Observations of Settled Asbestos Dust in Buildings

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Asbestos surface dust sampling and analysis has gained increased usage by industrial hygienists, engineers and others.[1] Early attempts at sampling asbestos dust consisted of collecting unknown amounts of dust and debris from surfaces with analysis by polarized light microscopy (PLM) or X-ray diffraction (XRD). Results were often reported only as "asbestos detected" or "not detected." False negatives were common since the resolution of PLM cannot detect individual asbestos fibers. These early methods also did not distinguish between dust and larger pieces of debris.

Recently a more sophisticated surface dust sampling and analysis method has evolved using transmission electron microscopy (TEM). The method was refined in a draft document by the USEPA and ultimately published by ASTM as standard method D 5755-95 in October 1995.[2] In this method dust is vacuumed from a measured surface area, analyzed by TEM, and reported as asbestos structures per square centimeter (s/cm^2) or structures per square foot (s/ft^2) of area sampled.

The question that usually arises is what do the results mean? At what concentration should a surface be considered clean? When is the concentration sufficiently elevated that it poses a risk of exposure? To answer such questions it becomes necessary to gather a database to which samples may be compared. The data summarized in this paper may provide some basis for comparison.

From 1989 through 1995 the authors have collected hundreds of surface dust samples. Sample sites included: buildings with asbestos-containing spray-applied fireproofing, acoustical plasters, buildings without these materials, and outdoors.

Methods Employed

The sampling and analytical procedures used for the samples summarized herein were similar to those described in ASTM standard method D 5755-95, or the earlier draft USEPA method. [2,3]

All samples were collected from horizontal surfaces except for some outside samples which were collected from building facades. The surface area sampled was usually 100 cm^2. If different, the results were normalized.

Samples were collected using a battery operated personnel sampling pump calibrated to 2.0 liters per minute. The calibrations were performed using the soap bubble technique or a calibrated rotometer. Samples were collected on 0.45µm pore size mixed cellulose ester filters housed in 25mm diameter cassettes. A nozzle consisting of a 25mm long piece of Tygon™ tubing was attached to the cassette inlet with the end cut at a 45 degree angle. For some of the samples collected (1989-1991) the inlet end of the nozzle was serrated.

Surface dust was vacuumed through the nozzle into the cassette by passing the nozzle across the surface for approximately two minutes. The nozzle was either capped or removed and placed inside the cassette. The cassette was then sealed for transport to the laboratory. With each batch of samples a field blank was also collected and submitted to the laboratory for analysis. Selection of sample locations were at random from the surface sampled, such as metal shelving in a storage room. The actual surface sampled (e.g., metal, polished wood or plastic) had a visual accumulation of dust and no debris (particles greater than 1mm in diameter) on the surface sampled.

The samples included field blanks, samples collected outside of buildings, samples collected inside buildings with no friable asbestos-containing surfacing materials, samples collected in buildings with friable asbestos-containing acoustical plaster, and samples collected in buildings with friable asbestos-containing fireproofing. Samples from outside of buildings were collected from exterior surfaces of 5 buildings located in a large northeastern US city. The sampling protocol included taking 5 samples from each roof, 5 samples from window sills (outside at various heights), and 5 from facades (vertical surfaces).

Table 1.
Results of 44 field Blank Samples

38 SAMPLES	NO STRUCTURES DETECTED
6 SAMPLES	1 STRUCTURE DETECTED

Table 2.
Results of 79 samples collected outside in a large city

Asbestos Structures /cm^2

BUILDING NUMBER	NUMBER OF SAMPLES	GEOMETRIC MEAN	ARITHMETIC MEAN	RANGE
3700	16	3800	14,000	<400 - 93,000
3800	16	600	1400	<400 - 7,800
4100	17	930	9100	<400 - 110,000
4200	15	3200	5700	<500 - 16,000
4300	15	17,000	33,000	<500 - 140,000

Table 3.
Results of 28 samples collected in 6 buildings with no known surfacing ACM

Asbestos Structures /cm^2

BUILDING NUMBER	NUMBER OF SAMPLES	GEOMETRIC MEAN	ARITHMETIC MEAN	RANGE
2100	3	150	160	<240 - 240
2200	1	240	240	240
2400	7	4700	33,000	400 - 210,000
3900	6	260	360	<300 - 1200
4000	5	550	690	<300 - 1400
6800	6	<190	<190	<300 - <400

In the laboratory, the dust was transferred into an aqueous solution. Serial dilutions were performed as necessary to obtain a concentration suitable for analysis. An aliquot was filtered and prepared for analysis by TEM. Asbestos structures identified by asbestos type were counted, sized, and characterized as fibers, bundles, clusters, or matrices. Results were reported as asbestos structures per square centimeter or asbestos structures per square foot of surface sampled.

Results

The results of 319 samples collected at 66 buildings are summarized in Tables 1-6. Table 1 summarizes the results of 44 field blank samples. In 6 samples, 1 asbestos structure was detected. One possible source of the asbestos could be a result of uncapping and re-capping the cassette in the field. In each of these 6 instances, blank correction of the actual samples would not have changed the reported value.

Table 2 summarizes the results of 79 surface dust samples collected from the exterior of buildings. One sample collected from roofing tar suspected of being an asbestos-containing material and having a value of 880,000 s/cm^2 is not included in Table 2. The distribution of results appears log-normal. Accordingly, the appropriate measure of central tendency is the geometric mean value. The geometric means for the 5 buildings are listed in Table 2. The average of the geometric mean values for all buildings is 5100 s/cm^2. The corresponding arithmetic mean is 12,700 s/cm^2. Looking into the data further, the geometric mean values for samples collected on roofs, facades, and windowsills are 2000 s/cm^2, 2800 s/cm^2, and 4700 s/cm^2, respectively. Virtually all the structures detected were chrysotile (i.e., one structure out of over 1000 characterized was an Amosite fiber).

Table 3 summarizes the results of 28 samples collected from surfaces not recently cleaned in 6 buildings with no known friable asbestos-containing surfacing materials. The 6 buildings were generally greater than 20 years old and most had other sources of asbestos-containing materials such as floor tile, pipe/boiler insulation, drywall joint compound or asbestos cement board. The average of the geometric mean values for the 6 buildings is 1000 s/cm^2. The corresponding arithmetic mean is 5800 s/cm^2.

One sample had an unusually high result (270,000 s/cm^2). This result may have been due to an improperly performed removal of asbestos-containing floor tile, although this cannot be confirmed. If this sample is excluded the average geometric and arithmetic mean values for the 6 buildings drop to 650 s/cm^2 and 930 s/cm^2, respectively. The chrysotile form of asbestos was the predominant type found in all the samples.

Table 4 summarizes the results of 34 samples collected in 12 buildings with asbestos-containing acoustical plaster. All samples were collected in rooms having the acoustical plaster from surfaces having visible surface dust. Typical surfaces sampled included the top of exit signs, picture frames and door ledges which were probably not cleaned frequently. The acoustical plaster in all 12 buildings contained typically 2-10 % chrysotile. In some of the 12 buildings the acoustical plaster appeared to have been painted on one or more occasions.

The average of the geometric mean values for the 12 buildings is 160,000 s/cm^2. The corresponding average of the arithmetic mean values is 2.2 million s/cm^2.

Table 5 summarizes the results of 41 samples collected in 18 buildings with spray-applied fireproofing. These samples were collected from horizontal surfaces below the fireproofing with no suspended ceiling or other significant obstruction between the surface sampled and the in-place fireproofing. These samples were typically collected in mechanical spaces from the top of electrical boxes, light fixtures and metal air ducts. While the cleaning frequency for these surfaces was largely unknown, most were probably not cleaned with any regularly, if at all. The fireproofing typically contained between 10 - 25 % chrysotile asbestos.

The average of the geometric mean values for the 18 buildings is 3.6 million s/cm^2. The corresponding average of the arithmetic mean values is 6.5 million s/cm^2. The lowest concentration measured was 7,000 s/cm^2 and the highest concentration was 140 million s/cm^2.

Table 6 summarizes the results of 93 samples collected above ceilings in 29 buildings with spray-applied asbestos-containing fireproofing. These samples were typically collected from the top surface of suspended metal light fixtures or metal air ducts located above a suspended ceiling composed of non-ACM ceiling tiles. The structural fireproofing usually contained from 10 - 25 % chrysotile asbestos. The fireproofing was usually applied to steel beams and columns with overspray onto a corrugated steel or concrete deck. In some instances the fireproofing covered the entire deck. The age of the buildings at the time of sampling was typically 20 - 30 years.

The average of the geometric mean values for the 29 buildings is 3.8 million s/cm^2. The corresponding average of arithmetic mean values is 9.5 million s/cm^2. In one sample, no asbestos structures were detected and a limit of detection of 3500 s/cm^2 was reported. The higher than normal limit of detection was due to a large amount of non-asbestos dust in the sample. The highest concentration measured was 220 million s/cm^2.

Discussion and Conclusion

A summary of surface dust results for all building categories is presented in ***Table 7***. While the results indicate somewhat higher values outside buildings with no surfacing ACM than inside such buildings, these values are 2-3 orders of magnitude lower than values found in buildings with friable asbestos-containing surfacing materials. It should also be noted that the samples collected inside buildings with no surfacing ACM were not taken in areas with damaged other sources of asbestos. Samples collected by the authors in boiler rooms in other buildings without surfacing ACM have shown considerably higher results.[4]

Table 4.
Summary of results for 34 samples collected in 12 buildings with acoustical plaster

Asbestos Structures /cm^2

BUILDING NUMBER	NUMBER OF SAMPLES	GEOMETRIC MEAN	ARITHMETIC MEAN	RANGE
1000	3	16,000	32,000	3600 - 77,000
1100	3	50,000	90,000	19,000 - 220,000
1200	3	48,000	680,000	3600 - 2,000,000
1300	2	24,000	79,000	<3600 - 160,000
1400	3	6200	9000	<3600 - 18,000
1800	3	12,000	52,000	3500 - 150,000
1900	3	3200	4800	<3500 - 11,000
2700	3	170,000	380,000	63,000 - 990,000
4600	3	23,000	78,000	6700 - 220,000
5000	3	1,400,000	25,000,000	82,000 - 74,000,000
5100	2	27,000	28,000	20,000 - 37,000
5700	3	130,000	480,000	8400 - 1,200,000

Table 5.
Results of 41 samples collected in 18 buildings with spray-applied fireproofing with no ceiling present

Asbestos Structures /cm^2

BUILDING NUMBER	NUMBER OF SAMPLES	GEOMETRIC MEAN	ARITHMETIC MEAN	RANGE
1500	2	180,000	280,000	68,000 - 500,000
1600	1	140,000	140,000	140,000
1700	4	110,000	490,000	7000 - 1,700,000
2000	4	530,000	740,000	130,000 - 1,600,000
2500	2	170,000	560,000	25,000 - 1,100,000
2600	2	2,300,000	2,400,000	2,000,000 - 2,700,000
2800	3	470,000	660,000	190,000 - 1,400,000
2900	6	880,000	3,300,000	54,000 - 13,000,00
3200	3	17,000,000	35,000,000	3,100,000 - 81,000,000
3300	2	100,000	120,000	67,000 - 160,000
3400	1	350,000	350,000	350,000
4700	3	22,000,000	53,000,000	9,000,000 - 140,000,000
5300	3	2,300,000	2,800,000	1,500,000 - 5,200,000
5400	1	2,800,000	2,800,000	2,800,000
5800	1	670,000	670,000	670,000
5900	1	3,500,000	3,500,000	3,500,000
6100	1	59,000	59,000	59,000
6200	1	10,000,000	10,000,000	10,000,000

The source of asbestos structures found outside of buildings in a large urban area may be the result of past and present renovation and demolition activities causing the release of asbestos to the outside air. It may also be partially attributed to degradation of brake pads and clutch facings, although some claim little asbestos is released in this manner since the heat of friction transforms chrysotile asbestos into fosterite (a non-asbestos mineral).[5] Some may also be attributed to fiber release from natural sources during groundbreaking and excavating activities.

The average asbestos surface dust concentration for buildings with acoustical plaster was 160 times the average found in buildings without acoustical plaster. In some of the samples additional analyses demonstrated the dust was attributed to the in-place acoustical plaster by finding particles such as gypsum or perlite adhering to asbestos fibers which matched the acoustical plaster matrix. It was often possible to match matrix particles found in dust samples to the matrix of fireproofing located in the vicinity.

Table 6.
Results for 93 samples collected above ceilings in 29 buildings with spray-applied fireproofing

Asbestos Structures /cm²

BUILDING NUMBER	NUMBER OF SAMPLES	GEOMETRIC MEAN	ARITHMETIC MEAN	RANGE
1500	3	380,000	830,000	82,000 - 2,100,000
1600	4	23,000	43,000	<3500 - 77,000
1700	1	19,000	19,000	19,000
2000	1	1,400,000	1,400,000	1,400,000
2500	3	1,700,000	12,000,000	63,000 - 35,000,000
2800	6	7,700,000	12,000,000	2,700,000 - 27,000,000
3000	3	12,000,000	76,000,000	210,000 - 220,000,000
3200	1	52,000,000	52,000,000	52,000,000
3300	2	16,000,000	53,000,000	2,400,000 - 100,000,000
3400	6	490,000	670,000	84,000 - 1,400,000
3500	10	1,700,000	7,600,000	60,000 - 38,000,000
3600	5	1,100,000	2,100,000	420,000 - 2,200,000
4400	3	220,000	2,100,000	2100 - 5,400,000
4500	4	1,200,000	1,300,000	810,000 - 2,400,000
4800	3	180,000	1,100,000	34,000 - 3,300,000
4900	3	17,000	160,000	1000 - 470,000
5200	3	2,300,000	2,400,000	1,800,000 - 3,500,000
5400	2	1,600,000	2,300,000	620,000 - 4,000,000
5500	3	3,900,0000	5,700,000	1,000,000 - 10,000,000
5600	3	180,000	320,000	35,000 - 670,000
5800	2	44,000	52,000	24,000 - 79,000
5900	2	470,000	540,000	280,000 - 800,000
6000	3	560,000	650,000	260,000 - 1,100,000
6100	2	84,000	87,000	64,000 - 110,000
6300	3	330,000	520,000	120,000 - 1,200,000
6400	3	51,000	90,000	21,000 - 220,000
6500	3	1,100,000	28,000,000	13,000 - 82,000,000
6600	3	180,000	240,000	72,000 - 460,000
6700	3	3,900,000	13,000,000	920,000 - 27,000,000

Table 7.
Summary of Surface Dust Results for All Building Categories[1]

BUILDING CATEGORY	NUMBER OF BUILDINGS	ASBESTOS STRUCTURES /cm²
OUTSIDE BUILDINGS	5	5100
NO SURFACING ACM	6	1000
ACOUSTICAL PLASTER	12	160,000
FIREPROOFING (NO SUSPENDED CEILINGS)	18	3.6 MILLION
FIREPROOFING (ABOVE SUSPENDED CEILINGS)	29	3.8 MILLION

[1] AVERAGE OF GEOMETRIC MEAN VALUES FOR ALL BUILDINGS IN THE CATEGORY.

The wide range of concentrations found on surfaces below in-place surfacing materials may be due to several factors. These factors include the condition of the material, water damage, friability, material matrix, percent of asbestos in the material, air movement, and past maintenance/renovation practices. The influence of vibration, temperature and humidity may also be important.

One of the most influential factors is the frequency and efficacy of cleaning. This may partially explain why the fireproofing buildings exhibit concentrations 20 times higher than the acoustical plaster buildings. The surfaces sampled in the acoustical plaster buildings were generally within the living space and therefore subject to more frequent cleaning. Another factor that may partially explain the difference between the acoustical plaster and fireproofing buildings is the acoustical plaster was sometimes painted. One or more coatings of paint (such as latex) would probably reduce the amount of asbestos released.

Some variation will inevitably be introduced by slight differences in sampling technique from sample-to-sample and between sampling personnel. Almost all samples (greater than 90%) were collected by one individual in an effort to reduce variability.

When evaluating dust sampling results the researcher must have an understanding of the potential routes of exposure. Since the principle route of exposure for asbestos is inhalation the researcher should consider the results with an eye toward reentrainment of the dust. In buildings the principle method of reentrainment is through human activity. Custodial, maintenance, service workers, and general building occupants may through their activities cause asbestos-containing dust to become airborne and available for exposure. Other sources of reentrainment may include air movement and vibration.

Some researchers have evaluated the reentrainment potential of asbestos-containing surface dust. In some instances a specific activity coupled with a know concentration of asbestos in the surface dust has permitted the calculation of a dust reentrainment constant, or "K factor." The K factor is a ratio of the measured airborne concentration to the surface concentration for a given activity. K factors reported by

Millette and Hays for six studies indicate a range of 10^{-3} to 10^{-6}, with 10^{-5} appearing typical for routine custodial and maintenance activities.[5] While it appears that no universal K factor exists for asbestos on surfaces, the information is useful when evaluating sample results.

It is apparent there is no single number that can be referenced to delineate when a surface is "clean." It appears that concentrations of asbestos dust less than 1000 s/cm^2 are unlikely to result in elevated exposures. At the opposite extreme, values in excess of 100,000 s/cm^2 should be a cause for concern. Values between these two extremes require the investigator to carefully consider possible exposure scenarios, including reentrainment mechanisms and the exposed population.

Surface dust sampling and analysis for asbestos is a useful assessment tool for building evaluations. It should be used in conjunction with other available information about the building and the asbestos-containing materials. Together this information will assist the investigator in recognizing potential exposure sources and develop plans or procedures to reduce or eliminate the exposures. **EIA**

Acknowledgments

The authors gratefully acknowledge the analytical work performed by William E. Longo, Ph.D. (Materials Analytical Services, Inc., Norcross, GA), James R. Millette, Ph.D. (MVA, Inc., Norcross, GA), and Kenneth Rhodes (currently with Geo-Analytical Services, Inc., Atlanta, GA).

REFERENCES

1) Millette, J.R. and S.M. Hays, *Settled Asbestos Dust Sampling and Analysis,* Boca Raton, FL, Lewis Publishers, 1994, pp. 16-17.

2) American Society for Testing and Materials, *Standard Test Method for Microvacuum Sampling and Indirect Analysis of Dust by Transmission Electron Microscopy for Asbestos Structure Number Concentrations,* ASTM Standard D 5755-95, Philadelphia, ASTM, 1995.

3) Clark, P., *Standard Test Method for Sampling and Analysis of Dust for Asbestos Structures by Transmission Electron Microscopy (Draft),* Cincinnati, OH, USEPA, August 1989.

4) Ewing, W.M., et al., "An investigation of Airborne Asbestos Concentrations During Custodial and Maintenance Activities in a Boiler Room," Paper presented at the American Industrial Hygiene Conference, Boston, MA, June 3, 1992.

5) Personal communication with Walter C. McCrone.

6) Millette & Hays, pp. 59-65.