_M / O_{POP} = 0.0000000001$</p>	<p align="center">EPA's All-Cause Asbestos Related Risk Calculations</p> <p>EPA Unit Risk = 0.23 f/mL</p> <p>Assumptions: No asbestos fiber type considerations Cumulative Asbestos related risk (lung cancer & Meso) No consideration for smokers Occupational exposures are 4.38 times greater than environmental exposures</p> <p>Exposure Estimates: LADE AVG= f/mL Working Exposure= N/A f/mL Cum. Env. Exposure= 0.0002 f/mL</p> <p>All cause asbestos related risk= Unit Risk * Env. Exposure * Population</p> <p>All cause asbestos related risk= 2 in Lower Manhattan based on environmental exposures</p>
<p>Assumptions: 8% of smokers develop LC 90% of LC found in smokers 1/5 of Lower Manhattan Residents smoke (NYC DHMH)</p> <p>$Obs_L = \frac{R_L * E_{CA} * Exp_L}{100}$</p> <p>30 Yr. Working Exposure= 0.00054 f/mL-yr $R_L = 0.062$ $Exp_L = 782$</p> <p>No. of expected LC Deaths</p> <p>$Obs_L = 782$ $Obs_L - Exp_L = \mathbf{0.0003}$</p>	

REFERENCES

- Arrow, K.J., Eads, G.C., Hahn, R.W., *et al.*, (1996) Benefit Cost Analysis and the Environment - Response to Kasting, J.F. and Schultz, P.A., *Science*, Volume 272, Number, 5268, Pages 1571-1573.
- Avraham, R. (2006) Putting a Price on Pain-and-Suffering Damages: A Critique of the Current Approaches and a Preliminary Proposal for Change, *Northwestern University Law Review*, Volume 100, Number 1, Pages 87-120.
- Berman, D.W., Crump, K.S., Chatfield, E.J., (1995) The Sizes, Shapes, and Mineralogy of Asbestos Structures that Induce Lung Tumors or Mesothelioma in AF/HAN Rates Following Inhalation, *Risk Analysis*, Volume 15, Number 2, Pages 181-195.
- Berman, D.W. and Crump, K.S. (2003) Final Draft: Technical Support Document for a Protocol to Assess Asbestos-Related Risk, Pages 1-474.
- Berman, D.W. and Crump, K.S. (2008a) Update of Potency Factors for Asbestos-Related Lung Cancer and Mesothelioma. *Critical Reviews in Toxicology*, Volume 38, Pages 1–47.
- Berman, D.W. and Crump, K.S. (2008b) A Meta-Analysis of Asbestos-Related Cancer Risk That Addresses Fiber Size and Mineral Type. *Critical Reviews in Toxicology*, Volume 38, Pages 49–73.
- Berman, D.W.(2010) Comparing milled fiber, Quebec ore, and textile factory dust: Has another piece of the asbestos puzzle fallen into place? *Critical Reviews in Toxicology*, Volume 40(2), Pages 151–188.
- Bernstein, D.M., Morscheidt, C., Grimm, H., (1996) Evaluation of Soluble Fibers using the Inhalation Biopersistence Model, a Nine-Fiber Comparison, *Inhalation Toxicology*, Volume 8, Pages 345-385.
- Bernstein, D.M, Chevalier, J., Smith, P., (2003a) Comparison of Calidria Chrysotile Asbestos to Pure Tremolite: Inhalation Biopersistence and Histopathology Following Short-Term Exposure *Inhalation Toxicology*, Volume 15, Pages 1387–1419.
- Bernstein, D.M., Rogers, R., Smith, P., (2003b) The Biopersistence Of Canadian Chrysotile Asbestos Following Inhalation. *Inhalation Toxicology*, Volume 15, Pages 1247–1274.
- Bernstein, D.M., Rogers, R., Smith, P., (2004) The Biopersistence of Brazilian Chrysotile Asbestos Following Inhalation, *Inhalation Toxicology*, Volume 16, Pages 745–761.
- Bernstein, D.M., Rogers, R., Smith, P., (2005a) The Biopersistence of Canadian Chrysotile Asbestos Following Inhalation: Final Results Through 1 Year After Cessation of Exposure, *Inhalation Toxicology*, Volume 17, Pages 1–14.

Bernstein, D.M, Chevalier, J., Smith, P., (2005b) Comparison of Calidria Chrysotile Asbestos to Pure Tremolite: Final Results of the Inhalation Biopersistence and Histopathology Examination Following Short-Term Exposure, *Inhalation Toxicology*, Volume 17, Pages 427–449.

Bernstein, D.M., Rogers, R., Smith, P., (2006a) The Toxicological Response of Brazilian Chrysotile Asbestos: A Multidose Subchronic 90-Day Inhalation Toxicology Study with 92-Day Recovery to Assess Cellular and Pathological Response, *Inhalation Toxicology*, Volume 18, Pages 313–332.

Bernstein D.M. and Hoskins, J.A., (2006b) The health effects of chrysotile: Current perspective based upon recent data, *Regulatory Toxicology and Pharmacology*, Pages 1-23.

Bernstein, D.M., Donaldson, K.A., Decker, U., *et al*, (2008) A Biopersistence Study following Exposure to Chrysotile Asbestos Alone or in Combination with Fine Particles, *Inhalation Toxicology*, Volume 20, Pages 1009–1028.

Boscarino, J.A., Galea, S., Adams, R., *et al.*, (2004), Mental health Service and Medication Use in New York City After the September 11, 2001, Terrorist Attack, *Psychiatric Services*, Volume 55, Number 3, pages 274-283.

Bostrom, A. (1997). Risk Perceptions: “Experts” Vs. “Lay People”, *Duke Environmental Law & Policy Forum*, Volume 8, Number 101, Pages 101-113.

Breyse, P.N., Williams, D.L, Herbstman, J.B., *et al.* (2005), Asbestos Exposures to Truck Drivers During World Trade Center Cleanup Operations. *Journal of Occupational and Environmental Hygiene*, Volume 2, Pages 400-405.

Campbell, H.F. and Brown, R.P.C., (2003) Benefit Cost Analysis: Financial and Economic Appraisal using Spreadsheets. *Cambridge University Press*.

Camus, M., Siemiatycki, J., Case, B.W., *et al.*, (2002) Risk of Mesothelioma Among Women Living Near Chrysotile Mines Versus US EPA Asbestos Risk Model: Preliminary Findings *Annals of Occupational Hygiene*, Volume 46, Supplement 1, Pages 95–98.

Center of Disease Control and Prevention Fact Sheet

http://www.cdc.gov/tobacco/data_statistics/fact_sheets/health_effects/tobacco_related_mortality/index.htm#men accessed November 19, 2011.

Chang, S., Long, S.R., Kutikova, L., *et al.*, (2004). Estimating the Cost of Cancer: Results on the Basis of Claims Data Analyses for Cancer Patients Diagnosed with Seven Types of Cancer During 1999 to 2000. *Journal of Clinical Oncology*, Volume 22, pages 3524-3530.

Chronic Hazard Advisory Panel (CHAP) on Asbestos (1983), U.S. Consumer Product Safety Commission, Pages 1-181.

Chatfield, E.J., and Kominsky, J.R., (2001). *Summary Report: Characterization of Particulate Found in Apartments after Destruction of the World Trade Center*, for the Ground Zero Elected Officials Task Force, Pages 1-50.

Contaminants of Potential Concern (COPC) Committee of the World Trade Center Indoor Air Task Force Working Group, (2003a), “*World Trade Center Indoor Environment Assessment: Selecting Contaminants of Potential Concern and Setting Health-Based Benchmarks*”, Pages 1-79.

Contaminants of Potential Concern (COPC) Committee of the World Trade Center Indoor Air Task Force Working Group, (2003b), “*World Trade Center Indoor Environment Assessment: Response to Peer Review Comments on the Report for Selecting Contaminants of Potential Concern and Setting Health-Based Benchmarks*”, Pages 1-27.

Contaminants of Potential Concern (COPC) Committee of the World Trade Center Indoor Air Task Force Working Group, 2004, “*Addendum/Errata to the report titled “World Trade Center Indoor Environment Assessment: Selecting Contaminants of Potential Concern and Setting Health-Based Benchmarks (May, 2003)”*”, Pages 1-3.

Dickie, M., and Gerking, S. (2002), Willingness to Pay for Reduced Morbidity. *USEPA Funded Research, R-82871701-0*, Pages 1-38.

Doll, R. (1955) Mortality from Lung Cancer in Asbestos Workers. *British Journal of Industrial Medicine*, Volume, 12, Pages 81–86.

Dreessen, W.C., Dallavalle, J.M., Edwards, T.I, *et al.*, (1938). A Study of Asbestosis in the Asbestos Textile Industry, *Public Health Bulletin*, Number 241, Pages 1-126.

Executive Order #12291 (1981) 46 FR 13193, 3 CFR, The White House.

Executive Order #12866 (1994) Regulatory Planning and Review, The White House.

Farrow, S. and Toman, M., (1998) Using Environmental Benefit-Cost Analysis to Improve Government Performance, *Resources for the Future*, Discussion Paper 99-11, Washington, D.C., Pages 1-16.

Gavett, S.H., Haykal-Coates, N., McGee, J.K., *et al.*, (2002). Toxicological Effects of Fine particulate Matter Derived from the Destruction of the World Trade Center, *EPA/600/R-02/028*, Pages 1-54.

Granger, H., McKee, T.R, Millette, J.R., *et al.*, (2001) Preliminary Health Hazard Assessment: World Trade Center, Submitted to American Industrial Hygiene Association, Pages 1-9.

Grether, D.M and Plott, C.R., (1979) Economic Theory of Choice and the Preference Reversal Phenomenon *The American Economic Review*, Volume 69, Number 4, Pages 623-638.

Hammond, E.C., Selikoff, I.J., and Siedman, H., (1979). Asbestos Exposure, Cigarette Smoking and Death Rates, *Annals of the New York Academy of Sciences*, Volume 330, Pages 473-490.

Health Effects Institute – Asbestos Research (HEI-AR, 1991). *Asbestos in Public and Commercial Buildings: A Literature Review and Synthesis of Current Knowledge*.

Hein, M.J., Stayner, L., Lehman, E., *et al.*, (2007) Follow-up study of chrysotile textile workers: cohort mortality and exposure-response, *Occupational Environmental Medicine*, Published online, Pages 1-24..

Hodgson, J.T., and Darnton, A. (2000) The Quantitative Risks of Mesothelioma and Lung Cancer in Relation to Asbestos Exposure. *Annals of Occupational Hygiene*, Volume 44, Pages 565-601.

Hoskins, J. (2001). Toxicological Insight into Low Level Exposure to Chrysotile. *The Health Effects of Chrysotile Asbestos: Contribution of Science to Risk-Management Decisions. Canadian Mineralogist, Special Publication 5*, Pages 251-260.

Ilgren, E.B., (2001) Health Risks from Exposure to Asbestos, Metals and Various Chemicals Due to Collapse of the World Trade Center: An Environmental Residential Survey with a Commentary Related to Ground Zero Workers. *Indoor & Built Environment*, Volume 10, Pages 361-383.

Jenkins (2001), World Trade Center Asbestos, *Memorandum to Lillian Bagus and Robert Dellinger*, dated December 3, 2001.

Kalton, G., Ferraro, D., Rizzo, L., (2004), Sample Design Options for the Survey of Apartments Participating in the World Trade Center Residential Clean-up Program, *Westat for US-EPA*, Pages 1-10.

Kasting, J.F., & Schultz, P.A., (1996) Benefit Cost Analysis and the Environment. *Science*, Volume 272, Number 5268, Pages 1571-1573.

Kelly, K.E., (1991) The Myth Of 10^{-6} As A Definition Of Acceptable Risk, *84th Annual Meeting, Air & Waste Management Association*, Vancouver, B.C., Canada, Pages 1-9.

Kopp, R. J., Krupnick, A.J., Toman, M., *et al.*, (1997). Cost Benefit Analysis and Regulatory Reform: An Assessment of the Science and the Art, *Resources for the Future*, Discussion Paper 97-19. Washington, DC, Pages 1-60.

Landrigan, P.J., Liroy, P.J., Thurston, G., *et al.*, (2004) Health and Environmental Consequences of the World Trade Center Disaster. *Environmental Health Perspectives World Trade Center Mini-Monograph*, Volume 112, Number 6, Pages 731-739.

Langer, A.M., Wolff, M.S., Rohl, A.N., *et al.* (1978) Variation of Properties of Chrysotile Asbestos Subjected to Milling. *Journal of Toxicology and Environmental Health*, Volume 4, Pages 173-188.

Langer, A.M. and Nolan, R.P., (1994a) Chrysotile: Its Occurrence and Properties as Variables Controlling Biological Effects. *Annals of Occupational Hygiene*, Volume 4, Pages 427-451.

Langer, A.M., and Nolan R.P., (1994b) Chrysotile Biopersistence in the Lungs of Persons in the General Population and Exposed Workers, *Environmental Health Perspectives*, Volume 102, Supplement 5, Pages 235-239.

Langer, A.M., (2001) Health Experience of Some U.S. and Canadian Workers Exposed to Asbestos; Foundation for Risk Assessment. *The Health Effects of Chrysotile Asbestos: Contribution of Science to Risk-Management Decisions. Canadian Mineralogist, Special Publication 5*, Pages 9-20.

Langer, A.M. and Morse, R.G., (2001), The World Trade Center Catastrophe: Was the Type of Spray Fire Proofing a Factor in the Collapse of the Twin Towers? *Indoor and Built Environment*, Volume 10, Number 6, Pages 350-360.

Langer, A.M., (2003), Reduction of the Biologic Potential of Chrysotile Asbestos Arising from Conditions of Service on Brake Pads, *Regulatory Toxicology and Pharmacology*, Volume 38, Pages 71-77.

Lethborg, C., Cox, S., Aranda, S., *et al.*, (2007) To What Extent does Meaning Mediate Adaptation to Cancer? The Relationship Between Physical Suffering, Meaning of Life, and Connection to Others in Adjustment to Cancer, *Palliative and Supportive Care*, Volume 5, Pages 377-388.

Lidell, F.D.K., McDonald, A.D., McDonald, J.C., *et al.*, (1997) The 1891-1920 Birth Cohort of Quebec Chrysotile Miners and Millers: Development from 1904 and Mortality to 1992. *Annals of Occupational Hygiene*, Volume 41, Number 1, Pages 13-36.

Lioy, P., Weisel, C.P., Millette, J.R., *et al.*, (2002) Characterization 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, *Environmental Health Perspectives World Trade Center Mini-Monograph*, Volume 110, Number 7, Pages 703-714.

Lorber, M., Kahn, H., White, P., *et al.* (2004), Discussion Options for World Trade Center Sampling *US-EPA*, Pages 1-19.

Mattei, S., (2003). Pollution and Deception at Ground Zero, *The Sierra Club*, Pages 1-197.

Mazurek, J.V. (1996), The Role of Health Risk Assessment and Cost-Benefit Analysis in Environmental Decision Making in Selected Countries: An Initial Survey. *Resources for the Future, Discussion Paper 96-36*. Washington, D.C., Pages 1-43.

- McDonald, J.C., (2010) Epidemiology of Malignant Mesothelioma—An Outline, *Annals of Occupational Hygiene*, Volume 54, Number 8, Pages 851–857.
- McGee, J.K., Chen, L.C., Cohen, M.D., *et al.*, (2003). Chemical Analysis of World Trade Center Fine Particulate Matter for Use in Toxicologic Assessment, *Environmental Health Perspectives, World Trade Center Mini-Monograph*, Volume 111, Number 7, Pages 972-980.
- Merewether, E.R.A, and Price, C.W., (1930) Report on Effects of Asbestos Dust in the Lungs and Dust Suppression in the Asbestos Industry. *Her Majesties Stationary Office*, London, Pages 1-34.
- Mossman, B.T., Bignon, J., Corn, M., *et al.*, (1990) Asbestos: Scientific Developments and Implication for Public Policy, *Science*, Volume 247, Number 4940, Pages 294-301.
- Nadler, J., (2002) Lower Manhattan Air Quality, *U.S. Congressman Jerrold Nadler, White Paper* Pages 1-29.
- National Institute for Occupational Safety and Health (NIOSH, 1994), Asbestos and Other Fibers by PCM, Method 7400. Manual of Analytical Methods, 4th Edition.
- National Emissions Standard for Hazardous Air Pollutants (NESHAPs, 1990). *40 CFR Part 61*.
- Nicholson W.J., (1986) *Airborne Asbestos Health Assessment Update*. United States Environmental Protection Agency, US-EPA-600/8-84/003F. Office of Health and Environmental Assessment, U.S. Environmental Protection Agency, Washington, DC.
- Nicholson, W.J. (1989) Airborne mineral fibre levels in the non-occupational environment. In: J Bignon, J Peto & R Saracci, Non-Occupational Exposure to Mineral Fibres, *International Agency for Research on Cancer Scientific Publications 90*: 239-261.
- Nicholson, W. J., Perkel, G., Selikoff, I.J., (1982). Occupational exposure to asbestos: population at risk and projected mortality--1980-2030. *American Journal of Industrial Medicine*, Volume 3(3), Pages 259-311.
- Nolan, R.P, Langer, A.M., Wilson, R., *et al.*, (1999). A Risk Assessment for Exposure To Gunerite Asbestos (Amosite) in an Iron Ore Mine. *National Academy of Sciences*, Volume 96, Pages 3412-3419.
- Nolan, R.P, Ross, M., Nord, G.L., *et al.*, (2005). Risk Assessment for Asbestos-Related Cancer From the 9/11 Attack on the World Trade Center. *Journal of Occupational and Environmental Medicine*. Volume 47, Pages 817-825.
- Nolan, R.P, Ross, M., Nord, G.L., *et al.* (2006) Asbestos Fiber-type and Mesothelioma Risk in the Republic of South Africa *Clay Science*, Volume 12, Supplement 2, Pages 223-227.

Nowinski, P.A., 1986, Chronology of Asbestos Regulation in United States Workplaces, Asbestos-Related Malignancy, , *Elsevier Science Health Science Division*, Chapter 5, Pages 99-134.

New York City Department of Environmental Protection (1991), Asbestos Rules and Regulations, *Rules of the City of New York, Title 15*, Chapter 1, Pages 1-67.

New York City Department of Health and Mental Hygiene / Agency for Toxic Substances Disease Registry (2002), Final Technical Report of the Public Health Investigation to Assess Potential Exposures to Airborne and Settled Surface Dust in Residential Areas of Lower Manhattan, *as part of the World Trade Center Environmental Assessment Working Group*, Pages 1-127.

New York State Department of Labor (1994), Asbestos, *Part 56 of Title 12 of the Official Compilation of Codes, Rules and Regulations of the State of New York*, Pages 1-66.

Ogden, T.L., (2007) Chrysotile Asbestos Consensus Statement and Summary, Chrysotile Asbestos Expert Panel, *Health Canada*, Pages 1-47.

Occupational Safety and Health Administration (OSHA, 1988) Toxic and Hazardous Substances, Asbestos, *29 CFR 1910.1001*.

Pierce, J.S., McKinley, M.A., Paultenbach, D.J., *et al*, (2008) An Evaluation of Reported No-Effect Chrysotile Asbestos Exposures for Lung Cancer and Mesothelioma. *Critical Reviews in Toxicology*, Volume 38, Pages 191–214.

Price B., and Ware A., (2004) Mesothelioma Trends in the United States: An Update Based on Surveillance, Epidemiology, and End Results Program Data for 1973 through 2003, *American Journal of Epidemiology*, Volume 159, Pages 107 - 112.

Rogli, V.L., Vollmer, R.T., Batnor, K.J., *et al.*, (2002) Tremolite & Mesothelioma, *Annals of Occupational Hygiene*, Volume 46, Number 5, Pages 447-453.

Ross, M., and Nolan, R.P., (2003) History of Asbestos Discovery and Use and Asbestos Related Disease in Context with the Occurrence of Asbestos with Ophiolite Complexes, *Geological Society of America*, Special Paper 373, Pages 447-470.

Saarino, L., Arman, M., Ekstrand, P., (2011) Power Relations in Patient's Experience of Suffering During Treatment for Cancer, *Journal of Advanced Nursing*, Volume 68, Pages 271-279.

Sinha, P., Depro, B., Braum, F., (2010), Regulatory Impact Analysis for Existing Stationary Compression Ignition Engines, *NESHAPs Report 452/R-10-002* for US-EPA, Pages 1-147.

Stayner, L., Kuempel, E., Gilbert, S., *et al*, (2007) Respiratory Disease Risk in Exposed Workers Asbestos Fiber Dimensions in Determining an Epidemiologic Study of the Role of Chrysotile, *Occupational Environmental Medicine*, published online 20 Dec 2007.

Sunstein, C.R., (2001) Cost-Benefit Default Principals, *Michigan Law Review*, Volume 99, Number 7, Pages 1651-1723.

Sunstein, C.R., (2004) Lives, Life-Years, and Willingness to Pay, *Columbia Law Review*, Volume 104, Pages 205-252.

Tweeddale, G. and McCulloch, J. (2004). Chrysophiles versus Chrysophobes: The White Asbestos Controversy, 1950s–2004 *The University of Chicago Press on behalf of The History of Science Society*, Volume 95, Number 2, Pages 239-259.

US-DOL, (2011). Consumer Price Index. All Cities. Web Access, <ftp://ftp.bls.gov/pub/special.requests/cpi/cpi.ai.txt>, November 23, 2011.

US-EPA, (2003a), 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, *EPA/600/R-03/142*, Pages 1-119.

US-EPA, (2003b). World Trade Center Background Study Report, Interim Final, prepared for FEMA, *IAG No.: EMW-2002-IA-0127*, Pages 1-85.

US-EPA-OIG, (2003), EPA's Response to the World Trade Center Collapse: Challenges, Successes, and Areas for Improvement, *Report No. 2003-P-00012*, Pages 1-165.

US-EPA, (2003c), Interim Final WTC Residential Confirmation Cleaning Study, Volume 1 & 2, Pages 1-171.

US-EPA, (2005). World Trade Center Residential Dust Cleanup Program, Final Report, Pages 1-217.

US-EPA, (2004), Draft Proposed Sampling Program to Determine Extent of World Trade Center Impacts to the Indoor Environment, *EPA/600/R-04/169A*, Pages 1-36.

US-EPA Web-site, http://www.epa.gov/wtc/copc_study.htm, accessed August 31, 2005.

US-EPA Web-site, <http://yosemite.epa.gov/ee/epa/eed.nsf/pages/MortalityRiskValuation.html>, accessed September 13, 2011.

US-EPA, Integrated Risk Information System. Asbestos (CASRN 1332-21-4). Available online at <http://www.epa.gov/iris/subst/0371.htm>. Accessed August 31, 2005.

US-EPA, Asbestos Hazard Emergency Response Act (AHERA), 1987. *Final Rule and Notice for Asbestos-Containing materials in Schools* (40 CFR part 763).

US-EPA, Asbestos School Hazard Abatement Reauthorization Act (ASHARA), 1990 *Public Law No: 101-637*.

Van Oss, C.J., Naim, J.O., Costanzo, P.M., *et al.*, (1999), Impact of Different Asbestos Species and Other Mineral Particles on Pulmonary Pathogenesis. *Clays and Clay Minerals*, Volume 47, Number 6, Pages 697-707.

Wagner, J.C., Berry, G., Skidmore, J.W., *et al.* (1974) The Effects of the Inhalation of Asbestos in Rats, *British Journal of Cancer*, Volume 29, Pages 252-269.

WTC Community-Labor Coalition, (2005). WTC Community-Labor Coalition Comments on EPA's Draft Proposed Sampling Program to Determine Extent of World Trade Center Impacts to the Indoor Environment, Pages 1-32.

WTC Health Registry: <http://www.nyc.gov/html/doh/wtc/html/registry/about3.shtml> accessed September 4, 2011

Yabroff, K. R., Lamont, E.B., Marriotto, A., *et al.*, (2008). Cost of Care for Elderly Cancer Patients in the United States, *Journal National Cancer Institute*, Volume 100, Pages 630-641.

Yarborough, C.M., (2006) Chrysotile as a Cause of Mesothelioma: An Assessment Based on Epidemiology *Critical Reviews in Toxicology*, Volume 36, Pages 165–187.