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SUMMARY OF SYMPOSIUM ON HEALTH ASPECTS OF EXPOSURE TO ASBESTOS IN BUILDINGS

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SUMMARY OF

SYMPOSIUM ON HEALTH ASPECTS OF

EXPOSURE TO ASBESTOS IN BUILDINGS

Harvard University
Energy and Environmental Policy Center
John F. Kennedy School of Government
Cambridge, MA
December 14 - 16, 1988

by

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EXECUTIVE SUMMARY

The Energy and Environmental Policy Center of Harvard University's John F. Kennedy School of Government held a three day symposium on the Health Aspects of Asbestos in Buildings on December 14 - 16, 1988. The purpose of the symposium was to assess the health risk that buildings with asbestos containing materials (ACM) present to occupants, facility maintenance personnel, and workers engaged in asbestos removal activities. Internationally recognized experts addressed a series of questions, including: What is the extent of the health risk posed by asbestos in buildings? Who in the population is being exposed? How do we measure the level of exposure and how do we communicate the extent of the associated risk?

New interpretations of published findings on exposures in buildings and of occupational cohort studies were presented at the Harvard symposium. The toxicity of fiber type as well as factors influencing the response of individuals exposed to those fibers was discussed. Mesothelioma and lung cancer risks were projected through extrapolations from epidemiologic studies of workplace environments. The principal findings from the symposium are summarized below.

1. Asbestos is not a single mineral. It is a term used to refer to a number of fibrous inorganic minerals that share specific properties. The most common of these is chrysotile - representing over 95% of all asbestos used in buildings. The second major group is amphiboles - including amosite and crocidolite. The differences in fiber type and dimension can be of significance in determining health risks. For example, the amphibole fibers pose a much greater risk of mesothelioma than chrysotile fibers. Respirable fibers longer than ~5 μm are thought to be of much greater risk than short fibers. Measurements made by EPA indicate that exposures to fibers 5 μm and longer inside buildings are much lower than average airborne concentrations of all fibers.
2. Occupant risk should be determined by exposures to airborne fibers. At the present time there is no single optimum method to characterize potential exposure to airborne fibers from asbestos containing materials in buildings. However, the consensus view was that air sampling, using the direct

preparation TEM methodology, is the methodology of choice for current exposure assessment. The available asbestos air monitoring data base for buildings in the U.S. indicates extremely low average concentrations of airborne asbestos under normal building use conditions.

3. The extent of risks associated with exposures to asbestos in contaminated buildings differ for various groups who reside or work in these buildings. Custodial personnel, maintenance and construction workers may be exposed to elevated levels of asbestos for brief periods of time. In contrast, however, most office workers, teachers, students, and other building occupants typically do not come in close contact with asbestos containing materials.

4. There are considerable differences in the value of many of the earlier studies on asbestos health effects. A major, nearly universal deficiency was the differences in measurement techniques as well as uncertainties relating to the amount of asbestos fibers in the workplace environment. For example, a main data source, particle concentration measurements (pre-1960), did not count fibers separately, let alone differentiate them by size, length, or type. Consequently, most studies used to quantify risk were unable to quantify differences in response associated with fiber type and size. In some studies, impurities or the presence of other substances may have affected the risk estimates.

5. Process factors and environmental effects have, potentially, significant impact upon risk. Occupational cohort studies show that relative risk of lung cancer from exposures to amosite or mixed (amphibole and chrysotile) fibers is typically higher than risk associated with processes in which chrysotile is bonded with other materials, as in production of cement or friction products. However, studies of lung cancer among chrysotile textile workers show increases in relative risk higher than those encountered using mixed fiber types (insulation material or cement products).

6. Mesothelioma has been modeled as a risk independent of age. Risk increases in proportion to the product of exposure and as a power of time (typically around 3). For calculating mesothelioma risk, fiber type is believed to be

essentially important. The majority of asbestos-related mesotheliomas can be attributed to amphiboles (primarily crocidolite), a much less commonly used variety of asbestos in the U.S. The mesothelioma risk from exposure to chrysotile asbestos, the type of asbestos most commonly found in U.S. schools and buildings, is believed to be considerably lower. Present U.S. regulation does not consider variations in the biological potency of different fiber categories.

7. Lung cancer and mesothelioma risk models have been developed for asbestos exposure that are considered to be conservative (i.e., tend to overpredict rather than underpredict the risks). Recent data indicate that the average concentration of asbestos in schools and other buildings that have asbestos containing materials is generally well below the 0.001 (mixed) fibers/ml used in risk calculations performed for school children. Using these conservative risk models and exposures higher than typically measured, the projected lifetime risk from exposure to mixed asbestos fibers is one death among a cohort of 100,000 children.[1] These risk projections do not differ greatly among different investigators.

8. The risk of 1 in 100,000 is far less than most other commonly experienced environmental health risks, such as those attributable to environmental tobacco smoke and radon. Even though the risk posed by in-place asbestos is very small, both in absolute and relative terms, the public perception of these risks are high, which often leads to the decision to simply remove all of the asbestos containing materials from buildings that have ACM.

9. Removal itself is not without risk. Removal and disposal operations expose a large fraction of removers to high concentrations of airborne asbestos, and also may potentially increase rather than decrease indoor asbestos concentrations and the associated health risks. Thus, there exists a question

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[1] Assuming 10 year exposure to the mixed asbestos fibers from building insulation material at concentrations of 0.001 (regulatory) fibers/ml, where regulatory fibers are defined to be at least 5 μm in length, with a length-to-diameter ratio of 3 to 1 or greater.

whether removing asbestos containing materials now, as opposed to at the time of demolition, will reduce, or even increase, health risks.

10. In many cases, spending money on asbestos removal will likely decrease funding which might be available to support other public and educational measures which could be far more effective in reducing environmental health risks.

11. For buildings with ACM, air sampling and risk calculations should be performed as a component of selection of the most effective management strategy from the point of view of health protection and achieving a net risk reduction. This evaluation should include the risks to both groups: occupants of these buildings; and custodial and maintenance personnel and workers involved in the removal of the asbestos. The potential for exposure to asbestos fibers is much greater for the latter group than the former. Therefore, personal monitoring studies should be initiated to evaluate worker exposure and worker protection procedures under various conditions of asbestos management and abatement.

1. INTRODUCTION

The symposium organized on December 14 - 16, 1988 by the Energy and Environmental Policy Center of Harvard University and jointly co-sponsored by the Center, National Association of Realtors®, the Institute of Real Estate Management Foundation, the Urban Land Institute and the Safe Buildings Alliance was a constructive examination of the scientific knowledge fundamental to environmental asbestos risk management. The symposium identified inconsistencies between current and emerging information on risk of asbestos use in buildings and previous regulatory decisions. This summary provides an overview of the problem and reviews the major findings presented at the symposium. The titles of the papers presented are listed in the Appendix; they will be published in the proceedings of this meeting. Also included in the Appendix is a list of symposium participants.

This summary begins with a section reviewing the nature of the asbestos problem, followed by a synopsis of the various methods available for assessing concentrations and exposures. The third section of the report summarizes the present state of knowledge regarding the human health risks of exposures to asbestos. The fourth section presents a summary of key conclusions. Finally, the references cited in the text are contained at the end of this report.

1.1 The Nature of the Problem

Given the well established and highly publicized association between exposures to asbestos and the diseases of asbestosis, lung cancer or mesothelioma in occupationally exposed populations, "fiber phobia" among the general public is not unreasonable. Knowledge that asbestos related diseases have been documented in populations not working directly with asbestos material but living in adjacent communities or in the household of an asbestos worker, contributes to the fear that asbestos fiber exposure at any level is associated with an unacceptable risk.

Asbestos containing materials (ACM) are present in many homes, offices and school buildings, causing anxiety and concern for the well-being of the occupants. Homeowners, school board members, corporate counselors and CEO's are not expected to differentiate between serpentine and amphibole fibers, or between differential risk for smokers and non-

smokers. They are bombarded daily with news of dangers from a myriad of environmental and safety hazards. Radon gas in buildings, tobacco smoke, pesticides in food, and volatile organic compounds in air and water, as well as asbestos fibers are all concerns that must be dealt with by anyone who owns or manages a building. What experience would lead them to appreciate the potential new risk, such as high exposures to asbestos fibers by removal workers? It is not surprising that public and private managers reach the simplest and liability reducing decision - simply remove the asbestos containing material from their buildings. The correctness of their decisions appears to be bolstered by the Congressional action against asbestos in schools, by courts requiring manufacturers, insurers, installers to pay the cost of removal and by the promotional activities of companies involved with asbestos removal.

Surveys by EPA estimate that 20% of our nation's buildings (733,000 buildings, excluding schools and residential buildings with less than ten units) contain some friable asbestos materials (EPA 1988a). Separate surveys for the City of New York estimate that 67% of the buildings (153,000, excluding schools and one- or two-family homes), contain asbestos (NYC DEP 1988). The estimated cost of removing the asbestos from all buildings is enormous. For example, according to EPA's report to Congress (EPA 1988a), it will cost $51 billion to remove asbestos from all public and commercial buildings.

To address the efficacy of removing asbestos from buildings, we need to reassess whether we are effectively measuring the extent and magnitude of the hazard and whether the risks are large enough for concern - risks not only for the occupants of these buildings, but also for those workers involved in removal of asbestos. Ultimately, we must be confident that removing asbestos fibers either now or prior to demolition will result in a reduction of health risk. In light of scientific evidence published since the National Research Council's 1984 report on asbestos, the experience with current removal practices and the low level of demonstrated asbestos fiber exposures in buildings, and new information on the potential hazards of man-made mineral fibers used as substitute insulation, there is a reasonable conclusion that removal of asbestos may actually increase health risk.

Given this new information, it is appropriate to reappraise the credibility of the scientific data base and assertions made with respect to the health risk of asbestos in

buildings. The 100th Congress of the United States was in accord with this appeal when it authorized $2,000,000 to be matched with private contributions for jointly funded asbestos research. Excerpting from the appropriations language....

> "This research is intended to determine actual airborne exposure levels prevalent in buildings, to characterize peak exposure episodes and their significance, and to evaluate the effectiveness of asbestos management and abatement strategies in a scientifically meaningful manner. The conferees believe it is important that the sponsorship of and participation in this effort encompass the full range of private interests, including current and former product manufacturers, realtors, developers, building owners and managers, mortgage bankers, the insurance industry, labor organizations and environmental groups."

1.2 Background on Asbestos and its Use

Asbestos, because of its high tensile strength and thermal properties, has been used in a variety of building materials, including thermal and acoustical insulation, fire protection, and the reinforcement of building products, since the beginning of this century. Asbestos has been used in paints, wall and ceiling plaster as well as in ceiling acoustical and vinyl floor tiles. Until banned during the 1970s, sprayed-on asbestos materials were used to coat pipes, boilers and steel structural beams, structural concrete and the underside of concrete and steel pay decks. Table 1 summarizes some of the important uses of asbestos. Figure 1 indicates the substantial decrease in the U.S. consumption of asbestos since 1973 - a decrease which coincides with EPA's banning certain applications.

It is important to remember that asbestos is not a single mineral. Asbestos is a term used to refer to a number of fibrous inorganic minerals that share specific properties of asbestiform habit, flexibility, high tensile strength, and stability in hostile chemical environments. The serpentine mineral chrysotile is the most commonly used asbestos, representing over 95% of all asbestos used in buildings. Most of the chrysotile asbestos used in the U.S. is imported from Canada. The second major group of asbestos minerals are amphiboles, including amosite and crocidolite. South Africa is a major supplier of these fibers. Used in a number of commercial applications, they have been historically important in terms of worker exposure and disease.

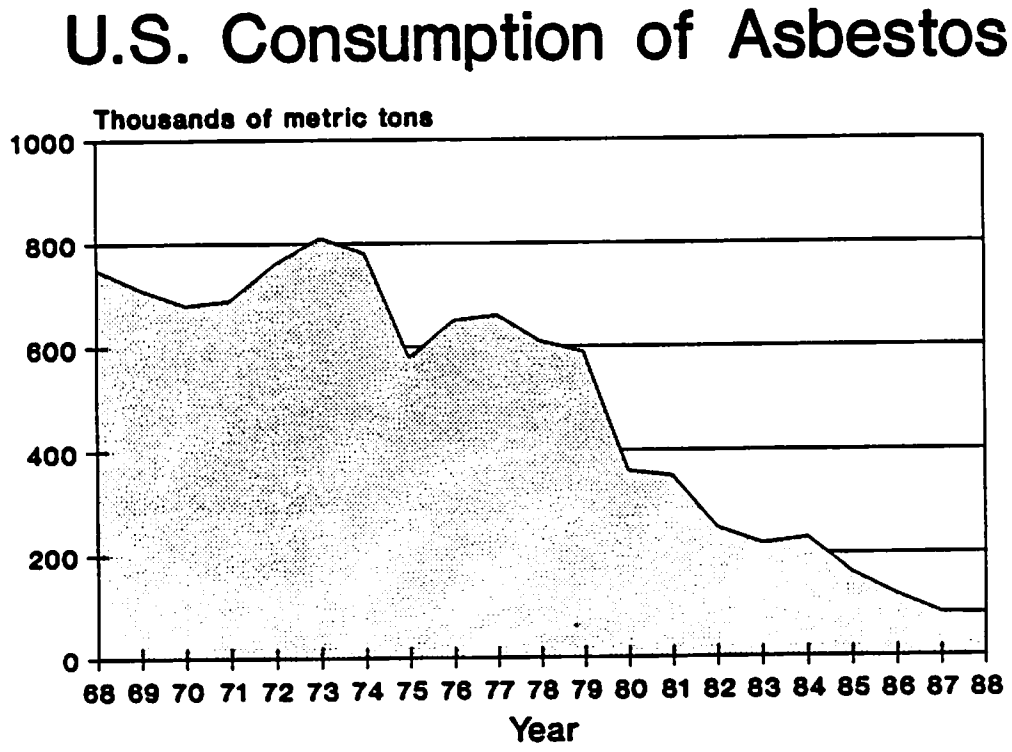
Table 1

SUMMARY OF ASBESTOS-CONTAINING BUILDING PRODUCTS

Product	Dates Used	Average % asbestos
Floor tile and sheet	1950 - present	20
Asphaltic coatings and sealants	1900 - present	10
Cement pipe and sheet	1930 - present	30
Roofing felt	1910 - present	15
Corrugated paper pipe wrap	1910 - present	80
Sprayed insulation	1935 - 1978	50
Trowelled insulation	1935 - 1978	70
Preformed pipe wrap	1926 - 1975	50
Insulation board	unknown - present	30
Boiler insulation	1890 - 1978	10
Other uses	1900 - present	<50

Source: Progressive Builder, September 1986.

Figure 1



Adapted from: Chemical & Engineering News, March 4, 1985

In the mining, milling, fabrication and installation of asbestos, fiber bundles may be manipulated so that individual bundles break open, releasing fibrous particles that are inhalable. However, once asbestos is in place, or in the matrix of a product, fiber bundles are not disrupted without application of external mechanical force, i.e. they do not degenerate spontaneously. This last point is important in evaluating the public health risk to occupants in a building containing asbestos materials. The magnitude, and even existence, of risk will depend on the activities of the occupants. Office workers or school children would have less exposure to fibers under passive circumstances of occupancy than a maintenance worker installing cables in an area where contact with an asbestos-containing material is likely. The population at greatest risk are removal workers who must deliberately disturb the asbestos.

The distinction of different fiber types is also important in evaluating health effects data. Similar to other mineral deposits, asbestos ores may contain a variety of impurities, some of which are source specific. Further, depending on product formulation, different asbestos fiber types might be mixed. There have been many occupational mortality studies of asbestos workers indicating differential response by fiber type. Occupational groups studied include production workers (miners and millers), textile mill workers, insulation installers, cement product workers, structural material fabricators, gas mask fabricators, and car mechanics. These studies have been reviewed in several documents including Omenn et al., 1986; USEPA 1984; CPSC 1983; Ontario Royal Commission 1984; British Health and Safety Commission 1985; NRC 1984 and others. It is concluded that based on these earlier worker studies amphibole fibers (amosite and crocidolite) seem to pose a much greater risk of mesothelioma than chrysotile fibers alone (Langer and Nolan 1988; Liddell 1988).

2. METHODS FOR ASSESSING CONCENTRATIONS AND EXPOSURES

To estimate exposures to asbestos containing materials in buildings, it is necessary to have adequate methods to accurately characterize the airborne fiber concentrations. This characterization ideally should include fiber dimension (length and diameter), concentrations, and fiber type.

EPA regulatory programs rely on visual inspection methods to determine response to ACM, eg. if one sees damaged asbestos materials, one should consider remedial action.

There is, however, a lack of correlation between visual assessment methods and fiber concentrations obtained from air samples in spaces with damaged ACM. Participants in the symposium felt that visual inspection does not quantify exposure and is, therefore, not reliable for risk assessment. Since the results of air sampling are directly utilized in risk assessment, future risk assessments should rely more on quantitative air sampling techniques than the subjective (non-quantitative) method of visual inspection. Discussion of various sampling techniques and their current limitations is summarized below.

2.1 Physical Methods of Measurement and Analysis

At the present time there are two analytical methods typically employed to determine the concentration of airborne asbestos fibers: phase-contrast microscopy (PCM) and transmission electron microscopy (TEM). They vary dramatically in their analytical sensitivity, technical sophistication, and cost.

The method that has been most commonly employed is phase-contrast microscopy (PCM). This method counts fibers longer than 5 μm. According to the National Institute for Occupational Safety and Health (NIOSH), fiber resolution possible with PCM is 0.25 μm diameter under the most ideal conditions. Standard phase-contrast microscopes have a functional resolution limit at about 0.5 μm. Therefore, particles with a smaller diameter will not be visualized, and not included in the fiber counts developed using PCM. This method is unable to differentiate between different types of fibers, including non-asbestos fibers, such as glass fiber, mineral wool and cellulose. Therefore, it lacks both adequate sensitivity and specificity.

With the TEM, the commonly achieved point-to-point resolution is orders of magnitude smaller than obtainable with PCM. Therefore, all fibers may be visualized. TEM can utilize an energy dispersive x-ray spectrometry and selected area electron diffraction to identify the fiber types present. EPA currently requires the use of transmission electron microscopy (TEM) to determine airborne fiber concentrations for area clearance following asbestos material removal.

There are currently two protocols used to prepare an air sample for TEM analysis: the direct method and the indirect method. Each has its own preparation procedure, either of which can result in variability (Chopra 1978). The direct analysis method retains

particles on a filter and preserves the pattern of deposition for visualization and characterization. This, of course, should best represent the particles in the airborne state, and should best characterize potential biological effect. However, there are several limitations of this methodology. For instance, if filter loadings are high, it may be difficult or even impossible to visualize, identify and count individual fibers. Also, entire filter surfaces are never completely scanned. Rather, a series of grid pore openings or "fields" are examined. Fiber concentrations are based on statistical analysis of a small portion of the total filter. Unfortunately, non-uniform deposition of fibers on the TEM sample is typical in the direct methodology.

The indirect preparation method suspends the collected particulate matter in liquid and after agitation, refilters it. This filtration should result in a more uniform deposition of particulates and can be diluted to provide a suitable particle distribution, i.e., no particle overlap. On the other hand, it also has been shown to break up fiber bundles thereby modifying both size and fiber number. This greatly improves counting capability with titration, enhances the statistical reliability, and facilitates identification of individual fibers, but also changes the population size distribution and can increase fiber counts. Thus, with this technique probable biological relevance is greatly reduced.

Because of the introduction of size-number artifacts when using the indirect method, an earlier practice (1960s to early 1970s) was to grind the sample to break down chrysotile fibers into individual fibrils, all assumed to have a uniform diameter. By measuring total fiber length and applying a density factor, fiber mass per volume of air rather than fibers per volume of air was reported. However, there is no systematic or universal transformation to equate mass to fiber concentrations. To date, there is no method or procedure that will allow the results obtained by PCM, TEM direct, or TEM indirect to be compared on a uniform basis.

The ability to accurately quantify the low fiber concentrations in buildings is critical to the assessment of risk. It is clear that occupational studies using PCM methods found fiber concentrations several orders of magnitude higher than currently measured in schools and other buildings. PCM methodology has been practical for occupational settings but is less useful for assessing low level and nonhomogeneous fiber concentrations in buildings. PCM cannot differentiate among fiber types which is important to identifying risks from

asbestos fiber exposures in buildings where asbestiform, natural, and synthetic fibers can coexist. For the purposes of exposure and risk assessment, TEM method, incorporating analytical capabilities, should be used as the primary method for air sampling in buildings.

2.2 Building Assessment Methods

The Symposium focused on several issues regarding building assessment methods. Discussions on the 1984 EPA Report entitled "Asbestos in Buildings: A National Survey of Asbestos-Containing Friable Materials" centered on the reanalysis of data regarding the type and condition of asbestos found in the buildings sampled. Further discussions involved EPA's 1988 air monitoring study "Assessing Asbestos Exposure in Public Buildings" which reviewed the relationship between buildings that have asbestos-containing materials in them and the concentration of airborne asbestos fibers found there.

Fundamentally, risk to human health cannot be attributed to just the presence of asbestos-containing material in a building. For a risk to exist, respirable asbestos fibers must be present in the airborne state and be inhaled by building occupants. There are two major methods that are employed in attempting to assess the asbestos exposure potential to building occupants: (1) the simple identification of ACM in buildings by visual inspection to evaluate the condition of ACM and to assess its potential for disturbance; and (2) air monitoring techniques. The relative merits of these two exposure assessment techniques is currently being debated. However, the Symposium participants agreed on several points that are elaborated below.

Visual inspections evaluate asbestos containing materials by classifying the types found, note their location, accessibility, amount, condition, percentage of asbestos and attempt to determine the potential level of disturbance. Bulk samples of suspect material are collected and analyzed in the laboratory by polarized light microscopy (PLM) to determine if the materials actually contain asbestos. The results from these visual inspections are then incorporated in a summary index which is used as an indicator of exposure potential. Recent studies report the use of visual inspection. These studies include the U.S. Environmental Protection Agency's 1988 report to Congress on ACM in public buildings, and the City of New York's Department of Environmental Protection's study of in-place asbestos (NYC DEP 1988).

Participants felt that visual inspection methods are an efficient way to inventory ACM in buildings. However, several limitations of the ratings used for survey data were discussed. Concern was expressed for the ability of inspectors to consistently and accurately assess the condition of ACM. It is not clear that the potential disturbance of ACM can be consistently determined.

Perhaps more important with regard to assessing exposure potential was the discussion of the relationship between asbestos survey findings and airborne asbestos levels in buildings. The 1988 EPA report (EPA 1988b) stated that the differences among airborne asbestos levels in buildings with ACM deemed to be in "good" or "bad" condition, buildings containing no ACM, and outside air, were not significant. These data, which are summarized in Table 2, support the position held by most of the attendees that the use of these "ratings" to assess the risk to occupant health are a poor surrogate for actual air monitoring.

Measurement of airborne asbestos levels have also been criticized for their inability to reliably represent past or future contamination levels, and that an air sample could be a "snapshot in time" or may not be taken in an area where contamination exists.

The use of various "passive" sampling methods was also discussed. These methods rely on collection and analysis of settled dust from horizontal surfaces as an indicator of previous releases. Limitations of these methods have to do with unknown collection/transfer efficiencies as well as the uncertainty in knowing how long the dust has been allowed to accumulate. These methods are generally only used to obtain relative differences between areas in a building and not useful for quantitative risk assessment.

Therefore, at the present time there is no single optimum method to characterize potential exposure to airborne fibers from ACM in buildings. Projections of future (potential) exposures should include judicious interpretation of many sources of data. However, the consensus view was that air sampling in buildings should be used to enhance exposure assessment and risk estimation.

Table 2

COMPARISON OF OUTDOOR AND INDOOR ASBESTOS CONCENTRATIONS (structures/ml)

		Inside Buildings		
	Outdoor	No ACM	"Good" ACM	"Bad" ACM
MEAN	0.00039	0.00099	0.00059	0.00073
MEDIAN	<0.00001	0.00010	0.00040	0.00058
N	48 (sites)	6 (bldgs)	6 (bldgs)	37 (bldgs)

Note: Concentrations are building averages - 7 samples per building

Source: EPA 1988b

2.3 Measurement and Exposure Issues in Buildings

The asbestos air monitoring data base for buildings, which has grown significantly during the past two years, indicates extremely low average levels of airborne asbestos under normal building use conditions. Early TEM measurements of airborne asbestos levels (EPA, 1975; Nicholson, 1978; EPA, 1980; EPA, 1983), which were large enough in EPA's judgement to justify initiation of an asbestos regulatory program, were obtained using the indirect filter preparation method. These measurements, therefore, were reported in mass units (nanograms per cubic meter of air). Exposure measured in mass units, however, does not reflect health risk as directly as exposure measured in fibers per milliliter of air (fibers/ml). More recent data, obtained using the direct preparation TEM methodology and generating data on fibers/ml, indicate lower average exposure levels than were indicated by the earlier indirect methodology studies.

EPA's recent report to Congress concerning asbestos in public and commercial buildings (EPA, 1988a) provides a summary of TEM data utilizing the direct filter preparation method for 94 non-school buildings and 41 school buildings. The average airborne asbestos concentration in non-school buildings was reported to be 0.006 fibers/ml. The average for the studied school buildings was reported to be 0.03 fibers/ml. Since these data were compiled from a number of different air monitoring studies with different degrees of documentation, the averages should be interpreted as representing concentrations for all asbestos structures visible with TEM (i.e., fibers both longer and shorter than 5 microns and other asbestos fibers that may not be considered respirable).

In a different study, detailed documentation, however, is available for the 43 non-school buildings with ACM which were studied by EPA and 73 schools which were studied by asbestos product manufacturers where asbestos removal was imminent (EPA, 1988b; Price, 1988). In the EPA study, the average airborne asbestos concentration when all structures are counted was 0.00070 structures/ml. Of the 387 samples collected in this study, including 48 outdoor samples and samples in 6 buildings with no friable ACM, 83 percent yielded no measurable asbestos fiber counts. Restricting the asbestos count to only those fibers 5 microns in length or longer resulted in an average concentration level approximately 8 times lower, 0.00008 fibers/ml. In the 73 school buildings, the average airborne concentration counting all asbestos structures was 0.01773 structures/ml. Restricted to fibers 5 microns or longer, the average concentration was 0.00022 fibers/ml. The average of measurements taken outdoors in these studies is comparable to the measured indoor level. In general, these results demonstrate that airborne asbestos levels inside buildings are low and suggest that in many buildings the difference between prevalent indoor and outdoor asbestos fiber concentrations is not significant from a public health perspective.

As stated above, occupant risk should be determined by exposures to airborne fibers rather than the presence of asbestos-containing materials in the building. At present there is insufficient information to correlate the relationship between potential exposure and actual indoor concentrations of airborne asbestos fibers. This is due, in part, to the fact that only a few studies have been conducted to examine this relationship. Also, the very nature of periodic or episodic fiber releases makes it difficult to detect a relationship in

short-term surveillance or cross-sectional monitoring studies. As a result, the distribution of concentrations both within and across buildings has been not fully characterized. This is primarily a concern for those occupationally exposed, i.e., those who disturb the ACM.

By definition, personal exposures are determined by the fiber concentrations in the immediate vicinity of the breathing zone. Fixed location monitoring within a structure only provides an estimate of what exposures might be for occupants of that building. For example, the actual exposure in the breathing zone of a facility maintenance employee replacing ceiling panels might be quite different than the concentrations monitored at some other fixed location. When considering exposure, it must be recognized that occupants will have different potentials for both short-term and long-term exposures. It is important to differentiate these exposure grouping for both control strategies and risk assessment.

The occupants of buildings can generally be categorized in two groups in respect to potential exposure to asbestos containing materials. The first, and much more numerous group includes occupants who do not come in close contact with asbestos-containing materials. Most office workers, teachers, and students would be in this first category. The second, and smaller, group includes those whose work potentially places them in close physical contact with asbestos material. Several job categories would be included in this group, such as custodial, maintenance, and construction personnel, telephone and computer installers, and ventilation system workers. This distinction is quite important to exposure risk assessment. The lower fiber counts reported in building surveys to date are a better indication of potential exposure for the first, larger occupant group. These lower fiber counts indicate for this group that risk is low and that the frequency of episodic releases are also low.

Similar conclusions cannot be inferred for the occupations that come in close physical contact with ACM. Exposures encountered by these occupational groups can be characterized, but with difficulty (Sawyer 1977). The exposure data of interest is really the cumulative exposure to asbestos fibers over a time period of months to years. In order to understand the factors that contribute to exposure, it may be important to examine short-term episodic conditions for worker populations. Information on the short-term exposure profiles can be used to develop worker protection procedures and to formulate specific removal or containment programs. The only way to adequately address this issue is to

conduct personal monitoring during tasks representative of work procedures involving a variety of conditions and materials (Sawyer 1979). Workers' exposures must be monitored while they engage in the routine and unusual activities that have the potential to generate airborne asbestos fibers.

Personal monitoring of asbestos fiber exposures for members of the group that do not come in direct physical contact with ACM is also needed. This effort would demonstrate the relationship between fixed location area monitoring and personal exposures. Issues that need to be resolved concern the potential that asbestos removal might actually increase exposure to this group of building occupants. For example, the currently required (AHERA) monitoring for reoccupancy may not represent fiber concentrations that would result from resuspension of settled fibers. Aggressive sampling in post-abatement areas evaluated by the EPA has shown fiber levels to increase 3 to 6 times over preabatement levels (Karaffa et al., 1987). Burdett et al., (1988, 1989) found fiber levels increasing 10 to 100 times after incomplete dry removal. Further, the comparison to ambient fiber concentrations as the criteria for reoccupancy does not address the change in exposures to occupants before and after removal. It is the net change in estimated lifetime exposures, before and after asbestos removal, that will determine the effectiveness of abatement strategies.

3. ASSESSING HEALTH RISKS

Essentially, all of our current information on health hazards associated with the inhalation of asbestos fibers comes from studies of diseases among workers exposed to asbestos in various occupational settings. Both occupational cohort studies and animal experiments indicate that three forms of disease can be associated with inhalation of asbestos fibers: (1) asbestosis-fibrosis or scarring of the lung, (2) lung cancer, and (3) mesothelioma - a malignancy of the pleura and peritoneum, linings of the lung and abdomen.

Deaths from asbestosis are observed only among individuals that have been occupationally exposed to high levels of asbestos (Nicholson 1986). Present levels of asbestos in workplaces utilizing current control procedures are not expected to produce any measurable impairment (Berry et al., 1980). Further, if asbestosis occurs, due to recent and

much lower levels of asbestos exposure in workplaces, it has a slow progression and rarely results in serious disability or increased mortality (Jones et al., 1989). Consequently, there does not seem to be any evidence that asbestosis is a concern as a result of environmental exposures.

The papers presented at the Harvard Symposium by Drs. D. Liddell, J. Hughes and J. Peto summarized the occupational data base and risk models used in projecting lung cancer and mesothelioma risks for environmental exposures to asbestos. Uncertainties surrounding the exposure variables and the estimated dose-response functions, used in the development of risk models for asbestos, were also addressed by these presenters. Using conservative (pessimistic) assumptions, mesothelioma and lung cancer risk projections from exposures to indoor asbestos for school age children and the general population was generally agreed by all of the symposium participants to be quite small. For example, associated lifetime risk of death is estimated to be around 1 in 100,000 for 10 years of occupancy in contaminated buildings with 0.001 regulatory fibers/ml of mixed fiber types. Researchers attending the meeting attempted to put these uncertainties and risks in perspective by comparison with model predictions of risks to school children and building occupants from other environmental hazards. This comparison of asbestos risk to other life risks was considered essential to provide understanding of the significance of this level of exposure. The principal findings from the symposium regarding these risk issues are summarized below. We also note that many of the issues discussed in this section were previously addressed and summarized in Hughes and Weill (1986).

3.1 Sources of Exposure Data and Uncertainties in the Dose-Response Models

The epidemiologic studies of asbestos health effects are based on occupational exposures to asbestos which occurred many years ago. These studies cannot be considered without recognizing the fact that these occupational exposures were much greater than those found inside buildings today, and were measured using techniques less appropriate to risk estimation. Based on a method developed for measuring exposure to respirable silica dust, particle measurements, instead of fiber counts, were made. For subsequent studies, the particle concentrations were converted to fiber concentrations, usually on the basis of relatively few comparative measurements in occupational settings. Unfortunately,

there are many inconsistencies in this process. According to Peto (1989), no single or consistent relationship exists between particle counts taken in the past with different instruments, or in conversion of particles to fiber concentration. For many occupational cohorts there were also very few exposure data in areas of heavy contamination (Peto 1989).

Animal experiments and physiologic evaluations suggest that asbestos fibers of different length and diameter will have different potencies. According to Lippmann (1988), mesothelioma is most closely associated with fibers longer than ~5 μm and thinner than ~0.1 μm, and that lung cancer is most closely associated with fibers longer than ~10 μm (the approximate diameter of an alveolar macrophage) and thicker than ~0.15 μm. However, these experimental observations have not been fully corroborated with effects observed with humans.

There is general agreement that crocidolite and amosite asbestos pose much greater risk of mesothelioma than chrysotile (Liddell 1988; Hughes and Weill 1986; Langer and Nolan 1988). Most commercial asbestos (i.e. over 95%) used in the United States has been Canadian chrysotile. Therefore, the application of mixed fiber risk models may be conservative. This is an important point for public policy, because present U.S. regulations do not consider variations in the biological potency of different fiber categories (Corn 1988).

Establishing a relationship between estimated dose and observed effects, such as lung cancer or mesothelioma, requires formulation and application of suitable statistical models. According to Peto (1988), the majority of the dose-response relationships reported for lung cancer and mesothelioma have been based on two assumptions: (1) the increase in relative risk for lung cancer is proportional to cumulative asbestos exposure and constant over time, and the effects of asbestos and cigarette smoking are multiplicative; (2) the increase in mesothelioma incidence caused by asbestos exposure is approximately proportional to the product of the mean asbestos concentration to the 3rd power of time since it occurred, independent of age or smoking history at initial exposure (Peto et al., 1982).

The assumptions of the asbestos lung cancer model, that the risk is linearly related to both concentration and duration of exposure, and relative risk (observed/expected) is constant over time are based on analyses of data with certain limitations (Hughes and Weill

1986). Many experts believe that the utilized risk models are conservative, i.e. most likely to lead to overprediction of risks rather than an underprediction.

The mesothelioma risk model is based on more assumptions than the lung cancer model and relies on fewer quantitative data (Hughes and Weill 1986). Although the model fits the available data sets over a certain time period following first exposure, there is a possibility that the mesothelioma risks after many years (50+) does not rise as steeply as predicted by the model (Hughes and Weill 1986). If this is in fact the case, the current models could considerably overestimate lifetime mesothelioma risks.

In summary, it is difficult to establish the reliability of these risk models in predicting incidence of lung cancer or mesothelioma from environmental exposures to asbestos. The main reason for this difficulty is the frequently encountered "low dose extrapolation" problem, i.e. when models that are developed using high industrial asbestos exposures experienced in the past are used to predict population risks at the current low levels (cf. Zeise et al., 1987). In spite of these difficulties the existing asbestos risk models seem to produce risk projections consistent with the observed background mesothelioma rates of about 2 per million persons (McDonald 1985).

It is important to note that even with the statistical uncertainties in the estimated cancer or mesothelioma risks, asbestos risk estimates reported by various researchers are in close agreement. The summary of these risk estimates presented in Hughes and Weill (1986) suggests that the six commonly reported lung cancer and mesothelioma risk estimates, are typically within a factor of 3 of the mean estimate (i.e. three times higher or lower than the average of all the risk estimates). This finding indicates that different investigators have adopted similar methods but may have used rather different model parameters or data sets to predict asbestos health risks.

3.2 Projected Asbestos Risks and Their Significance

Using the risk models developed it is possible to estimate the magnitude of cancer and mesothelioma risks that may be posed by asbestos in contaminated buildings or schools. Recent data, mostly collected and reported by EPA contractors, suggest that the average level of asbestos in schools and other buildings that have asbestos containing materials, is generally well below the 0.001 fibers/ml (Corn 1988; Price 1988; EPA 1988b) used in the

risk calculations performed for school children (Peto 1988 and Hughes 1988). Using these models, the prediction of total additional lifetime risk of death from asbestos related lung cancer or mesothelioma is 1 in 100,000 or less. It is important to note that these are individual probabilities of death and not actual deaths. Furthermore, these deaths, if they ever occur, will not occur until much later in life. Although these predictions cannot be tested directly, it is shown that these estimates are again consistent with the fairly stable background risk of mesothelioma for population groups with no history of asbestos exposure.

These risks may be put in perspective by comparing the projected asbestos risks to other known risks. First of all, a risk of 10 lifetime excess deaths among one million school age children exposed to 0.001 (mixed) fibers/ml for 10 years is a small fraction of expected deaths from non-asbestos related causes, in this same cohort of children. According to Hughes and Weill (1986), using recent U.S. data, out of this population of 1 million students, approximately 32,000 would be expected to die from lung cancer (90% of those deaths would result from active smoking). As shown in Table 3, the lifetime risk of 1 premature death in 100,000 associated with asbestos exposures is also small compared to other environmental risks. For example, lifetime risk of premature death due to indoor environmental tobacco smoke (i.e. living with a smoker) or living in a house that has radon is two to four hundred times greater than the projected risks of dying from exposures to asbestos at concentrations stated above. For most urban areas, such as Los Angeles, and industrialized communities in New Jersey and West Virginia, lifetime cancer risk from ambient air toxics are at least ten times greater than the estimated 1 in 100,000 asbestos risks (Sullivan et al., 1989).

Table 3

PUBLISHED ESTIMATES OF RISK FROM VARIOUS CAUSES (MAINLY U.S. DATA)*

Cause	Voluntary (V) or Involuntary (I)	Lifetime Risk of Premature Death (per 100,000)
Smoking (all causes)	V	21,900
Smoking (cancer only)	V	8,800
Motor Vehicle	I	1,600
Frequent Airline Passenger	V/I	730
Coal Mining Accidents	I/V	441
Indoor Radon	V/I	400
Motor Vehicle - Pedestrian	I	290
Environmental Tobacco Smoke/Living with a Smoker	I/V	200
Diagnostic X-rays	I	75
Cycling Deaths	I/V	75
Consuming Miami or New Orleans Drinking Water	I	7
Lightning	I	3
Hurricanes	I	3
Asbestos in School Buildings	I	1

* Sources of Risk Estimates: Commins (1985), Weill and Hughes (1986), Wilson and Crouch (1982)

As discussed previously in Section 2.3, the extent of risks associated with exposures to asbestos in contaminated buildings differ for various groups who reside or work in these buildings. Custodial personnel, maintenance and construction workers may be exposed to elevated levels of asbestos for brief periods of time under episodic conditions. However, it is often difficult to estimate or measure the magnitude of these brief but potentially high levels of asbestos exposures of these individuals. In contrast, most office workers, teachers, and other building occupants typically do not come in close contact with asbestos containing

material. The low airborne concentrations of asbestos commonly found in buildings with ACM are often indicative or representative of the typical exposures to asbestos by the occupants of these buildings. Keeping these distinctions of potential exposures in mind, government and individuals managing these risks have to decide when to best remove friable asbestos in buildings, and under what controls.

Removal itself is not without risk. Studies of asbestos fiber levels in the United Kingdom (Burdett et al., 1989) have shown that most containment methods used during asbestos removal are not efficient enough to prevent leakage. These studies have also shown that post-removal residual asbestos can continue to pose risks to the building occupants, depending on the amount of remaining asbestos, the time of re-occupation, the ventilation, and the degree of disturbance (Burdett et al., 1989). Moreover, the environment surrounding a building going through asbestos removal can also become contaminated due to spillage of bulk material. Recent data reported in the United States also indicate that removal of asbestos containing building materials frequently creates higher concentrations of indoor asbestos levels during and after removal, than before (Burdett et al., 1989; Corn 1988; Hughes and Weill 1986; Burdett et al., 1988; and Sawyer 1988).

In terms of an effective risk management strategy it is clear that asbestos removal actions should be evaluated seriously, considering the fact that likely risk from exposure to asbestos present in most buildings is very small, both in absolute and relative terms. Case-specific measurements and risk calculations should ideally be used to guide the decisions on whether and when to remove asbestos materials.

4. CONCLUSIONS

The Harvard Symposium considered new evidence on a wide scope of subjects. This evidence included the appraisal of information on exposures both in buildings as well as occupational cohort studies. The toxicity of fiber type as well as factors influencing individual response were discussed. Risks to building occupants were projected for mesothelioma and lung cancer based on extrapolations from epidemiologic studies.

Using the conservative lung cancer and mesothelioma risk models, a lifetime risk of one death among a cohort of 100,000 children, exposed to 0.001 (mixed) fibers/ml for 10 years, was projected. However, adults who occupy buildings with ACM and are exposed to similar concentrations of asbestos will be at a much lower risk because of age dependence of the risk models used. Comparison of the projected asbestos risks to other commonly experienced environmental health risks, such as environmental tobacco smoke and radon, revealed that most of these risks are far greater than those posed by exposures to asbestos in buildings. In some cases, asbestos removal and disposal operations are shown to increase indoor asbestos concentrations, and thus the associated health risks, as compared to concentrations prior to removal. Issues relevant to assessing the risk of asbestos containing materials in buildings are:

- types of asbestos found in these settings
- actual fiber counts in schools and other buildings
- risk associated with these exposures
- significance relative to other life risks
- more cost-effective risk mitigation strategies
- when to optimally remove asbestos
- potential health risk due to removal
- risks of substitute man-made mineral fibers

Factors were also identified that could influence the direction of asbestos control policies in the U.S. The EPA promulgation of regulations and guidance makes it extremely difficult to modify established positions in light of more recent evidence. Consequently, EPA may find it difficult to incorporate newer concepts in the formulation of future asbestos policies. Another factor is the presence of an organized asbestos removal industry with a collective self-interest to promote additional removal.

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At this time EPA should incorporate recent findings of low asbestos exposure and associated minimal health risk in buildings with ACM in the formulation of new asbestos policies. The U.S. must also formulate an asbestos risk management policy consistent with the latest risk assessment evidence. Otherwise there will be a mismatch between the risk of individual environmental contaminants and the allocation of resources to reduce them. In many cases, spending money on asbestos removal will likely decrease funding which might be available to support other public health and educational measures which could be far more effective in reducing environmental health risks.

REFERENCES

Berry, G. et al., "Asbestosis: A Study of Dose-Response Relationships in an Asbestos Textile Factory", British Journal of Industrial Medicine, 36:98-112, 1980.

British Health and Safety Commission. Health and Safety Executive, Asbestos: "Effects on Health of Exposure to Asbestos", Health and Safety Commission, HMSO, London. Guidance note EH35.HMSO, 1985.

Burdett, G.J., S.A.M.T Jaffery, and A.P. Rood, "Airborne Asbestos Fiber Levels in Buildings. A Summary of UK Measurements", Non-occupational Exposure to Mineral Fibres, edited by J. Bignon, J. Peto and R. Saracci, International Agency for Research on Cancer Scientific Publication No. 90, 1989.

Burdett, G.J., J.J. Smith, V.H. Ainslie, and C.D. Papanicolopoulos, "Airborne Asbestos Fiber Levels in Buildings and Their Impact on Risk Management", Paper presented at the Symposium on Health Effects of Exposure to Asbestos in Buildings, Harvard University, December 14-16, 1988.

Chemical & Engineering News. Zurer, P.S., "Asbestos: The Fiber That's Panicking America", Chemical & Engineering News, Vol. 63, No. 9, pp. 28-41, March 4, 1985.

Chopra, K.S., "Interlaboratory Measurements of Amphibole and Chrysotile Fiber Concentration in Water", Journal of Testing and Evaluation, Vol. 6, No. 4, pp. 241-247, July 1978.

CPSC. Report to the U.S. Consumer Product Safety Commission by the Chronic Hazard Advisory Panel on Asbestos, United States Consumer Product Safety Commission Directorate for Health Sciences, Washington, D.C., 1983.

Commins, B.T., The Significance of Asbestos and Other Mineral Fibers in the Environment. Commins Associates, Pippins, Altwood Close, Maidenhead, Berks Sl6 4PP, England, 1985.

Corn, M. "Issues Related to the Potential Health Hazard of Asbestos Containing Materials in Buildings", Paper presented at the Symposium on Health Effects of Exposure to Asbestos in Buildings, Harvard University, December 14-16, 1988.

EPA. Asbestos Contamination of the Air in Public Buildings, United States Environmental Protection Agency, Research Triangle Park, North Carolina, EPA-450/3-76-004, October 1975.

EPA. Measurement of Asbestos Air Pollution Inside Buildings Sprayed with Asbestos, United States Environmental Protection Agency, Washington, D.C., EPA-560/13-80-026, August 1980.

EPA. Airborne Asbestos Levels in Schools, United States Environmental Protection Agency, Washington, D.C., EPA-560/5-81-006, July 1983.

EPA. Asbestos in buildings: A National Survey of Asbestos-containing Friable Materials, United States Environmental Protection Agency, Washington, D.C., Office of Toxic Substances, EPA 560/5-84-006, 1984.

EPA. Study of Asbestos-Containing Materials in Public Buildings: A Report to Congress, United States Environmental Protection Agency, Washington, D.C., February 1988a.

EPA. Assessing Asbestos Exposure in Public Buildings, United States Environmental Protection Agency, Washington, D.C., EPA 560/5-88-002, May 1988b.

Hughes, J.M., "The Derivation and Use of Asbestos Risk Estimates", Paper presented at the Symposium on Health Effects of Exposure to Asbestos in Buildings, Harvard University, December 14-16, 1988.

Hughes, J.M. and H. Weill, "Asbestos Exposure - Quantitative Assessment of Risk", American Review of Respiratory Diseases, 1986.

Jones, R.N., J.E. Diem, J.M. Hughes, Y.Y. Hammad, H.W. Glindmeyer and H. Weill, "Progression of Asbestos Effects: A Prospective Longitudinal Study of Chest Radiographs and Lung Function", British Journal of Industrial Medicine, 46:97-105, 1989.

Karaffa, Mark A., C.E. Miller, R.A. Amick, J. Chesson, and C. Jackson, "Preliminary Evaluation of Potential Asbestos Exposure During Carpet Vacuuming in Buildings Containing Friable Asbestos Material", U.S. Environmental Protection Agency, Unpublished Draft Report, Cincinnati, Ohio. November 1987.

Langer, A.M. and R.P. Nolan, "Fiber Type and Mesothelioma Risk", Paper presented at the Symposium on Health Effects of Exposure to Asbestos in Buildings, Harvard University, December 14-16, 1988.

Liddell, D., "Epidemiological Observations on Mesothelioma and Their Implications for Non-Occupational Exposure to Asbestos", Paper presented at the Symposium on Health Effects of Exposure to Asbestos in Buildings, Harvard University, December 14-16, 1988.

Lippmann, M., "Review: Asbestos Exposure Indices", Environmental Research, 46:86-106, 1988.

McDonald, J.C., "Health Implications of Environmental Exposure to Asbestos", Environ. Health Perspective, 62:319-328, 1985.

National Research Council, Committee on Non-occupational Health Risks of Asbestiform Fibers. Asbestiform Fibers: Non-occupational Health Risks, National Academy Press, Washington, DC, 1984.

Nicholson, W.J., A.N. Rohl, R.N. Sawyer, E.J. Swoszowski, and J.D. Todaro, "Control of Sprayed Asbestos Surfaces in School Buildings: A Feasibility Study", Report to the National Institute of Environmental Health Sciences, June 1978.

Nicholson, W.J., "Airborne Asbestos Health Assessment Update", United States Environmental Protection Agency Office of Health and Environmental Assessment, Washington, D.C. EPA/600/8-84/003F, 1986.

NYC DEP. Final Report on the Assessment of the Public's Risk of Exposure to In-Place Asbestos. City of New York Department of Environmental Protection, New York, New York, 1988.

Omenn, G.S., J. Merchant, E. Boatman, J.M. Dement, M. Kuschner, W. Nicholson, J. Peto, and L. Rosenstock, "Contribution of Environmental Fibers to Respiratory Cancer", Environmental Health Perspective, 70:51-56, 1986.

Ontario Royal Commission. Report of the Royal Commission on Matters of Health and Safety Arising from the Use of Asbestos in Ontario: v. 1-3. Toronto, Ont., Canada: Ontario Ministry of the Attorney General, 1984.

Peto, J., "Fibre Carcinogenesis and Environmental Hazards", Paper presented at the Symposium on Health Effects of Exposure to Asbestos in Buildings, Harvard University, December 14-16, 1988. (Reprinted with permission from Non-occupational Exposure to Mineral Fibres, edited by J. Bignon, J. Peto and R. Saracci, International Agency for Research on Cancer Scientific Publication No. 90, 1989).

Peto, J., "Fibre Carcinogenesis and Environmental Hazards", Non-occupational Exposure to Mineral Fibres, edited by J. Bignon, J. Peto and R. Saracci, International Agency for Research on Cancer Scientific Publication No. 90, 1989.

Peto, J., H. Seidman and I.J. Selikoff, "Mesothelioma Mortality in Asbestos Workers: Implications for Models of Carcinogenesis and Risk Assessment", Br. J. Cancer, 45: 124-135, 1982.

Price, B., "Assessing Asbestos Exposure Potential in Buildings", Paper presented at the Symposium on Health Effects of Exposure to Asbestos in Buildings, Harvard University, December 14-16, 1988.

Progressive Builder. Oppenheim-McMullen, J. and B. Turner, "Facing the Asbestos Menace", Progressive Builder, pp. 21-22, September 1986.

Sawyer, R., "Asbestos Exposure in a Yale Building: Analysis and Resolution", Envir. Res., 13:1146-168, 1977.

Sawyer, R., "Indoor Asbestos Pollution: Application of Hazard Criteria", Ann. N.Y. Acad. Sci., 330:579-586, 1979.

Sawyer, R., "Asbestos Material Inventory, Control Concepts, and Risk Communication", Paper presented at the Symposium on Health Effects of Exposure to Asbestos in Buildings", Harvard University, December 14-16, 1988.

Sullivan, N., H. Özkaynak, J.H. Ware, M.A. Cohen, P.B. Ryan, and J.D. Spengler, "Report on Ambient Exposures to Volatile Organic Compounds in the Kanawha Valley", Report prepared for the National Institute for Chemical Studies and the United States Environmental Protection Agency, January 9, 1989.

Weill, H. and J.M. Hughes, "Asbestos as a Public Health Risk: Disease and Policy", Annual Review of Public Health, 7:171-92, 1986.

Wilson, R. and E. Crouch, Risk/Benefit Analysis. Ballinger Publishing Company, Cambridge, Massachusetts, 1982.

Zeise, L., R. Wilson, and E.A.C. Crouch, "Dose-response Relationships for Carcinogens: A Review", Environ. Health Perspective, 72:259-308, 1987.

APPENDIX
LIST OF SPEAKERS AND PAPERS PRESENTED

Session I - Scope of the Problem

Morton Corn — Johns Hopkins University, Baltimore, Maryland

Issues Related to the Potential Health Hazard of Asbestos Containing Materials in Buildings

Douglas Liddell — McGill University, Montreal, Quebec, Canada

Epidemiological Observations on Mesothelioma and Their Implications for Non-Occupational Exposure to Asbestos

Donald N. Dewess — University of Toronto, Toronto, Ontario, Canada

Economic Issues in Asbestos Control in Buildings

Session II - Health Studies

Arthur M. Langer and Robert P. Nolan — Brooklyn College, City University of New York

Fiber Type and Mesothelioma Risk

Brooke T. Mossman and Rhonda Gilbert — University of Vermont, Burlington, Vermont

Factors Influencing Individual Response to Asbestos: Effects of Smoking and Asbestos on the Development of Lung Cancer

Robert Sawyer — Entek, Inc., Troy, New York

Asbesots Material Inventory, Control Concepts, and Risk Communication

Session III - Physical Assessment Methods

Edward Peters — Arthur D. Little, Inc., Cambridge, Massachusetts

How Do Current Methods of Measuring Asbestos Exposure Address Risk to the General Population?

Bertram Price — Price Associates, Inc., Washington, D.C.

Assessing Asbestos Exposure Potential in Buildings

Peter S. J. Lees
Johns Hopkins University
Baltimore, Maryland

Air Sampling and Asbestos-Containing Materials in Buildings

James J. Smith, Garry J. Burdett, Vicki H. Ainslie and Chris D. Papanicolopoulos
Georgia Institute of Technology
Atlanta, Georgia

Airborne Asbestos Fiber Levels in Buildings and Their Impact on Risk Management

Session IV - Risk Assessment

Janet M. Hughes
Tulane University
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The Derivation and Use of Asbestos Risk Estimates

Julian Peto
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