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ASBESTOS CONTAMINATION OF THE AIR IN PUBLIC BUILDINGS

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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by

William J. Nicholson, Arthur N. Rohl, and Irving Weisman

Mount Sinai School of Medicine
City University of New York
New York, N.Y.

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EPA Project Officer: Alan J. Hoffman

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16. ABSTRACT

From 1958 through 1973 asbestos-containing material was used extensively for fireproofing high-rise office buildings. Earlier use of this material for decorative and acoustical purposes dates from the mid-1930's. Concern exists that these past uses of asbestos may lead to current contamination of building air. This may occur either through damage or erosion of acoustical spray materials or through erosion into building air supply systems of asbestos fibers from spray-lined plenum spaces in office buildings. In order to assess such possibilities, 116 samples of indoor and outdoor air have been analyzed for asbestos. Nineteen buildings in five United States cities were chosen to represent the various construction uses of asbestos-containing spray materials. The results of this sampling and analysis demonstrate that significant contamination can occur in the air supply systems of buildings in which fibrous type-dry spray asbestos-containing fireproofing materials were used. Moreover, erosion of similar materials applied for decorative or acoustical purposes was also found to occur. In contrast, no contamination was demonstrable in buildings in which cementitious spray material had been used. The contamination demonstrated here was manifest only through analysis procedures using electron microscopy. Optical microscopic analysis of building air was found to be inappropriate.

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From 1958 through 1973 asbestos-containing material was used extensively for fireproofing high-rise office buildings. Earlier use of this material for decorative and acoustical purposes dates from the mid-1930's. Concern exists that these past uses of asbestos may lead to current contamination of building air. This may occur either through damage or erosion of acoustical spray materials or through erosion into building air supply systems of asbestos fibers from spray-lined plenum spaces in office buildings.

In order to assess such possibilities, 116 samples of indoor and outdoor air have been analyzed for asbestos. Nineteen buildings in five United States cities were chosen to represent the various construction uses of asbestos-containing spray materials.

The results of this sampling and analysis demonstrate that significant contamination can occur in the air supply systems of buildings in which fibrous type-dry spray asbestos-containing fireproofing materials were used. Moreover, erosion of similar materials applied for decorative or acoustical purposes was also found to occur. In contrast, no contamination was demonstrable in buildings in which cementitious spray material had been used. The contamination demonstrated here was manifest only through analysis procedures using electron microscopy. Optical microscopic analysis of building air was found to be inappropriate.

Because of possible health effects associated with such contamination of public buildings, it is recommended that:

1) An inspection and monitoring system be developed that will verify the integrity of asbestos spray material used for acoustical or decorative purposes.
2) Periodic spot sampling and analysis of air in buildings using cementitious fireproofing material be made to verify continued safety.
3) Additional sampling and analysis programs be undertaken in buildings where fibrous spray fireproofing has been used so as to define the full extent of the problem.
4) An effective and economically feasible filtration system be developed for those buildings now sprayed with such fibrous materials.
5) Procedures be developed for maintenance activities that may be required in asbestos-sprayed spaces, and
6) Procedures be developed and specified for used in those buildings in which asbestos is to be removed because of unacceptable contamination.
7) The suitability of proposed EPA building demolition procedures for buildings with extensive spray asbestos be verified.

Introduction

A. Development of Asbestos-Containing Spray Insulation Materials

Sprayed inorganic fiber insulation was introduced in 1932 with the Limpet process, by the J.W. Roberts Company of Great Britain. Mr. N.L. Dolbey, Director of Research for this company, is usually acknowledged as the pioneer developer. British Railway coach makers used the sprayed product containing asbestos in their coaches to control condensation and noise; it also acted as a thermal insulating material. In 1935 the spray process was first used in the United States. Most of the material applied during the late 1930's was used for decorative finishes in night clubs, restaurants, hotels, etc.

When this material was found also to be useful as a fireproofing agent, such use gradually increased, and in 1950 the National Gypsum Company obtained the Underwriters Laboratories' approval of its brand of spray insulation for fireproofing. In early 1951 the Asbestospray Company also had an inorganic fiber blend tested and approved by the Underwriters Laboratories. The first use of sprayed "mineral fiber" as a fireproofing agent in a large multiple-story building occurred in 1958 with the erection of the sixty-story Chase Manhattan Bank building in New York City. In 1970, well over half of all the large multistory buildings constructed in this country made use of sprayed "inorganic fiber" as a fireproofing agent. (1)

Mineral fiber materials containing asbestos have four major insulation uses in the construction and shipyard industries: 1. fireproofing, 2. thermal insulation, 3. acoustical and decorative purposes, and 4. condensation control. Fireproofing accounts for the largest amount of mineral fiber sprayed in the United States. Formerly, structural steel in multistory buildings had to be encased in concrete to prevent buckling in the event of fire. The use of sprayed mineral fiber provides adequate fire protection, reduces installation costs, and reduces the weight load upon structural steel components.

Because the newly applied surface of sprayed mineral fiber can be shaped, the material not only provides good acoustical control but also can be used for decorative ceiling and wall coatings for large areas in public buildings, restaurants, and similar establishments.

Although the composition of the various spray products will vary with the intended use and the individual manufacturer, certain general formulations are similar. Most are termed "mineral fiber" materials, although naturally occurring mineral fibers are usually in a minority, and man-made organic fibers dominate.

The material used for fireproofing in building construction usually is a blend of 5 to 30% asbestos fiber (chrysotile), mineral wool, clay binders (as bentonite), adhesives, synthetic resins, and other proprietary agents, such as oils. The material used for acoustical and decorative purposes may contain a greater percentage of mineral wool and little or no asbestos fiber. Some materials are applied as a sprayed slurry (commonly known as cementitious spray) and will often contain vermiculite, gypsum, and shorter asbestos fibers. Because the cementitious material has a much greater density and increased weight per unit area, the supporting structure must be designed accordingly.

There are two principal methods of applying sprayed mineral fiber In the dry method, dry material, including binders, is dumped from a paper shipping bag into a large hopper, where the material is agitated and subsequently blown into a 2- or 4-inch hose. The hose conveys the dry material to a nozzle at the actual site of application. As the dry material leaves the nozzle, it passes through the focus of a ring of fine water jets. Mixing takes place at this focal point, which is usually 4 to 8 inches from the end of the nozzle, The operator is able to control the air, material, and water mix, with valves at the nozzle. This produces a fibrous matrix held to the steel by the water-activated binders.

The wet method differs in that the material is premixed with water in the hopper, and the resulting slurry is pumped to the nozzle and sprayed upon the surface to be coated. The nozzle used is similar to that used to apply plaster. The Portland cement and gypsum present in the cementitious wet mix provide a bond to building steelwork. Of the two application procedures, the surface produced by the cementitious procedure is significantly less friable.

B Extent of Use of Asbestos Spray Insulation

The quantity of mineral fiber used for spray applications in the United States increased steadily from 1958 through 1970. Spray industry sources (2) estimated that 40,000 tons of material were used for fireproofing alone in 1968. In 1969 and 1970, a survey of asbestos emissions in New York City was accompanied by a survey of buildings under construction using spray fireproofing material (see Appendix 1). These major office buildings in Manhattan used, over a two-year period, in excess of 2,000 tons of spray fireproofing material, estimated to contain approximately 700 tons of asbestos. Smaller buildings and construction in other boroughs would use perhaps an equal amount of asbestos material.

The majority of the spray fireproofing material applied in New York City was of the fibrous, dry sprayed, type. This also found extensive use in other eastern metropolitan areas. In contrast, on the west coast, cementitious type material dominated, while in the central portions of the country, a mix of the two occurred. Considering the use in different areas, it is estimated that approximately equal amounts of asbestos were applied by the two methods.

The extent of use of asbestos for decorative purposes is difficult to estimate. It is applied extensively in the dry fibrous form on ceilings and walls of auditoriums, night clubs, restaurants and many public buildings. Additionally, asbestos is commonly added to paints which are sprayed in apartment and office buildings to provide a textured surface. The extent of this use of asbestos is unknown. It apparently continues even today, in violation of the prohibition of sprayed asbestos containing materials.

C. Purpose of the Present Study

At the time this study was initiated, scant information existed on possible air contamination in public buildings from the past applications of asbestos containing fireproofing. To provide such information, a sampling and analysis program was initiated to determine the asbestos air concentration in a variety of buildings in five major U. S. cities. Through a comparison of the concentrations of asbestos measured within buildings to those measured in the ambient air, it would be possible to determine if erosion of asbestos from spray fireproofing occurred. Moreover, the magnitude of the asbestos concentrations would be useful in the assessment of potential health effects from such contamination.

Sampling Program

A. Identification and Selection of Buildings

Surveys were undertaken in New York City, in Chicago and in the San Francisco area to select buildings appropriate for this study. Additionally, arrangements were made through the regional office of the Environmental Protection Agency in Boston to sample the JFK Building in that city. In each of the three other areas, cooperation of local officials was obtained and the building selection program was accomplished by these local groups.

1. New York City

For logistical reasons, and because of its size, the greatest number of buildings selected for sampling were in New York City. Here, the cooperation of the Department of Air Resources was of paramount importance. The New York City effort was under the direction of Harold Romer, Consultant to the Commissioner of Air Resources. From Building Department records, spray asbestos industry sources and architectural firms, over 40 buildings in New York City were identified in which asbestos containing spray fireproofing was used within the air supply system or as acoustical covering in various rooms.

A questionnaire was developed to identify use of asbestos within these buildings (Appendix 2). The questionnaire was sent to the building manager of each of the identified buildings. This produced only a limited response and personal follow-up calls on each building manager were undertaken. These initial interviews obtained information about the type of air supply system used in the building and the use of asbestos fireproofing or acoustic material. Often, however, specific information on the brand of asbestos spray which had been used and the brand of sealant, if any, which had been used to coat the asbestos spray material could not be obtained. The interviews concluded with a tour through the equipment rooms which housed the fans for the ventilation and the air filtration systems. In all, ten buildings were selected for sampling.

2. Chicago

With the cooperation of the Department of Health (Dr. Murray Brown) and the Buildings Department (Mr. John Connelly), two buildings were selected in Chicago and a visit made to determine the suitability for sampling.

3. San Francisco - Berkeley

Building selection in the San Francisco area was made by the subcontractor, the Air and Industrial Hygiene Laboratory of the State Department of Health. Here, in order to provide a balance to the type of buildings sampled, specific emphasis was placed on selecting buildings in which cementitious fireproofing material had been used. Six buildings were selected, including one building that had no asbestos used in its construction. The buildings sampled were constructed

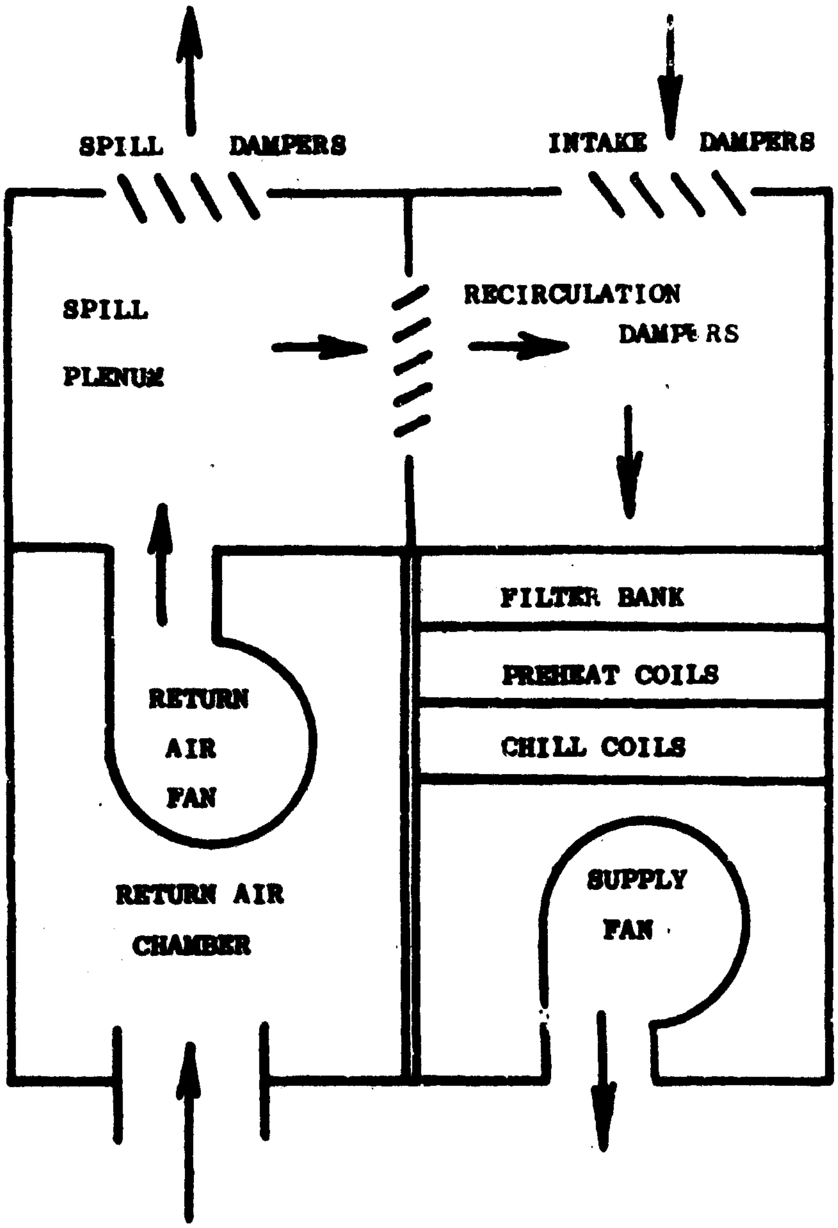

Figure 1

The air from the ceiling plenums is returned through the return air fan chamber to the spill plenum. There approximately 20% is exhausted and the remainder recirculated. The recirculated portion is mixed with fresh air from the intake dampers, filtered, conditioned (heated or cooled), and moved into the supply ducts by the supply fan.

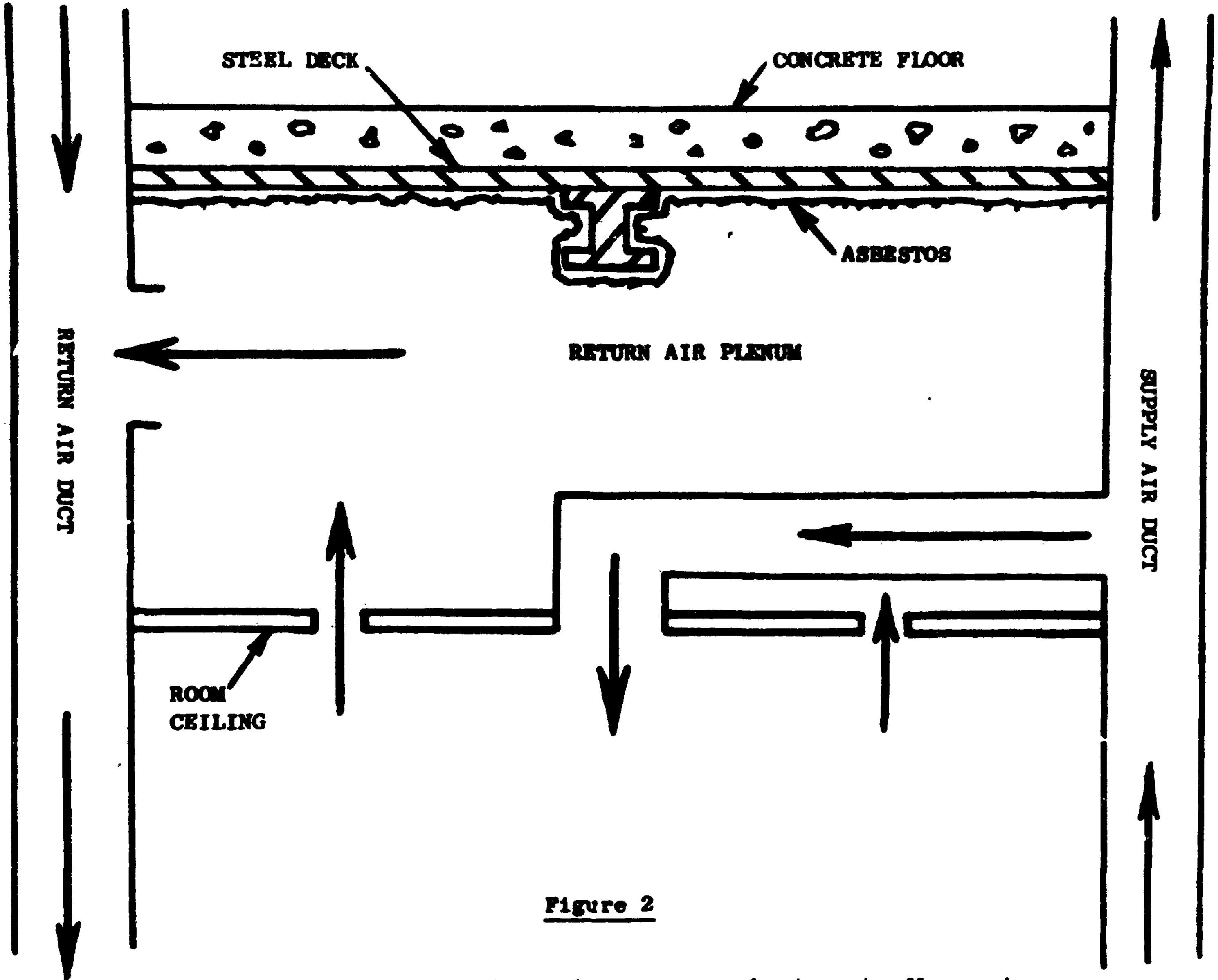

Figure 2

Cross-section of ceiling plenum space showing air flow and location of fibrous spray fireproofing covering structural members from 1958 through 1974.

4. Boston

The recently constructed JFK Building in Boston was selected by the EPA regional office as a potential building for sampling. The type of building construction and the materials used were determined locally and were verified by Mount Sinai personnel.

B Typical Air Ventilation Systems

1 Equipment Rooms

Large modern buildings, such as the 20 to 50 story office buildings sampled in this survey, have equipment rooms which take in fresh air and distribute conditioned air to each of 15 or 20 different floors depending on the horizontal dimensions of the building, the equipment room and its air supply systems may be divided into two, three, or four parallel vertical systems which service different sectors of the building Typically, a building will have one equipment room at approximately mid building elevation with its several parallel air supply systems, and a second equipment room at the top-most level with its several air supply systems Although details in layout vary from building to building, the essential features of the air flow are shown in Figures 1 and 2.

2. Air Supply

Large fans force the pre conditioned air into ducts made of sheet metal which are sometimes lined internally with acoustic fiberglass pads or boards in order to minimize the amount of fan noise which gets into the air ducts. The ducts lead to vertical risers which carry the air to the various floors for distribution by the local supply ducts These are usually externally insulated with fiberglass and aluminum foil insulation Local thermostats determine the amount of final cooling or heating of the air before it leaves the ducting and enters the room spaces through louvered ports

3. Ceiling Plenum and Return Air Fan

On each floor, the room air is exhausted into the ceiling plenum between the hung ceiling and the floor above. This plenum contains wiring ducts, and plumbing Most importantly, the underside of its upper surface is often covered with sprayed asbestos material which acts as fireproofing for the steel decking of the floor above The air exhausted into the plenum is thus exposed to the asbestos material

At several locations in each ceiling plenum, a sheet metal duct conducts the plenum air to a vertical masonry duct The air is then returned through this masonry duct to the return air fan chamber which may be lined with acoustical material made of fiberglass boards The surface of the boards is often protected from shedding into the air stream In some installations, the protection is merely chicken wire or expanded metal which provides a coarse physical restraint In other cases the surface is factory covered with an impregnated layer of fiberg[illegible] In still others, the fiberglass has a neoprene covering to prevent the fiberglass from shedding

4. **Spill Plenum and Intake Air**

The return air fan exhausts into a spill plenum. Depending on the temperature of the outside air and the building return air, the returned air may be entirely spilled to the outside, or may be recirculated to some degree. (See Damper Controls, below.)

The air to be recirculated passes through the recirculation dampers and mixes with fresh air which has been drawn through the intake dampers. The intake air is sometimes pre-filtered with coarse fiberglass filters which are typically 24"x24"x2". The mixed air is then drawn through the filter bank, which consists of multi-pocketed bags made of fiberglass or other fibrous materials.

5. **Damper Controls**

Three sets of dampers control the degree of recirculation and the amount of fresh air which is taken in. At the 100% outside air intake condition, all the returned air is spilled through the fully open spill dampers. In addition, the recirculation dampers are completely closed, and the intake dampers are completely open.

At the condition of minimum outside air intake, which occurs when the outside temperature is below 30° F, the spill dampers are selectively closed down so that only a few remain open to allow a minimum of the returned air to spill out of the return air plenum. In addition, the recirculation dampers are opened completely, and the intake dampers are closed down except for the minimum number which are mandated by the building code to remain open. This minimum is in the order of 20% fresh air intake at all times.

For conditions between 100% outside air intake and minimum outside air intake, the various dampers are modulated to permit some percentage of returned air to be spilled and for the rest to be mixed with the intake air and recirculated.

C. **Buildings Sampled**

The air in 19 buildings in the five cities was sampled. The buildings, and their type and use of asbestos, are shown in Table 1. The ratio between cementitious and fibrous type spray reflects the reported national use of these types of material.(2) Office buildings were the dominant type of structure sampled because of the preponderance of fireproofing material used in these structures and because of the number of people potentially exposed. Little spray fireproofing was used on apartment buildings. Additionally, a representative number of decorative and acoustic insulation uses of asbestos were sampled. The construction periods of the buildings ranged from 1958 through 1974, thus providing a representative sample of the effects of time on the possible erosion of asbestos.

The cities selected for sampling were chosen because of their importance as centers of construction activity and for travel convenience. Roughly 10% of all high-rise construction in the United States is in New York City. Chicago is also of obvious importance. San Franciscio, while having less construction activity than other major cities, provided a source of buildings with cementitious fireproofing (while New York provided an extensive source of buildings with fibrous spray fireproofing). Additionally, because of travel convenience, New York was the most extensively sampled. Cementitious and fibrous spray fireproofing shared equally in national usage. With the cities selected, we were able to achieve the same distribution among the buildings sampled in the cities selected.

Table 1

Buildings Sampled

	Type of Spray			Type of Building		
	Cementitious	Fibrous	Decorative Acoustic	Office	Apartment	Other
ons of ound						
	X			X		
h	X			X		
	X			X		
			X			X
		X		X		
			X		X	
	X			X		
			X			X
s		X		X		
		X		X		
		X		X		
		X (*)		X		
s		X		X		
	X			X		
			X			X
			X			X
		X		X		
	X			X		
	6	7	5	13	1	4
no spray materials used)						X

asbestos spray was utilized in this building

D. **Sampling Locations**

Samples were usually collected in the following locations:

1. Inside a return air fan chamber frequently located at the mid-building level. (This return air was most recently in contact with the fibrous spray material.)
2. An office whose air exhausts into the return air chamber and whose air supply is obtained from the air intake system located in the mid-building equipment room.
3. An outside roof or an air intake chamber before any mixing with return air has taken place. This air is ultimately fed to the office. The ambient air was usually sampled on the side of the building facing the prevailing winds so that the exhaust air of the building itself would not be sampled.
4. A second office at an upper level of the building whose air supply is derived from a supply system located in an upper equipment room.

Two consecutive days were set up with the building manager for the actual sampling times. The sampling equipment at each station consisted of:

a) a Millipore filter holder and filter,
b) a 10 liter per minute critical orifice in series with the filter, and
c) a vacuum pump.

In addition to the Millipore samples, small samples of the dirty air bag filters were taken, along with samples of the asbestos fireproofing spray material found in the ceiling plenums; also, samples of the acoustical fiberglass covering, if any, in the fan chambers or elsewhere. In all, 116 samples were collected from the buildings and ambient air.

E. **Sampling Procedures**

The air samples were collected on Millipore brand merbrane filters, 47mm diameter, 0.8μm pore size, mounted in a Millipore filter holder equipped with a 10 liter/min critical orifice at the vacuum end. The collecting surface of the filter was fully exposed to the air.

The filter holder was taped in a horizontal position (filter surface vertical) two or three feet above the floor, to a desk top or a chair leg so that no dust particles could fall directly on the filter surface. The filter holder was connected by means of a rubber hose two or three feet long to a vacuum pump which sat on the floor. Although the pumps were equipped with silencers and filters at both inlet and discharge ports, the pump noise was sufficiently high to be annoying to some office workers. The noise could be reduced somewhat by attaching a two-foot length of rubber hose to the discharge port.

The pumps were run for six to eight hours per sample, resulting in an average air volume of from 3 to 4 m^3 per sample in New York, Boston, and Chicago. Twenty-four-hour samples, with an air volume of about 7 m^3 were collected in San Francisco.

Results of Sample Analysis

A. Electron Microscopic Analysis

In the analysis of ambient air samples for asbestos, the presence of other organic and inorganic material presents significant problems. Typical urban air may contain 100 $\mu g/m^3$ of "suspended particulates." Such material is generally of respirable size and may include 25 to 50% of inorganic matter. In contrast, typical urban asbestos concentrations range from about 0.1 ng/m to perhaps 100 ng/m^3. Thus, asbestos may constitute only 0.0001 to 0.1% of the particulate matter present in a given air sample. Moreover, the asbestos found in the ambient air includes both micron-size fibers and numerous individual fibrils having diameters of from 20 to 40 nm and lengths of perhaps 100 nm. In many cases these fibers and fibrils may be agglomerated with a variety of other material present in the air sample. These considerations preclude the possibility of quantitative analysis of such ambient air samples by light microscopy, bulk spectroscopic techniques, or X-ray diffraction. The only effective analysis method has required the dispersion of mineral material, either by grinding or by ultrasonic disruption, and use of the electron microscope.

Following submission to the Environmental Protection Agency in North Carolina and coding, the 116 samples were analyzed using the technique described in Appendix 3. The results are listed in Table 2, along with a detailed description of the buildings, and a listing of the sampling parameters. Table 3 summarizes the sampling results by building site.

For each sample at least one grid square from four separate [illegible] grids was scanned. On about ten samples, usually those with exceptionally high values, eight grid squares were scanned from two sample preparations. In general, the scanning of additional squares yielded values approximating those originally obtained and the results were simply averaged. On one sample (73-000-128) a large clump was found on one grid square that yielded an extremely high mass value for the sample. Little was found on the reanalysis and the second value was adopted. The large clump was probably the result of contamination, as it would have been dispersed had it been present on the original sample.

The processing of blank filters with each set of four samples served to monitor contamination and provide a measure of laboratory background. These analyses indicated a background level of up to 10 ng existed, and this value was subtracted from the total mass of each sample tabulation. The variability in this background, however, could lead to a variation of up to 5 ng/m^3 in a given sample of the sets analyzed here. As the background is independent of the volume of air sampled, those samples with larger air volumes had the lower correction value.

Considerable variability exists in the air concentrations measured in the various buildings. Average values found for the air inside buildings range from 2.5 ng/m^3 to 200 ng/m^3, with individual measurements from 0 to over 800 ng/m^3. For the outside air, the variation for the average con-

Table 2 (i)

Building	Sample Location	Date	Total Flow (m^3)	Total Mass (ng)	Mass Conc. (ng/m^3)	Fiber Count	Fiber Conc. (f/ml)*	EPA Code No.	[illegible] State Code [illegible]
CALIFORNIA STATE HEALTH DEPARTMENT 2151 Berkeley Way Berkeley Cementitious spray (1966) in return air plenum.	Room B042	8-30-73	7	103	15			73-003-031	1A
	Room 2017	8-30	7	119	17	5	.0030	-032	1B
	Plenum Room 2017	8-30	6.9	18	2.6			-034	1D
	Outside	8-30	6.4	113	18			-033	1C
GREAT WESTERN BUILDING 2150 Shattuck Avenue Berkeley Cementitious in air plenum. Built in 1970	3 floor	9-10-73	5.5	40	7.3			73-003-035	2A
	Room 903	9-10	5.3	57	11	6	.0048	-036	2B
	Plenum Room 903	9-10	5.1	13	2.6			-038	2D
	Outside, Roof	9-10	4.8	24	5.0			-037	2C

Building	Sample Location	Date	Total Flow (m^3)	Total Mass (ng)	Mass Conc (ng/m^3)	Fiber Count	Fiber Conc. (f/ml)	EPA Code No	Mt. Sinai Code No
STUDENT CAFETERIA UNIV. OF CALIFORNIA Telegraph Avenue Berkeley **Exposed decorative acoustic spray** **Built in 1958**	**SW Balcony 3 floor**	**9-14-73**	**6.0**	**22**	3.7	1	.0007	73-003-039	3A
	Serving Area 2 floor	**9-14**	**6.0**	**16**	**2.7**			**-040**	**3B**
	Serving Area 3 floor	**9-14**	**6.4**	**0**	0			**-042**	**3E**
	Roof	**9-14**	**6.0**	**29**	**4.3**			**-041**	**3C**
HARMON'S GYM UNIV. OF CALIFORNIA Berkeley No asbestos - control building Built in 1932	**Room 175F**	**9-18-73**	**6.2**	**74**	**12**	**3**	.0020	73-003-043	4A
	Room 91	**9-18**	6.2	**14**	2.3			**-044**	4B
	Main Gym East Balc.	**9-18**	**7.5**	**55**	7.3	33	.0186	**-046**	4E
	Roof	**9-18**	**6.0**	0	0			-045	**4C**

Table 2 (iii)

Building	Sample Location	Date	Total Flow (m^3)	Total Mass (ng)	Mass Conc. (ng/m^3)	Fiber Count	Fiber Conc. (f/ml)	[illegible] Code No.	[illegible] Sims Code No.
WELLS FARGO BUILDING **44 Montgomery Avenue** **San Francisco** **Fibrous spray in return air plenum** **Built in 1966**	**Filtered Supply**	**10-18-73**	**5.6**	**0**	**0**			73-003-048	5B
	Return Air	**10-18**	**5.5**	**7**	**1.3**			-049	5C
	Room 4318	**10-18**	**6.6**	**163**	**25**			-050	5E
	Outside	**10-18**	**5.6**	**22**	**3.9**	**1**	.0008	-047	5A
METROPOLITAN LIFE BUILDING **425 Market Street** **San Francisco** **Cementitious spray in return plenum**	**5 floor**		**7.6**	**1372**	**180**	**8**	.0045	74-000-108	6A
	4 floor Open Office		**8.0**	**90**	**11**			-111	6E
	Return Air Plenum		**7.6**	**101**	**13**			-109	6B
	Outside Air 37 floor		**7.2**	**331**	**46**	**9**	.0053	-110	6C

Table 2 (iv)

Building	Sample Location	Date	Total Flow (m^3)	Total Mass (ng)	Mass Conc (ng/m^3)	Fiber Count	Fiber Conc ([illegible])	[illegible]	[illegible]
TURIN HOUSE [illegible]09 Columbus Avenue New York City Apartment Building Ornamental spray paint [illegible]% asbestos	Apt. 10A	10-11-73	2.8 9.6	2 70	0.7 7.3	3 0	.0046 0	73-003-051 -054	CA-1 CA-4
	Apt. 2B	10-11-73	2.7 9.6	20 167	7.4 17	9	.0040	-052 -055	-2 -5
	Roof 17 floor	10-11-73	2.7 9.6	88 34	32 3.5			-053 -056	[illegible] -6
JFK BUILDING Government Center Boston Cementitious spray in plenum Fibrous glass lined ducts	10 floor	8-16-73 8-17	2.38 10.65	16 16	6.7 1.5			73-003-058 -062	JFK-2 -6
	21 floor (EPA-R.O.)	8-16 8-17	2.0 10.33	21 12	10 1.2			-059 -060	-3 -1
	Air Intake 26 floor	8-16 8-17	2.65 10.7	26 3	9.8 0.3			-057 -061	-1 -2

Building	Sample Location	Date	Total Flow (m^3)	Total Mass (ng)	Mass Conc. (ng/m^3)	Fiber Count	Fiber Conc. (f/ml)	[illegible] Code No.	[illegible] Code No
STEINMAN BUILDING City College of the City University of New York New York City	Room 313 Office	10-17-73	3.3	516	160	4	.0051	73-003-063	ST-1
		10-18-73	10.8	359	33	3	.0012	-067	ST-5
Chem. Eng. Dept.	Room 324	10-17-73	3.29	72	21	1	.0012	-064	ST-2
Acoustical spray		10-18	10.68	39	3.7			-068	ST-6
	Room 301 Lab	10-17-73	3.15	73	23			-065	ST-3
		10-18	10.8	85	7.9	5	.0020	74-000-015	ST-7
	Roof 6 floor (outside)	10-17-73	3.27	284	87			73-003-066	ST-4
		10-18	10.6	105	9.9			74-000-016	ST-8
EXXON BUILDING 1251 Ave. of Americas New York City	11 floor Office Room 1150	12-11-73	3.30	0	0			74-000-017	1251-1
		12-12	4.05	111	27			-021	-5
		12-13	3.65	112	31	0	0	-025	-9
Offices, 54 floors	Room 2772 Computer Room	12-12-73	2.95	71	24	1	.0014	-022	-6
Cementitious (Mono-Kote) on outside structural members.		12-13	3.70	204	55	0	0	-026	-10
Spray-Don(A) on floor decking, i.e. fibrous asbestos spray	32 floor Vacant off (stagnant)	12-11	2.80	115	41	1	.001	-018	-2
Sealant used, but name unknown	Return Air Plenum - R4 15 floor	12-11-73	3.15	71	22			-020	-4
		12-12	2.95	0	0			-024	-8
Built June, 1972		12-13	3.70	132	36	10	.0114	-028	-12
	Outside Air 15 floor	12-11-73	3.25	37	11			-019	-3
		12-12	2.95	0	0			-023	-7
		12-13	3.70	49	13	4	.0046	-027	-11

Building	Sample Location	Date	Total Flow (m^3)	Total Mass (ng)	Mass Conc. (ng/m^3)	Fiber Count	Fiber Conc. (f/ml)	EPA Code No.	Mt. Sinai Code No.
1133 Ave of Americas New York City	Room 216 Office	12-4-73	3.60	170	47	1	.0012	74-000-001	1133-1
Offices, 45 floors		12-5	3.30	184	56			-005	1133-5
Fibrous spray	32 floor Mail Room	12-4	3.78	79	21	0	0	-002	-2
No sealant			3.30	47	14			-006	-6
Built January, 1969	Return Air Plenum 12 floor	12-4	3.36	2	0.6			-003	-3
		12-5	3.30	119	36	1	.0013	-007	-7
	Outside Air 12 floor Balcony	12-4	3.36	11	3.3			-004	-4
		12-5	3.30	50	15			-008	-8
888 Seventh Avenue New York City	19 floor	11-12-73	3.35	22	6.6			74-000-009	888-1
Offices, 45 floors		11-13	4.85	213	44	12	.0104	-012	-5
Fibrous spray on beams and floor decking	45 floor	11-12	3.05	296	97	4	.0055	-010	-2
No sealant		11-13	5.00	34	6.8			-013	-6
Built in 1970	Outside Air 14 floor Balcony	11-12	3.00	28	9.3			-011	-3
		11-13	4.7	66	14			-014	-8

Building	Sample Location	Date	Total Flow (m^3)	Total Mass (ng)	Mass Conc. (ng/m^3)	Fiber Count	Fiber Conc. (f/ml)	EPA Code No	[illegible] Code No
McGRAW-HILL BUILDING 1221 Ave. of Americas New York City	6 floor Data Processing	12-14-73	3.10	129	42	24	.0326	74-000-029	1221-1
		12-18	3.70	0	0	24	.0274	-033	-5
Offices, 51 floors	17 floor Print Shop	12-14	3.00	24	8.0			-030	-2
Firebar type T on columns. Non-asbestos		12-18	3.70	0	0			-034	-6
Cafco D C-F in plenums.	Return Air Plenum R-2 16 floor	12-14	3.00	8.6	2.9	10	.0141	-031	-3
		12-18	3.60	8	2.2			-035	-7
Sealant used, but name unknown.	Outside Air	12-14	2.95	8	2.7			-032	-4
Building not completed as of 12-73, but heavily occupied.		12-18	3.70	5	1.4			-036	-8
HIPPODROME BUILDING 1120 Ave of Americas New York City	7 floor Vacant Office	2-19-74	3.80	52	14			74-000-101	1120-1
		2-20	3.35	36	11			-104	-5
Offices, 21 floors	Sewing Rm. 19 floor	2-19	3.60	45	12			-102	-2
Fibrous asbestos spray (floors 9-21)		2-20	3.20	38	12	18	.0230	-105	-6
Not known whether sealant was used.	Return Air Plenum R-3 21 floor	2-20	2.95	19	6.4			-106	-7
Floors 1-8 built 1958 Floors 9-21 built 1962	Outside Air 21 floor	2-19	3.70	38	10	1	.0013	-103	-4
		2-20	2.90	54	19			-107	-8

Table 2 (viii)

Building	Sample Location	Date	Total Flow (m^3)	Total Mass (ng)	Mass Conc. (ng/m^3)	Fiber Count	Fiber Conc. (f/ml)	EPA Code No.	[illegible] Sample Code No.
CNA INSURANCE PLAZA 315 S. Wabash Avenue Chicago Fibrous asbestos spray (Firebar) Built: 1974	9 floor Conference Area	3-20-74	1.60	140	87	0	0	74-000-120	CNA -1
		3-21	3.95	46	12	1	.0011	-123	-4
	8 floor	3-20	2.45	115	47	4	.0069	-121	-2
		3-21	3.00	40	13	4	.0056	-124	-5
	Return Air Mixing Chamber	3-20	2.40	507	210	6	.0105	-122	-3
	Generator Rm 17 floor Exposed Fibr Insulation	3-21	3.90	3230	830	18	.0195	-125	-6
U.S. GYPSUM BUILDING 101 S. Wabash Drive Chicago Cementitious asbestos spray Firecode plaster (USG Brand) Built: 1960's	14 floor	3-19-74	3.60	66	18			74-000-126	USG -1
	4 floor	3-19	3.40	3	0.9			-127	-2
	Outside 18 floor Balcony	3-19	3.45	84	24			-128	-3

Building	Sample Location	Date	Total Flow (m^3)	Total Mass (ng)	Mass Conc (ng/m^3)	Fiber Count	Fiber Conc. (f/ml)	EPA Code No.	Mt. Sinai Code No.
1700 Broadway New York City Offices, 4[illegible] floors Cementitious on columns, concrete facing elsewhere Built October, 1968	18 floor	2-21-74	3.45	25	7.5			74-000-112	1700-1
		2-22	3.85	45	12			-116	-5
	11 floor	2-21	3.30	77	23	4	.0051	-113	-2
		2-22	3.50	20	5.7			-117	-6
	Return Air Plenum 12 floor	2-21	3.40	67	20			-115	-4
		2-22	3.55	5	1.4	2	.0024	-119	-8
	Outside Air 12 floor	2-21	3.40	51	15			-114	-3
		2-22	3.55	12	3.4			-118	-7
TWA TERMINAL JFK Int'l Airport New York City Terminal ceiling is covered with sprayed fibrous material containing asbestos. Sealed and painted.	Return Air Plenum	4-2-74	4.05	25	6.2			74-000-141	TWA -1
		4-3	2.80	32	11			-145	-5
	Passage way Stored Asbestos	4-2	3.90	31	7.9			-142	-2
		4-3	2.70	510	190	6	.0094	-146	-6
	Ambassador Club Lounge	4-2	3.40	193	57	6	.0074	-143	-3
		4-3	2.80	8	2.9			-147	-7
	Inside Air top of roof near kitchen	4-2	3.45	43	12			-144	-4
		4-3	2.80	40	14			-148	-8

Building	Sample Location	Date	Total Flow (m^3)	Total Mass (ng)	Mass Conc. (ng/m^3)	Fiber Count	Fiber Conc. (f/ml)	EPA Code No	Mt. Sinai Code No.
BUDDHIST CHURCH 331 Riverside Drive New York City	Chapel Near Altar	3-28-74	3.60	58	16			74-000-129	331-1
		3-29	2.75	52	19			-132	-4
Basement gym ceiling covered with exposed fibrous asbestos material. Sealed, but damaged in spots. Gym air is completely exhausted to outside.	Basement Gym	3-28	3.50	3	0.9			-130	-2
		3-29	2.90	15	5.2			-133	-5
	Basement Gym	3-28	3.50	53	16	3	.0036	-131	-3
		3-29	2.90	336	110	4	.0058	-134	-6

*The fiber concentration was determined by optical microscopy using the procedures specified by the National Institute for Occupational Safety and Health. (3) The concentrations refer to all fibers longer than five microns per milliliter of air determined by phase contrast microscopy at 400X magnification.

Table 3

Summary of Average Asbestos Concentrations

	Average Asbestos Concentration in nanograms/meter^3	
	Building Air	Outside Air
New York		
Turin House	8.2	18
Steinman Building	41	33
EXXON Building	29	8.0
McGraw-Hill	9.2	2.0
Hippodrome Building	11	14
1133 Ave of Americas	29	9.2
888 7th Avenue	77	12
1700 Broadway	12	9.2
TWA Terminal	17	-
Buddhist Temple	27	-
Boston		
JFK Building	2.5	5.0
Chicago		
U.S. Gypsum	9.5	24
CNA Plaza	200	-
Berkeley		
Department of Health	12	18
Great Western	7.0	5.0
UC Cafeteria	2.1	4.3
Harmon Gym	7.5	0
San Francisco		
Wells Fargo	8.7	3.9
425 Market Street	68	46

centration at a given site extends from 0 to 87 ng/m^3. For the large majority of the samples, there was no significant difference between the average concentration of asbestos measured within the buildings and that measured outside at the same site. In several buildings, however, the possibility of indoor air contamination exists. Three buildings (1251 Ave. of the Americas, 888 Seventh Ave., and 1133 Ave. of the Americas) have average indoor air values at least three times greater and 10 ng/m^3 higher than concentrations measured outside. Additionally, one building (CNA Plaza), without a corresponding outside value, has extremely high concentrations. Also, isolated samples in three other buildings (Steinmar all, 331 Riverside Dr., and TWA Terminal) suggest the possible presence of isolated areas of contamination.

To further consider whether indoor air contamination exists, Table 4 shows the distribution of concentration values measured inside and outside of buildings. In the case of fibrous spray, a significant number of buildings have concentrations of asbestos exceeding 20 ng/m^3, whereas only one outside sampl taken at the same time exceeded this value. In contrast, only two out of 28 inside samples exceeded 20 ng/m^3 of air in buildings in which cementitious asbestos spray had been used.

Two buildings were sampled in which no spray asbestos had been applied. One, the Harmon Gym at the University of California, was constructed in 1932, prior to the introduction of such procedures. The second, the McGraw-Hill building in New York City, was fireproofed with a fibrous spray, Cafco DC-F and Firebar T, a cementitious material , which was used on the outside of the columns. Cafco DC-F is advertised to contain no asbestos, and this fact was verified by optical microscopic analysis of a sample of the applied material. It is believed that Firebar T also contains no asbestos, although a sample was not accessible for collection. While the possibility exists that some fibrous spray material in the building could have contained asbestos, this is thought to be unlikely, as New York City prohibited spraying of asbestos-containing material after February, 1972. The McGraw-Hill building was finished late in 1973, with most spraying likely to have been done in late 1972 or early 1973. Data from these buildings and all outdoor samples taken as controls during the sampling of buildings in which asbestos spray had been used are tabulated in Table 5. It is seen that little difference exists between the distribution of asbestos concentration in these two buildings and that of outside air.

Table 6 lists the distribution of all samples according to whether they were in areas with no asbestos present (outside air or buildings in which no asbestos material was sprayed), buildings with fibrous asbestos spray, or buildings with cementitious asbestos spray. These distributions are also represented graphically in Figure 3. Also shown on Table 6 are the number of samples having a concentration above and below 20 ng/m^3 for each of the three circumstances. A χ^2 test was applied to these data and the percentage of individual samples exceeding 20 ng/m^3 for fibrous spray is significantly different from those of outside air at the 0.01 level of confidence. On the other hand, there is no significant difference in the distribution of air concentration in buildings usin cementitious fireproofing material.

The concentration distribution of samples taken inside and outside of buildings with sprayed asbestos material

Asbestos Conc. (ng/m^3)	Number of samples in concentration range: Used in Plenum, inside	Used in Plenum, outside	Decorative, inside	Decorative, outside	Total, inside	Total, outside
Cementitious Spray						
0 - 2	4	1	2	0	6	1
2.1- 5	2	2	2	2	4	4
5.1- 20	13	3	3	0	16	3
20.1- 50	1	2	0	1	1	3
50.1-200	1	0	0	0	1	0
200.1 +	0	0	0	0	0	0
Fibrous Spray						
0 - 2	5	1	1	0	6	1
2.1- 5	0	2	2	0	2	2
5.1- 20	10	7	10	1	20	8
20.1- 50	13	0	3	0	16	0
50.1-200	3	0	4	1	7	1
200.1 +	2	0	0	0	2	0

Table 3

The concentration distribution of all outside air samples and those in buildings in which sprayed asbestos material was never used

Asbestos Conc. (ng/m^3)	Samples in concentration range: Buildings	Outside	Total
0 - 2	4	2	6
2.1- 5	4	6	10
5.1- 20	3	11	14
20.1- 50	1	3	4
50.1-200	0	1	1
200.1 +	0	0	0

Table 6

The concentration distributions of control samples and samples taken in buildings with asbestos spray

ncentration range nograms/m^3	Number and percentage of samples within range					
	All control samples (no asbestos)		All buildings with fibrous asbestos spray		All buildings with cementitious asbestos spray	
0 - 2	6	17%	6	11%	6	21%
2.1- 5	10	29%	2	4%	4	14%
5.1- 20	14	40%	20	38%	16	57%
20.1- 50	4	11%	16	30%	1	4%
50.1-200	1	3%	7	13%	1	4%
200.1 +	0	0%	2	4%	0	0%

mber of samples <20ng/m^3	30	28	26
mber of samples >20ng/m^3	5	25	2
^{2} of difference between asbestos samples and control		10.145	0.804
obability that difference is from chance		< 0.01	N.S.

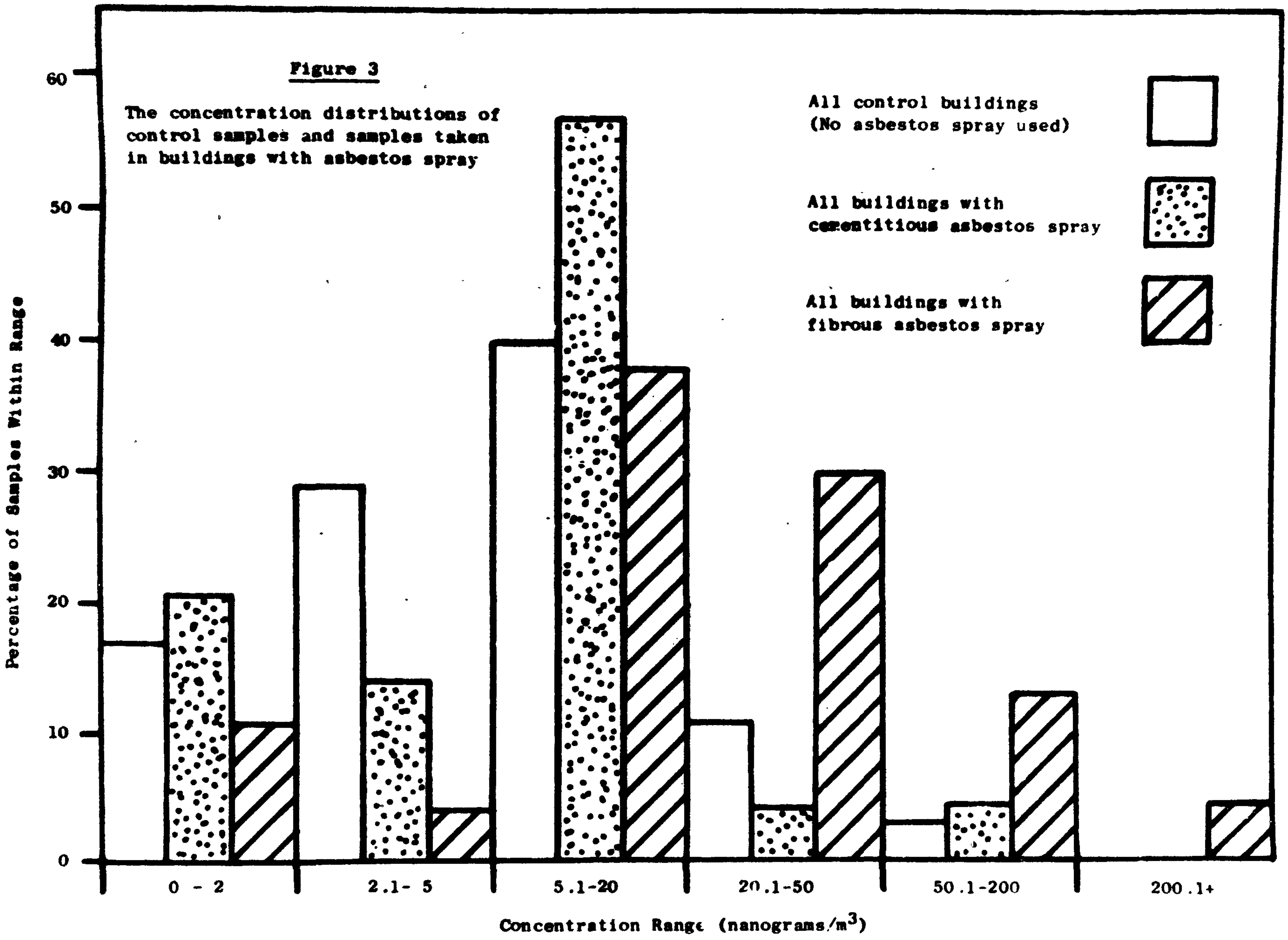
Figure 3
The concentration distributions of control samples and samples taken in buildings with asbestos spray
All control buildings (No asbestos spray used)
All buildings with cementitious asbestos spray
All buildings with fibrous asbestos spray
Percentage of Samples Within Range
60
50
40
30
20
10
0
0 - 2
2.1- 5
5.1-20
20.1-50
50.1-200
200.1+
Concentration Range (nanograms/m3)

Of the four buildings that suggest possible contamination, two were recently constructed. One (CNA), in fact, still had construction activities taking place on upper floors. While possible contamination from such activities is unlikely, they cannot be ruled out. (The construction areas were outside the supply system sampled.) The other two buildings were also unique in that no sealant had been applied over the asbestos spray material.

Values for some isolated samples may be the result of special circumstances. Two TWA Terminal samples (74-000-142 and -146) were near a site of stored asbestos material, and the sample in the generator room of the CNA building (74-000-125) was in a room with extensive use of sprayed asbestos on the walls and ceiling.

Optical Microscopic Analysis

Table 7 lists the fiber concentrations measured using phase contrast optical microscopy at 400X magnification. The technique specified by the National Institute of Occupational Safety and Health for the analysis of asbestos samples collected in occupational circumstances was followed. (3) All fibers longer than five microns in 100 45 X 45-micron fields of view were counted, and a fiber concentration calculated. These concentrations are listed in Table 7, along with the mass concentrations determined by electron microscopy.

Figure 4 shows graphically the correlation between the asbestos concentrations determined by optical and electron microscopy. It is obvious that no correlation exists between these methods. This was to be expected, as fibers other than asbestos are likely to be present in the ambient air. According to the prescribed technique, all objects having a 3:1 length to width ratio and a length greater than five microns are to be counted. As many fibers present in the ambient air are other than asbestiform minerals, enumeration of such fibers using the NIOSH technique readily gives misleading results. In occupational circumstances, where the majority of fibers are indeed asbestiform, this procedure has practical utility.

Duplicate Analysis

Ten randomly selected samples were sent to the Air and Industrial Hygiene Laboratory of the California State Department of Health for duplicate analysis. These were analyzed using the method described in Appendix 4, and the results are listed in Appendix 5. Significant differences existed on three samples. Extremely high levels listed in the Appendix for samples 73-003-038, -046, and -054 suggested the possibility that inadvertent contamination may have occurred subsequent to the collection of the samples. All three of the high values occurred in a group of four samples sent at one time. In order to check this possibility, a second set of the lot of four samples was sent to Berkeley and the same four were reanalyzed at Mount Sinai. The results of this reanalysis indicated that inadvertent contamination had occurred at some point in the sample transfer or analysis process.

Table 7

Comparison of
Asbestos Air Concentrations
Determined by Electron
and Optical Microscopy

EPA Sample Number	Mass Concentration nanograms/meter^3 (Electron Microscopy)	Fiber Concentration fibers/milliliter (Optical Microscopy
E-73-003-032 AH	17.0	.0030
-036	10.8	.0048
-039	3.7	.0007
-043	11.9	.0020
-046	7.3	.0186
-047	3.9	.0006
-051	0.7	.0046
-054	7.3	0
-055	17.4	.0040
-063	156	.0051
-064	21.2	.0012
-067	33.2	.0012
E-74-000-001	47.2	.0012
-002	0	0
-007	36.1	.0013
-010	97.0	.0055
-012	43.9	.0104
-015	7.9	.0020
-018	41.1	.001
-022	24.1	.0014
-025	30.7	0
-026	55.1	0
-027	13.2	.0046
-028	35.7	.0114
-029	41.6	.0326
-031	2.9	.014
-033	0	.027
-103	10.3	.0013
-105	11.9	.0230
-108	181	.0045
-110	64.0	.0053
-013	23.3	.0051
-119	1.4	.0024
-120	87.5	0
-121	46.9	.0069
-122	211.3	.0105
-123	11.6	.0011
-124	13.3	.0056
-125	828	.0195
-131	15.1	.0036
-134	115	.0058
-143	56.8	.0074
-146	188.9	.0094

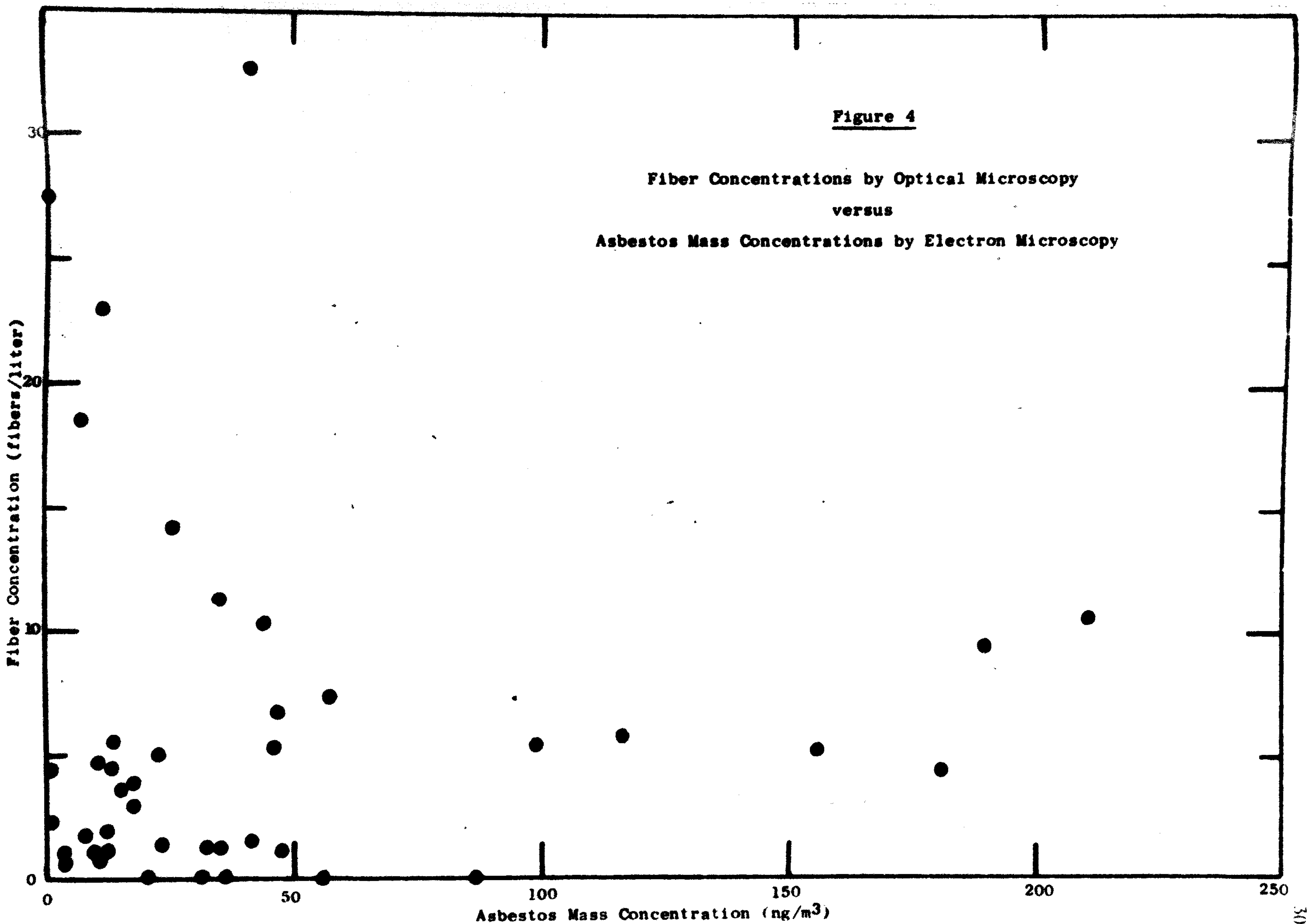
Figure 4
Fiber Concentrations by Optical Microscopy
versus
Asbestos Mass Concentrations by Electron Microscopy
Fiber Concentration (fibers/liter)
Asbestos Mass Concentration (ng/m3)
0
10
20
30
0
50
100
150
200
250

Table 8 lists the values obtained by each laboratory for the 10 samples. Except for 74-000-003 and -012, the agreement between laboratories is not beyond that which might have been expected (discounting sample 73-003-046, for which inadequate analysis was performed). The possibility that samples -003 and -012 were interchanged during the coding, shipment, and analysis procedure at one of the laboratories cannot be discounted, as the values would be in good agreement if the data for these two samples at one of the laboratories were interchanged.

D. Variability of the Data

Table 9 lists the two sets of results on the four samples replicated as mentioned in the previous section. As can be seen, reasonable agreement exists. Additionally, as part of a previous study of asbestos ambient air concentrations in major U.S. cities, 16 replicated samples were analyzed. In these, the average percent deviation from the mean was found to be 43%. Considering single samples, it is felt that an individual value is accurate within a factor of two or three of a sample mean.

The inaccuracy that exists in the value obtained in a specific analysis can result from several circumstances: a) statistical variation in the number of fibrils found in given grid squares, b) a much greater variation in volume of these fibrils, c) incomplete dispersal of chrysotile bundles, d) variability in the amount of material that may be lost during processing, and e) low-level contamination of the sample at various points during ints preparation and analysis.

The possibility of inadvertent sample contamination exists in spite of adherence to rigid clean room procedures. Such contamination was found in one ambient air sample analyzed at Mount Sinai, and in one group of samples analyzed at Berkeley. Undetected low-level contamination could exist in some of the samples analyzed here, although blanks processed with each set of four samples revealed no serious problem.

Table 8

Duplicate Analysis of Ten Ambient Air Samples

Sample Number	Asbestos Concentration (nanograms/meter^3)	
	Mount Sinai	Calif. Dept. of Health
74-000-003	0.6	120
74-000-012	44	0.4
74-000-023	0	13
74-000-032	2.7	0
73-003-038	2.6	0
73-003-046	7.3 (disregard, only 2 fibers observed)	< 800
73-003-054	7.3	0
73-003-064	21	0
74-000-110	46	14
74-000-119	1.4	2.2

Table 9

Replicate Analysis of Four
Ambient Air Samples

Sample Number	Asbestos Concentration nanograms/meter^3		
	1st Analysis	2nd Analysis	Average
73-003-038	0	5.3	2.6
-046	7.6	7.1	7.3
-054	3.2	11.4	7.3
-064	12	30	21

Environmental Asbestos Exposure and Possible Human Health Effects

A. Historical Perspectives

The first information on environmental risk from asbestos exposure came from South Africa in 1960. In that year, Wagner, Sleggs and Marchand (4) described 47 cases of mesothelioma found during a four-year period in the northern Cape Province, an area with extensive crocidolite asbestos mines. None were seen in the neighboring Transvaal Province or in 10,000 autopsy cases of workers who had died with known exposures to silica. Of the 47 cases, approximately half were found to have had either industrial or mining exposures to asbestos. Virtually all of the remaining cases were in individuals who simply lived or worked in the vicinity of the asbestos mines or mills.

Confirmation of environmental asbestos-associated disease soon appeared. Newhouse and Thompson reviewed all mesothelioma cases at the London Hospital.(5) They corroborated the close association with asbestos, 31 of the 76 cases having had documented occupational exposure. Of the remainder, 11 had lived, decades before, within one-half mile of an asbestos factory. A similar distribution of cases was found by Lieben and Pistawka (6) in Pennsylvania. One insidious form of indirect asbestos exposure is that of families of asbestos workers. In the previously mentioned studies, nine of the London mesotheliomas were in family members, as were three of the 46 Pennsylvania cases.

Additionally, evidence is accumulating that other than neoplastic disease is present among individuals exposed only to environmental or family circumstances. A recent study by Dr. Irving J. Selikoff of the Mount Sinai School of Medicine shows that 38% of family members of a group of former asbestos workers have X-ray abnormalities characteristic of asbestos exposure. (7)

Unfortunately, these data on the incidence of mesothelioma and other asbestos-related disease from environmental or family exposure to asbestos are severely limited. The exposures in question took place beginning 20, 30, 40, or more years ago. No knowledge exists of the associated asbestos dust exposure levels. Thus, we have no dose-response information on low-level asbestos exposure. We only have knowledge of a potential risk of disease, at exposures much below occupational ones. Obviously, additional research and continued surveillance are highly desirable.

B. Environmental Chrysotile Concentrations

In a previous study at the Mount Sinai School of Medicine, 187 samples from 49 United States cities, collected by the National Air Pollution Control Administration from their air sampling network during 1969 and 1970, were analyzed.(8) Biweekly, 24-hour samples in various three-month periods were composited and analyzed using techniques identical to those employed in this research. Table 10 gives the range of values obtained in this study. Table 11 lists the results obtained from a series of single samples collected in New York City by the Department of Air Resources at 12 sites in their sampling network.(9) In contrast to the NAPCA samples, which were collected over a 24-hour period, the New York City were obtained between 9 AM and 4 PM. At such times, of course, asbestos contributed to the ambient air by man's activities would have been greater.

Table 10

Chrysotile Content of Ambient Air Samples Collected by NAPCA

Fiber Range nanograms/meter^3	Number of Samples in Range
0.1 - 0.9	61
1.0 - 4.9	102
5.0 - 9.9	12
10.0 -19.9	9
20.0 -49.9	2
50 +	1
Total Samples	187

Table 11

CHRYSOTILE CONTENT OF AMBIENT AIR IN NEW YORK CITY BY BOROUGH

Sampling Locations	Number of Samples	Asbestos air level in 10^{-9} grams/m^3	
		Range	Average
Manhattan	7	8-65	30
Brooklyn	3	6-39	19
Bronx	4	2-25	12
Queens	4	3-18	9
Staten Island	4	5-14	8

Additionally, all of the New York City samples were collected during periods when the procedure of fireproofing high-rise buildings by spraying asbestos-containing materials was permitted. While no sampling station was known to have been located adjacent to such sites, unusually high levels could have resulted from these procedures.

To verify that construction sites were, indeed, a significant source of asbestos fiber, sampling was conducted in lower Manhattan about construction sites where extensive spraying or asbestos-containing fireproofing material was taking place. Table 12 shows the results of this sampling and demonstrates that spray fireproofing can contribute significantly to asbestos air pollution. In some instances, chrysotile asbestos levels approximately 100 times "background" are observed.

Sampling has also been done in homes of asbestos insulation workers and asbestos mill employees in order to determine home air concentrations in such circumstances. Here, also, the sampling and analysis procedures were identical to those used in this study. Results indicated that air levels in the homes of asbestos workers can range from 100 nanograms per cubic meter of air to as high as 5,000 nanograms per cubic meter of air. (10) It is noteworthy that the lowest of these levels exceeds any that have been measured in the ambient air of major U.S. cities, and the highest level is equalled only by the amphibole mass concentrations found in Silver Bay, Minnesota near the site of the Reserve Mining Company operation. (11)

For comparison purposes, Table 13 expresses the ranges of asbestos concentrations found in a variety of environmental and occupational circumstances. It is not possible, however, to use these concentrations as necessarily representative of the air levels that may have been present about past factories or in homes of workmen where asbestos-related disease has recently been manifest. However, the documentation of disease at concentrations much lower than occupational ones, strongly points to the need to conrol exposures in circumstances where they can contribute significantly to the ambient air. This is especially important where large populations may be exposed, such as was the case about spray sites in New York City, and is the case in the high-rise office buildings that were constructed using asbestos-containing spray fireproofing. Concentrations above 100 nanograms per cubic meter of air are highly indicative of erosion and approach concentrations measured in workers' homes (100-5000 ng/m^3) and about sites of neighborhood contamination (to 400 ng/m^3), where circumstantial evidence suggests the possibility of adverse health effects.

Table 12

CHRYSOTILE AIR LEVELS NEAR SPRAY FIREPROOFING SITES

Sampling Location	Number of Samples	Asbestos Air Level in 10^{-9} gm/m^3	
		Range	Average
1/8 - 1/4 mile	11	9 -375	60
1/4 - 1/2 mile	6	8 - 54	25
1/2 - 1 mile	5	3.5- 36	18

Table 13

Approximate Ranges of Asbestos Concentrations in Different Circumstances

Type of Sample	Mass Concentration of Asbestos (in 1 $^{-9}$ g/m^3)
Ambient Air (200 Samples in 50 U.S. Cities)	0.1 - 100
Near Asbestos Spray Fireproofing Operations and Other Sources (1/8 - 1 mile distant)	10 - 1000
Silver Bay, Minnesota (Reserve Mining Company Milling Operation)	10 - 5000
Homes of Asbestos Workmen	100 - 5000
Occupational Exposures	1000 - 100,000 +

[illegible]clusions and Recommendations

[illegible]. Decorative or Acoustic Spray Application

Indications of contamination of public buildings from the past application of acoustic spray exist in this study, as well as in many isolated circumstances. Noteworthy in this latter category are a school in Wyoming, a Yale library, the Long Beach Courthouse and a U.C.L.A. dormitory. In all circumstances where significant air contamination has arisen, however, directly visibly damage to the spray material was evident. Thus, visual monitoring of the structural integrity of this sprayed material appears to be sufficient to assess possible contamination. Where damage is found, however, corrective action should be taken. This action may extend from simply resealing the material with an overspray, to complete removal, as has been done in the specific cases mentioned above.

[illegible]. Cementitious Spray Fireproofing

No evidence was developed in this study for asbestos erosion from cementitious spray fireproofing material used in the plenums of building supply systems. This conclusion, however, is a tentative one, as it is drawn from a limited sampling program in only six buildings. Prudence would suggest that periodic sampling of such buildings be initiated in order to evaluate the the results presented here.

[illegible]. Fibrous Asbestos-Containing Spray Fireproofing

This study presents strong evidence for the erosion of fibers in some buildings fireproofed with fibrous-type, dry spray, asbestos-containing material. This was particularly evident in those buildings most recently constructed and in those in which no sealant was applied over the spray material. Moreover, all buildings will, at times, have repair and maintenance activities taking place in the plenum space that can lead to contamination incidents. Since visual monitoring of the integrity of the spray material in the plenum space is not possible, investigation should be made of feasible filtration systems that can be used in these buildings to remove any asbestos contamination that may occur.

Specific Recommendations

1. Future Monitoring

a. An effective inspection and monitoring program should be developed to verify the integrity of asbestos spray material used for acoustic or decorative purposes on the walls and ceilings of public rooms and buildings. This would be primarily a visual inspection to verify that damage to such material was not taking place. Only in isolated circumstances would air sampling be necessary.

b. Periodic spot sampling and analysis of the air in buildings using cementitious fireproofing whould be made in order to verify the results of this study and to assure that future air contamination of these buildings does not occur.

c. More extensive sampling and analysis for asbestos should be done in those buildings where fibrous spray fireproofing has been used, in order to define the full extent of asbestos air contamination.

2. Future Control Procedures

a. Research must be undertaken to determine an effective and economically feasible filtrations system that can be used in buildings with air supply plenums sprayed with such fibrous materials.

b. Procedures should be developed for used during maintenance activities that may be required in asbestos-lined plenum spaces in order to minimize possible building air contamination. Consideration should be given to system isolation, area enclosure, localized wetting, and cleanup by vacuuming.

c. Procedures must be developed and specified for use in those buildings in which the asbestos is to be removed because of unacceptable contamination. Here, consideration must be given to both occupational and future environmental exposures.

d. The suitability of proposed EPA building demolition procedures for buildings with extensive spray asbestos must be verified. The community contamination which could possibly result from such activities in the future may greatly exceed that which resulted from original application and from building use.

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APPENDIX I

Buildings Sprayed with Fireproofing Asbestos Compound

Address	Asbestos Compound (LBS)	Floor Area (SQ FT)	Height (FT)	No. of Stories	Asbestos * (LBS)
345 Park Avenue	175,000	1,634,670	681	44	52,500
7 East 42nd Street	268,370	312,039	388	27	80,511
1700 Broadway	55,000	557,649	503	41	16,500
141 West 54th Street	75,000	1,873,946	645	49	22,500
15 Columbus Circle	535,853	563,705	583	46	160,756
115 Broad Street	500,000	887,436	282	22	150,000
1 New York Plaza	2,250,000	2,525,841	664	50	675,000
100 Wall Street	600,000	472,748	365	23	180,000
TOTAL	4,459,223	8,828,034			1,337,767

* Asbestos compound contains 30% asbestos fibers, 60% mineral wool and 10% binder.

APPENDIX 2
THE CITY OF NEW YORK
DEPARTMENT OF AIR RESOURCES
51 ASTOR PLACE, N.Y. 10003

VENTILATION SYSTEM EMISSIONS STUDY

Date ______________

I BUILDING

1. Address ______________
2. Name of Building ______________ No. of Floors ______________
3. Owner ______________ Phone No. ______________
4. Address ______________
5. Management ______________ Phone ______________
6. Address ______________
7. Building Manager ______________ Phone ______________
8. Room No. ______________
9. Date of completion of construction ______________
10. Estimated No. of people working in the building ______________

II FIREPROOFING

A. How are the structural steel members fireproofed?

1. Fibrous asbestos spray? Yes ____ No ____ Brand ______________
2. Cementitious asbestos spray Yes ____ No ____ Brand ______________
3. Other. Describe ______________

____

B. What material is used for the decking?

1. Corrugated metal? ______________
2. Reinforced concrete? ______________
3. Describe the fireproofing applied to the decking. ______________

____

VENTILATION SYSTEM

A. 1. Does the ventilation system run continuously? _____Yes _____No

2. Daily hours of operation _____ AM to _______ PM.

3. Weekend hours of operation _____ AM to _______ PM.

4. Are the same ducts used for both heating and air conditioning? _____Yes _____No

B. AIR DISTRIBUTION

1. Are any of the ducts insulated internally? _____ Yes _____No

2. Describe the insulation material used. _______________

Brand _______________ Manufacturer _______________

3. Are the ducts insulated externally? _______Yes _______No

4. Describe the material _______________

Brand _______________ Manufacturer _______________

C. RETURN AIR SYSTEM

1. Is there a return air plenum? _____Yes _____No

2. Is the plenum insulated internally? _____Yes _____No

3. Type of insulation used in the plenum:

Fibrous asbestos spray? Brand _______ Mfgr. _______

Cementitious " " ? Brand _______ Mfgr. _______

Other. Describe. _______________

4. Was a sealant used? _____Yes _____No

Brand _______________ Mfgr. _______________

5. Are there return air ducts? _____Yes _____No

6. Are the ducts insulated? _____Yes _____No

7. Insulation used:

Fibrous asbestos spray? Brand _______ Mfgr. _______

Cementitious " " ? Brand _______ Mfgr. _______

Other. Describe.

RETURN AIR (Continued)

8. Was a sealant used? ______ Yes ______ No

Brand ____________________ Mfgr. ____________

D. BLOWER ROOM

1. Are the internal walls insulated? ______ Yes ______ No

Insulation material used: ____________________

Brand ____________________ Mfgr. ____________

2. Was a sealant used? ______ Yes ______ No

Brand ____________________ Mfgr. ____________

E. AIR FILTRATION

1. Describe the filters used for the recirculated air: ____________________

____

Brand ____________________ Mfgr. ____________

2. Total area of recirculated air filters. ____________________

3. Filter replacement schedule ____________________

4. Date of last filter change. ____________________

5. Describe the filters used for the make-up air. ____________________

____

Brand ____________________ Mfgr. ____________

6. Total area make-up air filters. ____________________

7. Make-up air filter replacement schedule ____________________

8. Date of last filter change ____________________

9. What is the percentage of make-up air? ____________________

IV ELEVATOR SHAFTS

1. Are passenger elevator shafts insulated? ______ Yes ______ No

Type of insulation:

Fibrous asbestos ____________________ Mfgr. ____________

Cementitious asbestos ____________________ Mfgr. ____________

Other ____________________ Mfgr. ____________

ELEVATOR SHAFTS (Continued)

2. Was a sealant used? ________ Yes ________ No

Brand ______________________________ Mfgr. ____________________

3. Are freight elevator shafts insulated?

Type of insulation:

Fibrous asbestos ____________ ____________ Mfgr. ____________________

Cementitious asbestos ________________ Mfgr. ____________________

Other ______________________________ Mfgr. ____________________

4. Was a sealant used? ________ Yes ________ No

Brand ______________________________ Mfgr. ____________________

CEILINGS

1. Are the ceilings covered with acoustic material? ________ Yes ________ No

Type of material used ____________ ____________ Brand ____________________

2. Are the ceilings painted? ________ Yes ____________ No

Textured paint? ____________ Yes ____________ No. Brand ____________

Other? ____________________________________ Brand ____________

FLOW DIAGRAM OF AIR SYSTEM

Sketch air-flow diagram showing blowers, filters, ducts, return-air plenums, fresh-air intakes, and floors serviced.

SAMPLES NEEDED

A. Building materials
   1. Plenum insulation
   2. Air-duct insulation -- internal
   3. Air-duct insulation -- external
   4. Blower room insulation
   5. Recirculating air filter
      a. Filter material   b. Dirt covering filter
   6. Roughing filter (fresh air pre-filter)
      a. Filter material   b. Dirt covering filter
   7. Ceiling materials
      a. Acoustic spray   b. acoustic tiles   c. textured paint
   8. Elevator shaft insulation

B. Air samples (during normal building operation)
   1. Room air -- 3 interior stations
   2. Blower room, before recirculation filters
   3. External air -- upwind

ASBESTOS SAMPLE PREPARATION AND ANALYSIS METHODOLOGY

Ashing

Samples collected on membrane filters are prepared for ashing by cutting a 1 cm square of the filter and placing it, dust side down, on a clean microscope slide. Two or three drops of acetone are added to the square to partially dissolve the filter and to fix the material to the glass slide. The sample is ashed in a low temperature activated oxygen asher for 10 minutes to one hour, depending on sample composition. (The cleaner samples will require the longer ashing period.) It is best to stop the ashing before complete combustion of the filter to minimize any loss of sample mineral material.

Rubout Procedure

Following ashing, the samples are dispersed in a nitrocellulose film and mounted on formvar coated electron microscope grids. The dispersal is accomplished by a "rubout" technique in which asbestos fibers are broken into individual fibrils. This procedure allows positive identification of chrysotile asbestos to be made on the basis of morphology alone. Moreover, large agglomerates of mineral particles, which could obscure the presence of asbestos fibers or fibrils, and to which asbestos fibrils could be attached, are broken into particles sufficiently small to allow all asbestos fibrils to be seen.

The rubout is accomplished by placing a large drop of a 1% solution of nitrocellulose in amyl acetate on the ashed residue. The flat surface near the edge of a clean watch glass is used to grind the residue into submicron sized particles. This grinding usually takes from 5 to 10 minutes, depending on the amount of residue present. Typically, the amyl acetate will evaporate in less than 5 minutes and additional drops of pure amyl acetate must be added to complete the rubout. (Adding the 1% nitrocellulose solution will result in an undesirably thick film.) During the final stages of the rubout, the solution and residue are dispersed over several cm of the microscope slide. After dispersing the ashed residue, some of which still remains on the watch glass, another drop of the nitrocellulose solution is placed on a second clean slide. During the dispersal of this drop over several cm of the slide, the major portion of the residue remaining on the watch glass is removed. By this procedure, less than 10% of the residue will remain on the watch glass.

The two slides are placed in contact and the ground residue and nitrocellulose solution further dispersed. The residue typically is spread over the width of the slide for a distance of from 5 to 7 cm. The two slides are then pulled apart. No pressure need be exerted during this procedure as surface tension will hold them in contact.

With practice, a uniform film is thus produced which can be tested by viewing against a light. (We earlier did particle counts to verify uniformity, but visual appearance proved to be as reliable an indicator of uniformity.) If the film is not uniform, amyl acetate can be added and the above procedure repeated.

Mounting

The edges of the slide with the attached film are scraped with a scalpel blade. By carefully dipping the slide in water at an angle of from 30°-50°, the nitrocellulose film can be floated onto the water.

Several procedures can be used to mount portions of the film onto formvar coated electron microscope grids. (Formvar coated grids have been found to be more stable than uncoated grids in the electron microscope.) Two such procedures are:

1) Grids are placed on top of the film and covered by a portion of ordinary Whatman filter paper. This sandwich is then deftly flipped over and out of the water. With some people success is achieved every time, with others, never.
2) Whatman filter paper is placed under the film, catching an edge of it. As the filter is withdrawn from the water, bringing the film with it, grids are placed at the intersection of the film and the submerged filter paper.

Additional procedures can be devised, depending on the ingenuity of the technician. After drying, the grids can be picked up from the Whatman filter paper and mounted in the electron microscope for scanning.

Electron Microscope Scanning and Counting

Typically, 8 grids are prepared from each sample ashed using material from widely separated portions of the prepared films from both slides. A single square of each grid is scanned at 40,000 X magnification to determine the quantity of chrysotile present. The identification of chrysotile is on the basis of morphology, either that of the classic tubular structure or that of altered chrysotile (as a result of either beam damage or physical damage prior to collection). Here the structure exhibits a dense, irregular, inner region, sometimes with a thin capillary, and an electron transparent irregular outer region. To gain experience in recognizing various forms of chrysotile, one can select an unaltered fiber and watch it deform in the electron beam. The use of carbon coated films can reduce this damage, but in practice this procedure has not been found necessary.

The length and diameter of each fiber are estimated with the aid of fiducial marks on the viewing screen and the mass of chrysotile per grid square determined. The total area of film prepared is used to calculate a dilution factor from the rubout. (Typically, 1 cm^2 of membrane filter sample is dispersed in 25 cm^2 of film.) Knowing the air volume passed through a given area of filter paper, the concentration of chrysotile asbestos in the sampled air can be obtained.

In practice, a reasonable statistical variation exists between the number of fibrils found on different grid squares. The variation exceeds that expected on pure statistical grounds as occasionally clumps of fibrils, resulting from the incomplete dispersal of a fiber bundle, are seen. However, greater variation occurs in the volumes seen on different grid squares as one large fibril can contribute 100 times the volume of a small one, hence, the need for counting several grid squares. Eight 100μ x 100μ squares have proved to be sufficient. The inaccuracies inherent in the sample preparation do not warrant additional effort in scanning.

Calibration

The above procedures are calibrated by processing filters prepared with known amounts of chrysotile. Here both clean membrane filters and filters previously used to collect ambient air samples are used. Triple air jet milled chrysotile is dispersed in H_2O to which Aerosol OT has been added. The solution is subjected to ultrasonic energy and diluted so as to produce a concentration of about 1 nanogram of chrysotile per cc. This solution is filtered through the membrane filter until 10 to 50 ngms of chrysotile is collected per cm^2 of filter. The above procedure is then followed as in the case of collected air samples. Recoveries range, typically, from

30% to 50% of the added chrysotile and this factor is applied to the data from the processed samples.

Clean Room Procedures

It has been found that strict adherence to clean room procedures must be followed. All sample processing should take place in a filtered air environment. The water used should be filtered through 0.22μ membrane filters. Blank controls must be run routinely to assure absence of contamination.

Appendix 4

Collodion Film Method for the Determination of Asbestos in Ambient Atmospheres

Collect atmospheric samples on 0.8 micron pore size Millipore filters for a period of about 24 hours at a rate of 10 liters per minure.

Add the collected air samples to separate 10 ml Conway cells. These wide-mouth cells expose the filters to more oxygen plasma than glass vials in the low temperature asher (LTA), which leads to efficient ashing of the sample.

Ash the samples in the LTA until the filters are completely decomposed, leaving a grey to white residue consisting of inorganic material. With our International Plasma LTA, the oxygen flow rate was set at 100 ml per minute, with an RF power setting of 200 watts. The required time for ashing was about 4 to 5 hours.

After completion of the ashing, add 1 ml of 0.25 percent collodion in amyl acetate to the samples contained within the glass-covered Conway cells. Mix by hand by rotating the cells several times, and then mix in a sonic bath for about 30 seconds to suspend and distribute the fibers in the viscous collodion solution.

Prepare a ring of known surface area by fusing a length of 1 mm polyethylene tubing into a ring. Float this ring on the surface of particle-free distilled water. Drop a 0.10 ml aliquot of the collodion suspension on the water surface inside the ring. The suspension will disperse, forming a uniform collodion film of known area within the ring.

Add three electron microscope grids of known mesh size to a submerged wire screen and draw the screen up through the cast film. Dry the grids for about thirty minutes under a 100 watt incandescent bulb before electron microscopic examination.

For a 300 mesh grid, count twenty random grid holes per grid on each of the three grids at 4000X. Size each fiber directly on the calibrated viewing screen. Calculate the number of fibers per sample using the following formula:

$$N = \frac{A \times n}{a \times g \times f}$$ where

N = Total number of fibers (per filter)
A = Area confined by polyethylene ring
n = Total fibers counted
a = Area of one grid hole
g = Number of grid holes counted
f = Aliquot fraction

The mass is calculated by $M = \frac{A \times m}{a \times g \times f}$ where m is the total mass calculated from the sized fibers.

Appendix 5

Air and Industrial Hygiene Laboratory
California Department of Health
Analysis of Air Samples
EPA Contract No. 68-02-1346

This attachment briefly reviews the microscopy data obtained by AIHL as part of EPA Contract No. 68-02-1346. Four samples to be analyzed were received at AIHL on December 23, 1973 and the remaining six on March 2, 1974.

Table I lists the light microscopy results. Originally we had intended to do all ten samples by light microscopy as well as electron microscopy. However, this was based on our expectation that at least one-half of each filter would be available to us. However, we only received a one-fourth section for each sample. Since one-eighth of a filter is required for any one of the three analysis which were carried out, the NIOSH method, the direct clearing electron microscopy method, and the parlodion film electron microscopy method, it was decided to use some of the sections for analysis by the alternate electron microscopic techniques. Thus Table I only lists four samples. When one-eighth sections are available for the samples not listed, we will be happy to analyze them by the NIOSH method.

Table II lists the mass data obtained by calculating the mass from the size distribution measured by electron microscopy. However, the following comments should be read before addressing the table.

For samples 003, 046, 054, 064 and 110, numerous bundles or aggregates of fibers bound and coated with a matrix material were observed. They were observed using both the direct clearing method (DCM) and the parlodion film method (PFM). Thus we believe these aggregates are not an artifact of the sample preparation. The matrix material binding these aggregates together withstands ashing in a muffle furnace at 450°C, and is not soluble in organic solvent. Since asbestos mass could not easily be estimated for the fibers contained in these bundles, the mass values given in the table for these samples exclude the asbestos in the bundles and thus must be considered minimum estimates of the mass.

In some cases separate measurements were made by two different AIHL microscopists. The differences in the mass values obtained varied from a factor of 2 to 10. In those cases where two separate determinations were made the average values are presented in the table.

The data in the table were obtained using the PFM. Sample 038 also was done by the DCM. The number of fibers and the corresponding mass were lower by the DCM. However, the frequency distribution of fibers vs grid holes showed less variability in the distribution of fibers counted by PFM than by DCM. This is shown in Table III. Thus, it was felt that, at least for this set of samples, the fibers may have sufficient inhomogeneous distribution over the filters, to cause large errors to arise in the use of DCM.

In a telephone conversation with you it was agreed that you would send us all the information about the filters analyzed by AIHL, i.e. where and when they were collected, flow rates, time of collection, and all other pertinent information including any inter-laboratory comparisons that were made. This would permit us to interpret the results, and if warranted publish, perhaps in cooperation with Mt. Sinai. For all ten samples, we of course have complete size distributions for both length and diameter, data which may prove invaluable in determining the source of the fibers. Thus I look forward to receiving the information from you.

Table I

LIGHT MICROSCOPY RESULTS (NIOSH METHOD)
Fibers > 5 μm in Length

Sample No.	Fibers per mm²	Fibers per Filter First Analysis	Fibers per Filter Second Analysis
038	8 fibers per mm²	8,600	0 ± 1,700
046	28 fibers per mm²	30,000	23,900
064	37 fibers per mm²	40,000	8,600

Note: Sample 054 had too much non-fibrous particulate matter present to permit fiber counting.

Table II

MASS DATA AS OBTAINED FROM ELECTRON MICROSCOPY SIZE DISTRIBUTION

Sample No.	Mass Nanogram per Filter First Analysis	Mass Nanogram per Filter Second Analysis+
003*	400	
012	2	
023	39	
032	No fibers found	
038	5,000	No fibers found
046	25,000*	< 5700 (2 fibers)
054	35,000*	No fibers found
064	900*	No fibers found
110	1,100	
119	25	

*Because these samples contained many bundles or aggregates consisting of fibers bound and coated with a matrix material, estimates of the mass of asbestos in the aggregates were not made. Thus the mass given here is a lower limit (of text).

+Second analysis by direct clearing method. The comparison of results from the two analyses made on fresh portions of the original samples suggests a strong possibility of contamination at same point in the procedure during the first analysis.

TABLE III

COMPARISON BETWEEN PFM AND DCM FREQUENCY DISTRIBUTIONS

FIBERS PER GRIDHOLE FOR SAMPLE #E-073-003-038

	Direct Clearing Method		Parlodion Film Method	
	Fibers per Gridhole	Frequency	Fibers per Gridhole	Frequency
	0	3	0	19
	1	2	1	22
	2	3	2	8
	3	1	3	3
	4	2	4	4
	5	1	5	2
	16	1	6	1
	59	1	7	1
	61	1		
	104	1		
Total Fibers	264		86	
Fields Counted	16		60	
Estimated 95% Conf. Intv. for the Total Number of Fibers	± 99 %		± 29 %	