PLAINTIFF'S EXHIBIT
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# asbestos: rationale behind a proposed air quality standard

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The following discussion presents a proposed asbestos air quality standard and the rationale utilized in its formulation. The criterion of mesothelioma has been selected as the basis for developing the subject standard. A concentration mesothelioma incidence envelope has been constructed for the general population, based on mesothelioma incidence due to industrial exposure. An ambient air quality asbestos standard of 30 nanograms per cubic meter, based on a 30-day average sample is recommended. This standard is projected to result in 150 nationwide fatalities. Available ambient air asbestos data indicates that non-urban and remote non-urban areas have asbestos levels typically less than 1 nanogram per cubic meter while urban areas are usually below 30 nanograms per cubic meter.

Dispersion calculations are used to determine the maximum allowable asbestos mass emission standard for manufacturing sources (24 grams per day) and a maximum allowable average asbestos concentration (25 micrograms per cubic meter). A family of curves for various workdays depicting the average allowable asbestos concentration as a function of total asbestos contaminated exhaust gas flow rate, consistent with the 24 grams per day emission standard are presented. In addition, a preliminary asbestos stack sampling train has been developed requiring electron microscopy as the analytical procedure to be used to determine the sample asbestos content.

The implementation of the proposed emission standard will lower the expected annual asbestos emissions from manufacturing operations in Connecticut to below one ton compared to the 10 tons emitted if the Federal EPA asbestos regulation is accepted. The proposed air quality standard will further reduce Connecticut asbestos-related fatalities to only two persons annually.

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"Asbestos," the generic name given to a variety of fibrous, silicate naturally occurring minerals, is present as an invisible and anonymous ingredient in a myraid of industrial products, such as paint, floor tiles, gaskets, cement, shingles, pipes, brake linings, fireproofing and insulating materials, and asbestos fabrics. The principal variety of asbestos used in industry is chrysotile (greater than 95%) with amosite and crocidolite being of lesser significance. Consumption of asbestos in the U. S. has risen from approximately 40,000 tons in 1905 to nearly 800,000 tons in the early 1970's, about a 20-fold increase.[1,2]

### Health Effects—Occupational

It has been well known for nearly half a century that some persons subjected to asbestos dust during work developed a severely crippling and sometimes fatal lung disease, called asbestosis. Asbestosis can be classified as an occupational disease which occurs after relatively heavy exposure to asbestos fiber dust. The use of antibiotics in the 1930's dramatically reduced the death rate from infectious pulmonary diseases that often had to be feared as a complication of asbestos; consequently, asbestos workers instead of dying from asbestosis, began living long enough to develop asbestos-induced cancer of the lung, gastrointestinal tract, stomach, and especially the lining of the stomach and lung (i.e., mesothelioma).[3,4] Asbestos has become one of the largest industrial causes of cancer in the world.[5] All the commercially used forms of asbestos can produce asbestosis, as well as the types of cancer previously mentioned.

Mesothelioma was regarded by pathologists, until recently as an extremely rare disease and at times, a medical curiosity. In 1965 Dr. Selikoff and his associates conclusively proved a causal link between asbestos fiber exposure and mesothelioma.[6,7] A significant and somewhat frightening feature of mesothelioma is the extended lag period between first exposure to asbestos fibers and the first symptoms of this form of cancer. It has been reported in the literature that this time period may be anywhere from *20 to 40 years*.[8-10] This long time interval emphasizes the latent insidious problem asbestos fiber exposure continually creates for individuals, both occupationally and *non-occupationally* exposed.

### Health Effects—Non-Occupational

Evidence that people other than those working directly with asbestos were also being subjected to asbestos fibers was of several types. In a few geographic regions where asbestos was mined and milled and asbestos-containing products manufactured, pathologic alterations (i.e., pleural calcification) were discovered in populations with no history of occupational exposure.[11-15] Recent studies have indicated that urban dwellers harbor high quantities of asbestos fibers in their lungs.[3,8,16-18]

The most serious implication of the hazards of non-occupational asbestos fiber exposure is the risk of contracting mesothelioma. Several studies have done much to verify the connection between asbestos fiber exposure and the incidence of mesothelioma among the general population.[3,6,19,20] Current cases of mesothelioma must be associated with asbestos fiber inhalation that took place 20, 30, or more years ago, when world consumption of asbestos was only about 500,000 tons/year, and that neoplasms associated with today's annual production of over 4,000,000 tons will not be evident until the 1990s. The health hazard that asbestos fiber exposure poses to the general public is compounded by the synergistic effect of tobacco smoke, and possibly other air pollutants, such as benzo(*a*)pyrene.[9]

### Relationship between Occupational Asbestos Exposure and Incidence of Mesothelioma

The Federal EPA has recognized the need to control the emission of asbestos fibers into the ambient air and has recently promulgated National Emission Standards for Hazardous Air Pollutants (*Asbestos*, Beryllium, and Mercury).[21] Alternatives to the EPA's required control strategies are conceivable and the following discussion presents one such option, the formulation of an asbestos ambient air quality standard and a compatible mass emission standard for manufacturing sources of asbestos emissions.

The probability of a person in the general community contracting mesothelioma has been chosen as the basis for developing the asbestos air quality standard. Most of the information presently available on exposure to asbestos has been collected in industrial environments. Studies presently available on mesothelioma incidences due to industrial exposure do not report the fiber concentration to which affected workers were exposed; however, a study by the National Institute for Occupational Safety and Health (NIOSH) reports short term fiber concentrations for a number of industrial settings.[22-26] While these short term fiber concentrations are of recent origin and as such are not directly related to the epidemiological studies of mesothelioma incidence, they do reflect the difference between well and poorly controlled processes; and thus can be used as an estimate of low or severe exposure.[23] Table I summarizes mesothelioma incidence data from several different studies along with high and low concentrations from the NIOSH document for shipyards, textile processes, construction operations, and insulation plants. These data were used to construct a concentration incidence envelope, depicted in Figure 1.

### Relationship between Fibers Greater than Five Microns to Nanograms of Asbestos

Asbestos fibers monitored in industrial settings (greater than 5 μm in length, length to width ratio of greater than 3) using phase contact (PC) light microscopy (430× magnification) account for approximately 2% of all asbestos fibers present (by number).[27] Hence, in the occupational environment every asbestos fiber greater than 5 μm in length corresponds to an actual fiber count of 50 (i.e., 1/0.02 = 50).

Table I. Incidence of mesothelioma and asbestos concentrations in occupational environments.[23]

| Industry | Cohort[a] Number of individuals | Mesothelioma incidence % | Reference | Highest[b] average concentration fiber/cm³ | Lowest[b] average concentration fiber/cm³ |
|---|---|---|---|---|---|
| Insulations plants | 689 | 2.18 | (23) | 74.4 | 0.1 |
| Shipyards | 3000 | 0.73 | (23), (26) | 8.7 | 0.3 |
| Construction | 632 | 0.63 | (23), (29) | 7.1 | 0.9 |
| Textile plants | 716 | 1.50 | (23), (25) | 29.9 | 0.1 |
| | 1300 | 1.00 | (23), (25), (30) | 29.9 | 0.1 |
| | ~1300 | 1.20 | (23), (24), (31) | 29.9 | 0.1 |

[a] Most of the individuals in these studies had been followed for 20 years or longer.
[b] Concentrations from NIOSH document.[23]

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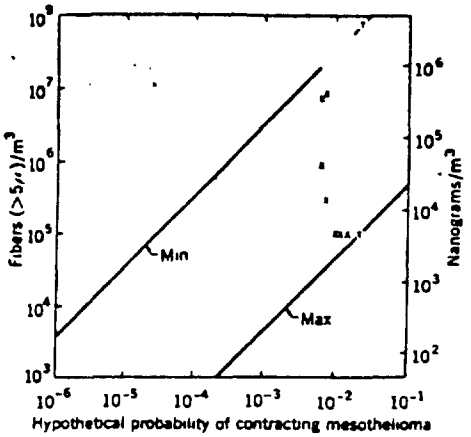


Figure 1. Expected incidence of contracting mesothelioma as a function of industrial air asbestos exposure (8-hr day, 5 day week).[23]

Dr. Thompson (personal communication) reported that there are about 1000 total asbestos fibers per nanogram of asbestos.[26] Therefore, 20 asbestos fibers greater than 5 μm long have been assumed equivalent to one nanogram of asbestos (i.e., 1000/50 = 20). This appears to be a reasonable assumption since Lynch and his co-workers reported, based on magnesium determinations, that for certain manufacturing operations, one ng of asbestos was equivalent to 6.7 to 22.5 fibers greater than 5 μm long as determined by PC.[27]

### Relationship between Non-Occupational Asbestos Exposure and Incidence of Mesothelioma

The mesothelioma incidence envelope depicted in Figure 1 appears as a function of both fibers greater than 5 μm in length and ng of asbestos/m³, respectively.

Occupational exposure concentrations, which are based on an 8 hr day, 5 day week must now be related to exposure levels for the general public (24 hr day, 7 day week) which contains many susceptible groups, such as the elderly and infants, who must non-voluntarily and continuously endure the ambient environment. This can be accomplished by dividing the occupational exposure levels by 4.2 (24 hr/8 hr × 7 days/5 days = 4.2).[32] A concentration-mesothelioma incidence envelope for ambient air asbestos exposure for the general public has thus been constructed, as shown in Figure 2.

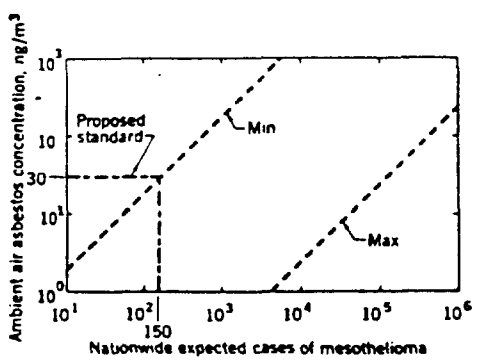


Figure 2. Nationwide expected cases of mesothelioma as a function of ambient air asbestos exposure (assumed population of United States was 230 million people).

### Ambient Air Asbestos Standard

Now that a set of curves relating the nationwide expected cases of mesothelioma as a function of ambient air asbestos expsoure has been constructed, a desired ambient air asbestos level can be decided on. This was accomplished by investigating the total number of nationwide fatalities attributed to automobile, aircraft, and railroad accidents for the year 1972. The *minimum line* (this reflects the smallest possible probability of contracting cancer) of the concentration-mesothelioma incidence curve was used. An ambient air asbestos standard of 30 ng/m³ was chosen. This level should result in about 1/10 the total nationwide number of fatalities (approximately 150) from airplane accidents and approximately the same number of deaths as from train mishaps; the maximum line, or greatest probability line, would have yielded over 100,000 expected fatalities. The use of the minimum line instead of an average line was chosen as a reasonable basis for setting the ambient air asbestos standard in order to account for some of the assumptions made in developing the concentration-incidence envelope.

### Ambient Air Asbestos Levels

How reasonable is the desired ambient air standard of 30 ng of asbestos/m³? Nonurban and remote nonurban airborne asbestos concentrations are typically less than 1 ng/m³.[28] Urban areas usually have asbestos concentrations below the desired 30 ng/m³ standard except in heavily industrialized areas (e.g., Manhattan, N.Y.C. and Philadelphia), around construction sites and toll booths.[28,33,34] The desired standard appears to be reasonably set and attainable.

### Comparison of OSHA and Ambient Air Asbestos Standards

The proposed American Conference of Government and Industrial Hygienists (ACGIH) Occupational Standard of 2 fibers greater than 5 μm in length/cm³ (or $2f/cm^3 \times 10^6$ $cm^3/m^3 \times ng/20f = 10^5$ ng/m³) is designed specifically to protect the workman from contracting asbestosis, which results from *heavy* occupational exposure to asbestos. This standard does not take into account the effect of asbestos as a carcinogenic agent.[8,22] The OSHA standard is equivalent to a general public exposure of 25,000 ng of asbestos/m³ (i.e., $10^5/4.2 = 25{,}000$). It is concluded that the proposed standard of 30 ng/m³ is not unreasonable even though it is approximately 1/1000 of the OSHA standard, since the latter standard is not nearly stringent enough to protect workmen from contracting cancer.

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### Asbestos Emission Standard

Figure 3 depicts the maximum allowable emission rate (consistent with the desired 30 ng/m³ ambient air standard based on both a 24 hr average and 30 day average sample) at corresponding distances from a source. These emission rate curves were constructed using dispersion estimates and local Connecticut meteorological assumptions.[34–36] Thus, the maximum allowable emission rate, consistent with the aforementioned assumptions, would be either 20 or 24 g/day, respectively, at a distance of approximately either 300 or 350 ft from the source. A 24 hour sampling period is not really long enough to reflect properly the average ambient asbestos levels in any region and is very sensitive to short term asbestos emissions. An ambient air standard based on a 30 day average sampling period is more manageable from a monitoring standpoint and more descriptive of the average ambient air asbestos concentrations for a particular area. It is therefore concluded that the ambient air

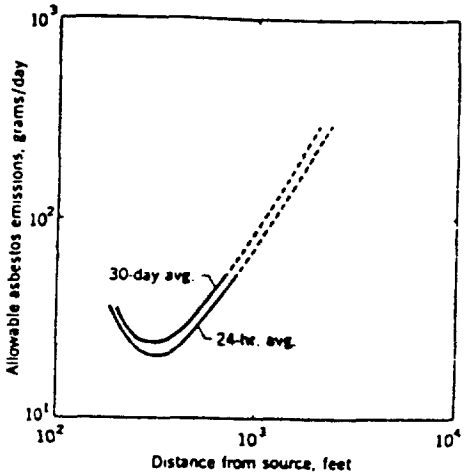


Figure 3. Calculated maximum allowable asbestos emission rate as a function of distance from source (assumed: 4 m/sec wind speed, 10m effective stack height, 40% frequency factor for wind direction, and C stability class).

asbestos standard should be based on a 30 day average sample and the corresponding maximum allowable asbestos emission rate is 24 g/day.

The aforementioned emission and ambient air quality standards result in a maximum daily inhaled asbestos dosage of 600 ng, (20 $m^3$/day (total average adult daily respiratory air intake) × 30 ng/$m^3$ = 600 ng/day). However, under adverse local meteorological conditions a person walking near or close to an asbestos emission source might be subjected to the same asbestos concentration as that of the plume itself for a short period of time. In order to protect such an individual the maximum allowable average asbestos plume concentration could be limited to 25 $\mu g/m^3$. A person walking "through the plume" will then experience an asbestos concentration for a 15 minute time period equivalent to 10 times his maximum allowable daily dosage.

Figure 4 depicts the average allowable asbestos concentration as a function of asbestos-contaminated exhaust gas flow rate for various periods of daily plant operation consistent with a maximum allowable emission rate of 24 g/day and the desired air quality standard. This Figure could be utilized as an emission standard of sorts; the larger the asbestos-contaminated gas flow rate the lower will be the allowable average asbestos plume concentration.

### Manufacturing Sources of Asbestos Emissions

A survey of asbestos users in Connecticut, summarized in Table II, indicates that annual state uncontrolled asbestos emissions could amount to almost 200 tons. Comments solicited from manufacturers of particulate control equipment, in addition to other reports, indicate that there should be no problem in obtaining at least a 95% asbestos emission control efficiency using either a high energy scrubber or a fabric filter and in many instances control efficiencies as high as 99.9% are attainable. It should be understood that there is scant actual supportive test data available; however, the criterion used to support the quoted efficiencies (experience with similar fibrous material dusts) should be valid.[37,38] Notwithstanding the employment of best available asbestos control technologies as required by the Federal EPA asbestos regulation almost 10 tons of asbestos might be emitted into the Connecticut atmosphere each year as a result of manufacturing operations. In order to evaluate properly the potential hazard of this airborne asbestos it is important to understand that 1 g of asbestos could contain up to 1,000,000,000 asbestos fibers and one inhaled asbestos fiber could potentiate a cancer. The implementation of the proposed 24 g/day emission standard in Connecticut would lower the expected annual asbestos emissions from manufacturing operations to below 1 ton and, thereby, provide the impetus for the development of improved asbestos air pollution control equipment. In addition, greater than 95% of the sources should have no problem meeting the proposed emission standard employing state-of-the-art control technology.

### Brake Lining Decomposition

Asbestos as a result of brake lining decomposition might contribute another 1.5 tons of airborne asbestos fibers into the Connecticut atmosphere each year.[3,39-42] Several investigators have suggested that the asbestos emitted as a result of brake usage is not a significant source of atmospheric asbestos; however, in New York City air asbestos concentrations contiguous to a toll booth were 3 to 5 times background levels.[43,44] Additional data are needed before the impact of brake lining decomposition on airborne asbestos levels can be ascertained.

### Demolition

The demolition of asbestos sprayed highrise buildings could result in the emanation of a large amount of asbestos fiber dust unless adequate precautions are taken. If the asbestos emissions caused by demolition operations could be accurately accounted for the actual annual tonnage of asbestos emitted into the Connecticut atmosphere might be significantly increased.

### Asbestos Stack Sampling Train

It has been suggested that an asbestos air quality regulation which employs an emission standard will suffer from the unavailability of an adequate stack sampling procedure; however, other investigators report that there should be no problems, either theoretical or physical in stack sampling for asbestos than there would be in sampling any complex source.[45] The stack sampling train depicted in Figure 5 (a modified version of the approved federal particulate train) might be used to measure asbestos stack emissions; however, this proposed train has never been field tested.

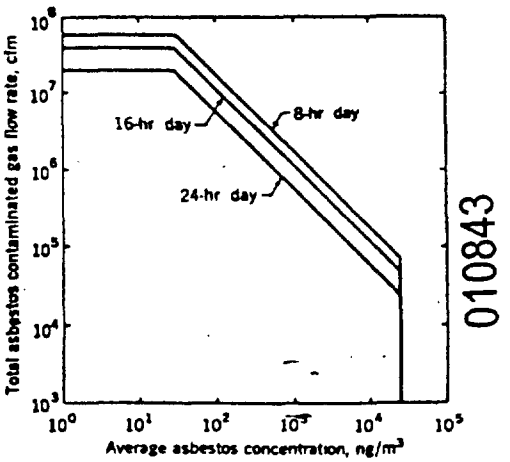


Figure 4. Total asbestos contaminated gas flow rate as a function of allowable asbestos air concentration.

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Table II. A survey of asbestos users in Connecticut, 1972.

| Type of source | Number of sources | Asbestos used, tons/year | Uncontrolled[a] emission factor, lb/ton | Potential uncontrolled emissions, tons/year |
|---|---|---|---|---|
| Asbestos cement, floor tile and paper mfg. | 17 | 600 | 4 | 1.2 |
| Friction product mfg. | 4 | 3200 | 120 | 192 |
| Textile mfg. | 12 | 400 | 40 | 0.8 |
| Miscellaneous mfg. | 10 | 900 | 10 | 4.5 |
| Vehicle brake lining & clutch facing erosion | $1.56 \times 10^6$ | N/A | <30 μg/mile[b] | 1.5 |
| Demolition operations | ~2500 | Unknown | Unknown | Unknown |

[a] W. E. Davis & Assoc.[39]
[b] Jacko *et al.*[40]

### Analytical Asbestos Determination

In the last few years, techniques for determining chrysotile asbestos concentrations (in terms of ng/m$^3$) in the ambient air, based on electron microscopy, have been developed and used with a reasonable degree of success.[28,33,38,41,44] Dr. Selikoff and his associates report that the unique morphology of chrysotile asbestos makes positive identification possible by transmission electron microscopy and the use of replicate analyses, repeated calibrations, and background measurements indicate that the accuracy of a given measurement is likely to be within 50% of the actual value and certainly within a factor of 2.[16,33] This technique should be more than adequate in determining the asbestos content of stack samples.

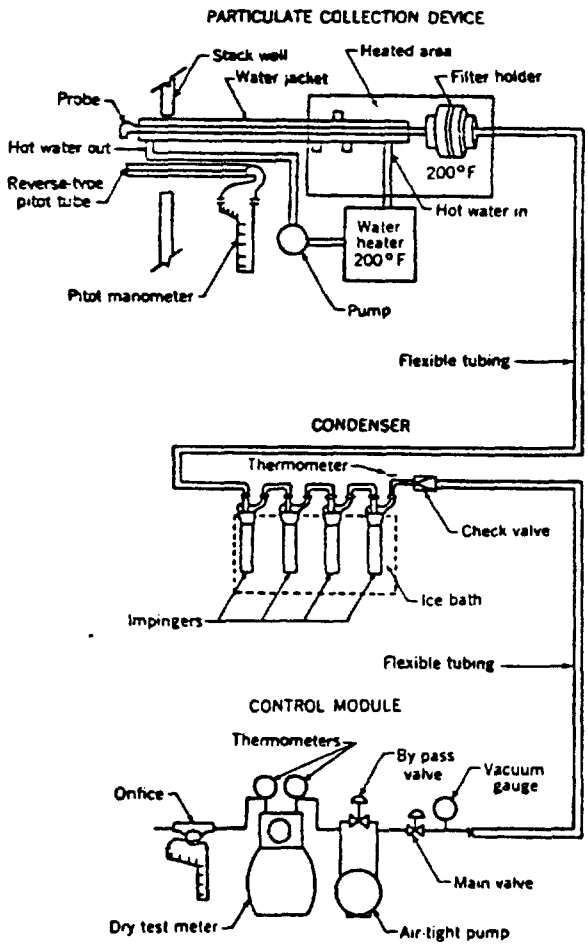


Figure 5. Proposed asbestos sampling train.

### Conclusion

In conclusion, it is believed that a reasonable approach aimed at controlling the dissemination of asbestos fibers into the ambient air has been presented. It is recommended that the rate of nationwide sampling of ambient air asbestos levels be stepped up and continued so as adequately to define the scope of the problem; studies around demolition sites and toll booths are particularly needed. In addition, epidemiological studies of persons who have died of mesothelioma would be useful since they would lead to a better definition of the maximum allowable daily asbestos intake.


### Acknowledgments

Mr. Paul Norton, Air Pollution Engineer, Department of Environmental Protection, Engineering Section, Air Compliance Unit, Hartford, CT, Dr. Robert S. Pogrund, Environmental Health Resource Center, Illinois Institute for Environmental Quality, Chicago, IL, Dr. Richard J. Thompson, Chief, Analytical Chemistry Branch, U.S. Environmental Protection Agency gave valued assistance.


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## Discussion

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It is always easy to find fault with another person's work, and it is difficult to come up with alternatives which cannot be criticized with just as much justification. Those of us associated with preparing the standards and regulations for environmental protection are often faced with the necessity of doing the best we can with a limited amount of information. This is particularly true when there is evidence that damage to the public health will result if we fail to act. Nevertheless, it is my contention that Messrs. Bruckman and Rubino have made some maneuvers which render their asbestos standards unsupportable. One of these is their decision to base their standards on the risk of mesothelioma alone. They fail to take into account the possible environmental asbestos hazard of lung cancer. Among asbestos