# CRITERIA FOR DETERMINING WORK RELATED HEAVY ASBESTOS EXPOSURE

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## INTRODUCTION

The objective of this paper is to derive from case records, guidelines for which occupations and operations constitute heavy asbestos exposure.

Schedule 3 of the Workers' Compensation and Assistance Act, Western Australia (1981) contains a list of specified industrial diseases for which Workers' Compensation may be obtained. One of the diseases listed in Schedule 3 is lung cancer associated with "any process entailing heavy exposure to asbestos dust." The term "heavy exposure" is not defined.

## METHOD

All claimants for Workers' Compensation for pneumoconioses attend at the Perth Chest Clinic. Perth Chest Clinic records of Workers' Compensation claimants diagnosed by the Pneumoconiosis Medical Panel as silico-asbestosis or asbestosis were examined for Wittenoom Australian Blue Asbestos (ABA) workers for the period 1 July 1987 to 31 December 1987 (15 cases) and the DOSHWA Asbestosis Register was examined for "non ABA" workers for the period 1 January 1979 to 31 December 1987 (36 cases). Mining and milling of blue asbestos was located in the town of Wittenoom, which is in the North-West of Western Australia, from 1943–1966. "Non-ABA" cases were further divided into Waterside Workers (9 cases), Asbestos-Cement Products Manufacturing Workers (9 cases), Railway Workers (5 cases) and "Other" (13 cases).

All the cases on the Perth Chest Clinic records who successfully claimed Workers' Compensation for mesothelioma from 1 January 1979 until 31 December 1987 were examined (101 cases). All the cases on the Perth Chest Clinic records who successfully claimed Workers' Compensation for lung cancer from 1985 (when lung cancer became a specified industrial disease under the Act) until 31 December 1987 were examined (12 cases). For each of the above three disease categories, the resulting data were classified according to occupation and duration of exposure.

## RESULTS

### Asbestosis and Silico-asbestosis

From 1 January 1979 until 31 December 1987 (9 years) the DOSHWA Asbestosis Register contains the names of 154 people. Of these, 118 (77%) had worked for ABA in Wittenoom.

As it is generally accepted that having worked mining or milling crocidolite asbestos at ABA for even relatively short periods constitutes a history of heavy exposure, it was decided to look at only a small number of ABA workers, namely those who had successfully claimed Workers' Compensation for asbestosis or silico-asbestosis between 1 July 1987 and 31 December 1987 (15 cases). Of these 15 cases, occupational histories were available for 14, and, of these, only 6 (40%) had worked exclusively in one type of operation, the remaining 8 having worked in multiple operations. These 14 workers had been engaged in a total of 21 different operations at ABA. The mean duration of working at ABA was 43 months (range 3–96 months).

Information was obtained from the Perth Chest Clinic records for the 36 "non-ABA" workers registered on the DOSHWA Asbestosis Register from 1979 until 1987 inclusive.

Of the 9 Waterside Workers registered, 78% were involved exclusively in the one operation of loading/unloading bags of asbestos. The mean duration of employment for waterside workers was 235 months (range 84–384 months). Of the 9 Asbestos-Cement Products Manufacturing Workers, 4 (44%) of these had worked in a single operation. The nine workers had worked in a total of 19 different operations. The mean duration of employment for this group of workers was 231 months (range 28–416 months). Of the 5 Railway Workers, 4 (80%) had worked in only one type of operation. The mean duration of working for the Railways was 223 months (range 72–504 months). The number of cases of asbestosis and silico-asbestosis amongst the different occupational groups described above, together with the mean durations of employment, standard deviations and ranges are summarized in Table I.

### Mesothelioma

All the cases of mesothelioma in the Perth Chest Clinic records from 1 January 1979 until 31 December 1987 were examined. There was a total of 101 cases of mesothelioma during this period. Of these, 9 cases were excluded because there was insufficient information regarding either the person's occupation or the duration of employment in a particular occupation. DOSHWA's Mesothelioma Register contains the names of a number of people who lived in Wittenoom but who did not work in the mine or mill at ABA. There were eight such cases identified up until November 1985. The last group under consideration contained 16 workers. This group covered a wide variety of different occupations including carpenters, truck drivers and insulation workers. The mean duration of employment in this group was 176 months (range 1–420 months). The numbers of cases of mesothelioma amongst the different occupational groups described above, together with the mean durations of employment, standard deviations and ranges are summarized in Table I.

## Lung Cancer

Of the 12 lung cancer patients who successfully claimed Workers' Compensation under the Act between July 1985 and 31 December 1987, 6 worked at ABA, 2 were Waterside Workers, 2 worked in the Railways, one for an Asbestos-Cement Products Manufacturer and one was an insulation worker. For the overall group of 12 lung cancer patients, the mean period of employment was 127 months (range 10–372 months). Of these 12 patients, all except for one (who gave a history of having been a lifelong non-smoker) had a history of moderate to heavy cigarette smoking over several years. Of the 11 smokers, it was possible in 10 of them to estimate the total cigarette consumption over their lifetime in terms of pack-years where one pack-year represents a person's smoking a packet of 20 cigarettes per day for a year (=7300 cigarettes per year). The mean lifetime cigarette consumption was 37.7 pack years (range 18–56 pack years). The numbers of cases of lung cancer in the other occupational groups are listed in Table I along with the corresponding means, standard deviations and ranges.

Lung cancers attributable to asbestos exposure should, strictly-speaking, be called bronchial carcinomas, as should the vast majority of lung cancers that are caused by other known agents.[1] All the common histological forms can occur (squamous carcinoma, small or oat-cell carcinoma and 3 adenocarcinoma). Amongst the 12 cases of lung cancer considered in this paper, there were 4 adenocarcinomas, 4 small cell carcinomas, 2 squamous cell carcinomas, one case who had two separate tumours (one a squamos cell carcinoma and one a small cell carcinoma) and one case in whom the histopathological diagnosis was not recorded.

## DISCUSSION

A widely held belief is that the increased risk of lung cancer due to exposure to asbestos occurs only where asbestosis is already present.[2] This theory contends that exposures to asbestos which are insufficient to cause asbestosis are also insufficient to cause lung cancer. The alternative point of view,

Table I

Numbers of Cases of Asbestosis/Silico-Asbestosis, Mesothelioma and Lung Cancer Amongst Different Occupational Groups with Mean Durations of Employment, Standard Deviations and Ranges (in Months)

| | Asbestosis or Silico-asbestosis | | Mesothelioma | | Lung Cancer | |
|---|---|---|---|---|---|---|
| | N | 14 | N | 61 | N | 6 |
| A.B.A. | MEAN | 43 | MEAN | 22.0 | MEAN | 39.3 |
| | S.D. | 25.1 | S.D. | 26.1 | S.D. | 46.8 |
| | RANGE | 3-96 | RANGE | 1-132 | RANGE | 10-133 |
| | N | 5 | N | 5 | N | 2 |
| RAILWAYS | MEAN | 223 | MEAN | 185 | MEAN | 94.5 |
| | S.D. | 180 | S.D. | 139 | S.D. | 36.1 |
| | RANGE | 72-504 | RANGE | 72-420 | RANGE | 69-120 |
| ASBESTOS | N | 9 | | | N | 1 |
| CEMENT | MEAN | 231 | NIL | | MEAN | 372 |
| PRODUCTS | S.D. | 159 | | | S.D. | N/A |
| MANUFACTURING | RANGE | 28-416 | | | RANGE | N/A |
| | N | 9 | N | 8 | N | 2 |
| WATERSIDE | MEAN | 235 | MEAN | 166 | MEAN | 264 |
| WORKERS | S.D. | 111 | S.D. | 141 | S.D. | 102 |
| | RANGE | 84-384 | RANGE | 24-396 | RANGE | 192-336 |
| | N | 13 | N | 16 | N | 1 |
| OTHER | MEAN | 150 | MEAN | 176 | MEAN | 195 |
| | S.D. | 148 | S.D. | 137 | S.D. | N/A |
| | RANGE | 24-456 | RANGE | 1-420 | RANGE | N/A |
| | | | N | 90 | N | 12 |
| | | | MEAN | 71.1 | MEAN | 127 |
| | | | S.D. | 107 | S.D. | 125 |
| | | | RANGE | 1-420 | RANGE | 10-372 |

which is also widely held, is that there is no demonstrated threshold level of exposure to asbestos below which there is no increased risk of lung cancer.[2]

Chase et al (1985)[3] have proposed, as its final determination, a "risk apportioned to asbestos" that is represented by a number between zero and one. This number reflects the strength of the evidence in support of each individual lung cancer being related to asbestos exposure. In 1984, Mowe et al[4] analysed mineral fibre concentrations in lung tissue by scanning electron microscopy in 73 males with malignant mesothelioma and in 36 controls who died of cardiovascular or cerebrovascular diseases. Their investigation showed apparent differences in the median lung fibre concentrations between occupational groups with different levels of asbestos exposure as judged from their occupational histories. Mowe and Gylseth[5] investigated 141 cases of malignant mesothelioma registered by the Cancer Registry of Norway 1970–79. Sixty-five of the cases were classified into four groups according to criteria of estimated probability of occupational asbestos exposure. These were definite, probable, possible and unlikely or unknown exposures.

In a survey undertaken by the Mines Department in 1966,[6] measurements were made of the concentrations of airborne respirable fibres of crocidolite greater than 5 microns in length in various workplaces at ABA in Wittenoom. A 0 to 10 scale of estimated fibre levels for both before and after September 1957 (when a less dusty mill started operating) applicable to all 87 job categories at ABA was developed using the judgement of an ex-superintendent of operations at Wittenoom (who had a detailed knowledge of all jobs on the site throughout the production period). Unfortunately, as far as could be determined, there are no records of similar information concerning airborne fibre concentrations pertaining to non-ABA work situations which would have prevailed in Western Australia at the time that contemporary Workers' Compensation claimants would have been occupationally exposed to asbestos. The occupations of the six ABA workers who developed asbestosis and who worked in a single type of job category were compared with their scores on the above 0–10 point scale. Because of the small numbers involved, it is difficult to draw any conclusions from this comparison although it is interesting to note that two workers whose fibre concentrations were considered to be relatively low (2 points) still had sufficient exposure to cause asbestosis after only three years of employment in each case.

Any approach which attempts to uncover a relationship between different occupations and heaviness of asbestos exposure cannot take into account variations in how various processes are performed. In other words, such an approach is unable to make allowances for the fact that one type of operation can result in different degrees of exposure according to the ways in which the work processes are performed. It would be simple and convenient if, for cases of asbestos-induced occupational lung disease, one could look at the durations of employment of the workers in various occupations and operations and assume that there is an inverse relationship between duration of occupational exposure to asbestos and the "heaviness" of exposure to asbestos entailed. If such an assumption were valid, one could then easily classify different occupations/operations according to the "heaviness" of exposure (e.g., heavy, moderate, mild, negligible, etc.). Unfortunately, there are a number of reasons why such an assumption would be invalid as well as a number of other difficulties with this approach. These include:

1. By utilizing Perth Chest Clinic records, one immediately introduces a form of selection bias, namely that patients with asbestos induced occupational lung disease who have not claimed Workers' Compensation are immediately excluded from further consideration.

2. There is a strong possibility of recall bias with respect to patients' recollections of their occupational histories.

3. The problem of multiple exposures refers to people who have been exposed to asbestos either in different occupations or who have performed different operations involving asbestos exposure while working in the same occupation.

4. The problem of intermittent exposure applies to the majority of cases where the information necessary to calculate an accurate equivalent continuous exposure was lacking.

5. The main problems encountered in recorded occupational histories were incomplete descriptions of jobs and incomplete information regarding the durations of exposure to asbestos.

## CONCLUSION

A solution to this problem may be found in studies which compare the amounts of asbestos fibre measured in lung tissue for equivalent durations of asbestos exposure in different occupations. Until such time as the results of these types of studies become available, it will be necessary for medical panels charged with the responsibility of making judgements regarding "heaviness" of asbestos exposure to exercise clinical judgement and assess each case on its merits. Heaviness of exposure to asbestos can be thought of as the product of intensity and duration. This formula is not necessarily valid however because it does not separate the effects of the two variables.[7] In the absence of any better alternative, it seems reasonable to make use of this formula, provided it is recognized that it may be an over-simplification of the true state of affairs. In determining the intensity of asbestos exposure in the absence of direct dust exposure measurements, one has to rely on an accurate description of the job to obtain an indirect indication of intensity. This can be partially corroborated by a knowledge on claimants who did similar jobs such as the subjective degree of dustiness of the working environment. The other parameter in the above formula is that of duration. In this regard the most important point to recognize is the distinction between duration of employment and duration of exposure. Apart from intensity and duration of exposure, the type of asbestos to which the claimant was exposed should be taken into account.

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# ASBESTOS EXPOSURE AMONG CONSTRUCTION WORKERS

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## INTRODUCTION

During the past two decades, construction materials containing asbestos have occupied an important place in Japanese construction industry. At present, of total asbestos consumed per year, 199,000 tons (77.8%) are used for the construction materials[1] and there are approximately 4,800,000 construction workers in Japan.[2] It is presumed that a large percentage of the construction workers is exposed to asbestos and recently the health hazards by asbestos have caused concern. However, there are few reports about the asbestos exposure at construction work sites.[3,4]

The objective of this study is to make clear the type of asbestos used in construction materials, the ambient asbestos concentration at construction work site and the working condition of workers handling asbestos-containing construction materials.

## METHODS AND MATERIALS

### Identification of Type of Asbestos

Asbestos-containing construction materials were randomly collected from construction work sites. Dust fractions for electron microscopic inspection were produced by scratching these construction materials with tweezers. Asbestos fibers of these samples were identified by transmission electron microscopy equipped with an energy dispersive X-ray analyzer.

### Measurement of Ambient Asbestos Concentration

In order to evaluate the asbestos exposure level to the workers, dust concentrations in construction work sites were measured by the membrane filter method using phase contrast microscopy, according to the standard techniques of the Japan Association of Industrial Health for asbestos sampling and analysis. Particles $> 5\ \mu m$ in length, $< 3\ \mu m$ in diameter with an aspect ratio >3:1 were counted.

### Questionnaire Survey

The working conditions were surveyed by use of a self-completion questionnaire on all the 10,922 members of All Kyoto Construction Worker's Union in Kyoto prefecture, Japan. The questionnaire included questions concerning sex, age, occupational category, duration of engagement in the present occupational category, use of asbestos-containing construction materials, asbestos dust exposure, protective and preventive measures, smoking history and respiratory subjective symptoms.

## RESULTS

### Type of Asbestos

Twenty four samples of asbestos-containing construction materials including 20 wall boards, two roofing materials, one vinyl asbestos floor tile and one sprayed wall material were collected from 22 construction work sites. Among 20 wall boards, chrysotile alone, amosite alone, and both were respectively detected from six, one, and 13 samples. From the remaining materials, only chrysotile was detected.

### Asbestos Exposure Level

The asbestos concentrations in 59 spots of 17 construction work sites were measured during a variety of operations, e.g., sawing, screwing, drilling, nailing, cutting, filing of asbestos-containing construction materials. Electric hand tools were used in sawing, screwing and drilling. Airborne asbestos concentrations are shown in Table I. The personal exposure levels were measured in the breathing zone of the workers using personal dust sampler. The ambient asbestos-concentrations were measured in the center of the room. Fifty four dust measurements were made indoors and five were made outdoors. Neither local exhaust ventilation equipments nor general ventilation equipments were provided in any work sites where we visited.

Concerning the results of the indoor measurements, air samples taken in the breathing zone of the workers reached more than 100 f/ml during sawing of asbestos cement board with electric circular saw (Figure 1). The ceiling limit of threshold limit value of asbestos is 10 f/ml in Japan. The ambient asbestos concentrations during screwing (Figure 2), drilling, or nailing often exceeded the value, because sawing is sometimes done during these works. If not so, the ambient asbestos concentrations were relatively low ranging from 0.3 to 14.1 f/ml. Table I also showed that the workers near the ones handling asbestos-containing materials are exposed to

Table I
Ambient Asbestos Concentrations in Construction Work Sites

| Operations | Number of samples | Sampling time (min) Range | Mean[1] | Concentrations (f/ml) Range | Mean[2] | Median |
|---|---|---|---|---|---|---|
| [ Indoor Work ] | | | | | | |
| Sawing[a] | 4 | 2.5-5 | 3.8 | 125-787 | 214 | 147 |
| 1.5-2m from the above work[a] | 3 | 2.5-5 | 3.5 | 103-630 | 245 | 232 |
| Screwing or drilling or nailing[a] (partly include sawing) | 8 | 10-120 | 48 | 1.3-131 | 11.0 | 12.3 |
| 1-10m from the above work[a] | 7 | 10-119 | 56 | 0.9-48.1 | 5.4 | 3.0 |
| Screwing or drilling or nailing[a] (not include sawing) | 8 | 2.6-110 | 48 | 0.3-14.1 | 2.0 | 2.5 |
| 1-4m from the above work[a] | 15 | 15-171 | 87 | 0.1-4.6 | 1.3 | 1.6 |
| Cutting and filing[a] | 1 | 1.0 | - | 12.1 | - | - |
| Inspecting work site[a] (5-30m from the work operating asbestos board) | 2 | 68-93 | - | 0.04-0.12 | - | - |
| Finishing or cleaning[a] (1 to 7 days after the work using asbestos board) | 5 | 15-93 | 45 | 0.1-0.5 | 0.3 | 0.3 |
| Center of room[b] (a day after the work using asbestos board) | 1 | 110 | - | 0.01 | - | - |
| [ Outdoor Work ] | | | | | | |
| Sawing[a] | 1 | 124 | - | 0.14 | - | - |
| Roofing[a] | 1 | 115 | - | 0.13 | - | - |
| 1-2m from the above work[a] | 1 | 115 | - | 0.05 | - | - |
| Nailing on exterior wall board[a] | 1 | 117 | - | 0.13 | - | - |
| Plumbing[a] (a day after the work using asbestos board) | 1 | 160 | - | 0.05 | - | - |

1: arithmetic mean, 2: geometric mean
a: Personal samples were collected. b: Area sample was collected
Sawing: with an electric circular saw, Screwing: with an electric screw driver, Drilling: with an electric drill, Nailing: with a hammer, Cutting: with a knife,

asbestos. The cleaning of the work sites was insufficient that ambient asbestos concentrations were from 0.1 to 0.5 f/ml after the use of asbestos wall board (Figure 3).

The outdoor ambient asbestos concentrations ranged from 0.05 to 0.14 f/ml.

## Working Conditions

6549 (60.0%) out of 10,922 workers belonging to All Kyoto Construction Worker's Union completed the questionnaire. Among them, male and female workers were 6500 (99.3%) and 49 (0.3%), respectively. In the following analysis, female workers were excluded because the number was very small.

The age of male respondents ranged from 17 to 84 years (mean 44.6, SD 11.0).

The distribution of the present occupational categories is shown in Table II. More than 40 kinds of trade categories were reported. Carpenters held a majority (40.8%) followed by plasterers (8.3%), electricians (4.4%), painters (4.1%) and plumbers (3.3%). The mean duration of engagement was 22.8 years (SD 11.4, range 0.2-65).

The number of workers who *often* handled asbestos-containing construction materials were 1360 (20.9%) and who handled *sometimes* were 2449 (37.7%). The distribution of the construction materials used by these workers is shown in Table III. Asbestos slate board was the most popular material, asbestos silicate-calcium board the next. Table IV illustrates the distribution of duration of handling asbestos-containing construction materials. The duration of handling ranged from less than one to 52 years (mean 14.1, SD 8.0). The distribution of mean number of days of handling asbestos-containing materials per month in the last one year is shown in Table V. Median value was 3 days per month.

Since construction workers have been not only directly exposed but also indirectly exposed to asbestos dust emitted by other workers in the work sites, the frequency of asbestos exposure either directly and indirectly was surveyed. The results are shown by main construction trade categories in Table VI. The frequency was varied by trade categories. Among them

Figure 1. Sawing asbestos-containing wall board with electric circular saw without local exhaust ventilation equipment. Ambient air was highly contaminated by asbestos.

Figure 2. Fixing wall board to metal studs with screws by electric screw driver.

Figure 3. A: Floor contaminated by asbestos-containing dust after sawing wall board. B: Sweeping floor with a broom. One can see the secondary asbestos dust emission.

Table II
Distribution of Occupational Categories

| | Number of workers | |
|---|---|---|
| carpenter | 2608 | (40.8%) |
| plasterer | 531 | ( 8.3%) |
| electrician | 280 | ( 4.4%) |
| painter | 261 | ( 4.1%) |
| plumber | 220 | ( 3.4%) |
| navvy | 209 | ( 3.3%) |
| sheet metal worker | 197 | ( 3.1%) |
| interior finish worker | 147 | ( 2.3%) |
| steel-frame worker | 129 | ( 2.0%) |
| cabinet maker | 126 | ( 2.0%) |
| helper | 118 | ( 1.8%) |
| tiler | 104 | ( 1.6%) |
| others | 1466 | (22.6%) |
| no answer | 104 | ( 1.6%) |
| total | 6500 | (100.0%) |

Table IV
Distribution of Duration of Handling Asbestos-containing Construction Materials (N=2501)

| Duration (years) | Number of workers | |
|---|---|---|
| 0< - 4 | 258 | (10.1%) |
| 5- 9 | 492 | (19.7%) |
| 10- 14 | 705 | (28.3%) |
| 15- 19 | 416 | (16.7%) |
| 20- 24 | 383 | (15.4%) |
| 25- 29 | 124 | ( 5.0%) |
| 30- 34 | 91 | ( 3.6%) |
| 35- 39 | 24 | ( 1.9%) |
| 40- 52 | 8 | ( 0.3%) |

Table III
Distribution of Numbers of Workers Using Asbestos-containing Construction Materials (N=3782)

| | Number of workers | |
|---|---|---|
| [ Materials containing asbestos ] | | |
| asbestos slate board | 2431 | (64.3%) |
| asbestos silicate-calcium board | 1747 | (46.2%) |
| heat insulating asbestos pad | 697 | (18.4%) |
| asbestos roofing materials | 639 | (16.9%) |
| asbestos cement parlite board | 600 | (15.9%) |
| sprayed asbestos | 478 | (12.6%) |
| parlite board | 429 | (11.3%) |
| asbestos felt | 336 | ( 8.9%) |
| asbestos pipe | 312 | ( 8.2%) |
| asbestos paper laminated plywood | 266 | ( 7.0%) |
| asbestos packing | 255 | ( 6.7%) |
| asbestos cloth and yarn | 230 | ( 6.1%) |
| rubber asbestos sheet | 184 | ( 4.9%) |
| asbestos gasket | 119 | ( 3.1%) |
| asbestos tape | 118 | ( 3.1%) |
| asbestos rope | 89 | ( 2.4%) |
| asbestos-containing paint | 72 | ( 1.9%) |
| [ Materials which contain asbestos or do not varies with the kind of productions ] | | |
| wood wool cement board | 1438 | (38.8%) |
| vinyl asbestos floor tile | 1173 | (31.0%) |

carpenters were most frequently exposed to asbestos.

As for the use of protective mask, 28 (0.8%) workers out of 3710 workers who have an experience in using asbestos-containing construction materials responded to use it *everytime* and 216 (6.6%) answered *sometimes.*

There were 2491 smokers (66.4%), 670 ex-smokers (17.9%) and 588 non-smokers (15.7%) among the workers who have an experience in using asbestos-containing materials.

The relationship between the mean days of handling asbestos-containing construction materials per month in the last one year and the prevalence of respiratory subjective symptoms (palpitation, shortness of breath, cough and sputum) is shown in Table VII. The prevalence of the symptoms increased with the mean asbestos-handling days per month. The correlation coefficients between the rank of mean days per month and the prevalence of the symptoms ranged from 0.080 to 0.206 ($p<0.0001$, Kendall's tau-C), while the correlation coefficients between the rank of mean days per month and smoking habit or age were not significant.

## DISCUSSION

The present study resulted in the following:

1. Not only chrysotile but also amosite are frequently used for the construction materials.
2. Ambient asbestos concentrations in the worker's breathing zone widely ranged from 0.04 to 787 f/ml depending on the kinds of work and the ventilatory conditions. Indoor sawing with electric circular saw was considered as one of the most hazardous operations.
3. A great number of construction workers are exposed to asbestos without appropriate countermeasures.
4. Of the workers handling asbestos-containing materials, 66.4% were the co-exposed to asbestos and smoking.
5. The prevalence of the respiratory subjective symptoms increased as the frequency of handling asbestos-containing materials increased.

There has been a paucity of literature dealing with the actual conditions of asbestos exposure among construction workers.

Fischbein et al. surveyed the asbestos exposure in the drywall construction trade in the United States. Of 15 industrial drywall taping and spackling compounds, they found chrysotile in nine, tremolite in one, and both in three, respectively. They showed that asbestos concentrations in the breathing zone of drywall tapers ranged 1.2-19.3 f/ml during pole sanding, 1.3-16.9 f/ml during hand sanding and 35.4-59.0 f/ml during dry mixing of taping compounds, respectively.[3]

Verma and Middleton investigated the asbestos concentrations in various operations of the drywall taping process in the province of Alberta, Canada. They showed that the asbestos concentrations in the breathing zone of workers ranged 1.2-12.4 f/ml during mixing, 1.2-24.2 f/ml during sanding and 4.0-26.5 f/ml during sweeping, respectively.[4]

Table V

Distribution of Mean Number of Days of Handling Asbestos-containing Construction Materials per Month in the Last One Year (N=1708)

| day/month | Number of workers |
|---|---|
| 0<-<1 | 47 ( 2.4%) |
| 1- 2 | 710 (36.6%) |
| 3- 4 | 399 (20.6%) |
| 5- 6 | 279 (14.4%) |
| 7-10 | 314 (16.2%) |
| 11-15 | 116 ( 6.0%) |
| 16-30 | 76 ( 3.9%) |

Table VI

Asbestos Exposure by Occupational Categories

| | Number of workers | Asbestos exposure | |
|---|---|---|---|
| | | often | sometimes |
| carpenter | 2608 | 15.0% | 43.4% |
| sheet metal worker | 197 | 5.6 | 32.5 |
| plumber | 220 | 8.2 | 26.8 |
| electrician | 280 | 7.5 | 27.5 |
| plasterer | 531 | 4.1 | 27.5 |
| helper | 118 | 5.0 | 21.0 |
| interior finish worker | 147 | 6.1 | 17.7 |
| steel-frame worker | 129 | 3.1 | 20.9 |
| painter | 261 | 3.8 | 19.2 |
| cabinet maker | 126 | 0.8 | 13.5 |
| navvy | 209 | 2.4 | 11.5 |
| tiler | 104 | 1.9 | 11.5 |
| total | 6500 | 8.9 | 29.1 |

Table VII

Relationship Between Mean Days of Handling Asbestos-Containing Materials per Month in the Last One Year and Prevalence of Respiratory Subjective Symptoms

| | | palpitation | | | shortness of breath | | |
|---|---|---|---|---|---|---|---|
| day/month | number | often | sometimes | total | often | sometimes | total |
| 0 | 1141 | 0.8% | 16.5% | 17.3% | 2.2% | 16.7% | 18.9% |
| 0<-<1 | 42 | 2.4 | 16.7 | 19.1 | 0 | 19.0 | 19.0 |
| 1- 2 | 642 | 2.8 | 19.2 | 22.0 | 3.7 | 19.5 | 23.2 |
| 3- 4 | 366 | 2.2 | 21.9 | 24.1 | 2.5 | 27.0 | 29.5 |
| 5- 6 | 254 | 3.5 | 24.0 | 27.5 | 4.7 | 24.0 | 28.7 |
| 7-10 | 296 | 3.4 | 24.3 | 27.7 | 5.7 | 24.3 | 30.0 |
| 11-15 | 108 | 4.6 | 23.1 | 27.7 | 5.6 | 23.1 | 28.7 |
| 16-30 | 69 | 7.2 | 31.9 | 39.1 | 8.7 | 30.4 | 39.1 |

| | | cough | | | sputum | | |
|---|---|---|---|---|---|---|---|
| day/month | number | often | sometimes | total | often | sometimes | total |
| 0 | 1141 | 3.3% | 24.4% | 27.7% | 7.8% | 25.6% | 33.4% |
| 0<-<1 | 42 | 2.4 | 31.0 | 33.4 | 4.8 | 38.1 | 42.9 |
| 1- 2 | 642 | 5.8 | 37.7 | 43.5 | 10.9 | 39.3 | 50.2 |
| 3- 4 | 366 | 7.4 | 41.5 | 48.9 | 13.4 | 42.1 | 55.5 |
| 5- 6 | 254 | 15.0 | 40.7 | 55.7 | 20.5 | 39.4 | 59.9 |
| 7-10 | 296 | 11.8 | 40.5 | 52.3 | 17.9 | 39.2 | 57.1 |
| 11-15 | 108 | 14.8 | 46.3 | 61.1 | 19.4 | 42.6 | 62.0 |
| 16-30 | 69 | 13.0 | 50.7 | 63.7 | 23.2 | 40.6 | 63.8 |

In Japan, no data on the asbestos exposure among workers during handling asbestos-containing boards at construction work sites has been reported in the literature. According to the present study, it was considered that the asbestos dust emission during indoor sawing with electric circular saw was larger than that of drywall taping process.

There are several reports on the health effect of asbestos exposure among the construction workers.[3,5-7] Fischbein et al. reported that pleural thickening was found in 8% of the 109 drywall tapers.[3] Hedenstierna et al. reported that 62% of the 423 construction workers who had been registered as exposed to asbestos had radiological evidence of pleural plaques in Sweden.[5] Ebihara et al. described that 1.27% of 3613 construction workers of over 40 years old had evidence of pleural plaques on chest X-ray, while none of 845 office workers had such evidence.[6] Nicholson et al. estimated that 2143 asbestos-related cancer deaths occurred in 1982 and these would rise to about 3400 annual deaths by the year 2000 among construction workers in USA.[7] The present study suggested that the prevalence of respiratory subjective symptoms elevated dose-dependently. The medical surveillance of workers who participated in the present study is now ongoing.

## SUMMARY

The actual condition of asbestos exposure among construction workers were surveyed. It was made clear that workers were exposed to high concentrations of asbestos without local exhaust ventilation equipment and respiratory protective equipment. On the basis of this study, there is urgent need to work out a sufficient countermeasure minimizing asbestos exposure in construction work sites.

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# DUST EXPOSURE RESULTS IN 359 ASBESTOS-USING FACTORIES FROM 26 COUNTRIES

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Mr. Chairman,
Ladies and Gentleman,

## PART I: DESCRIPTION OF THE SURVEY

It is a great pleasure for me to present, on behalf of the Asbestos International Association (A.I.A.) and for the first time at an international scientific conference, the results of an inquiry carried out from investigations in the member countries of this Association. The prime object of A.I.A. is to encourage protective measures to eliminate risks to health arising from exposure to asbestos and I believe that such an inquiry is also a helpful part of the motivation and the emulation necessary to achieve it.

The 1986 survey is the third one so conducted by sending out a questionnaire prepared by an A.I.A. Dust Advisory Panel (D.A.P.) including experts in the field of industrial hygiene. For 1986, twenty-six members out of 32 (Figure 1) provided useful figures, which is an increase of 3 as compared with the previous returns.

Furthermore, another inquiry was carried out in order to evaluate the representativity of the survey. This was achieved through a comparison between the number of asbestos workers whose exposure is known and the total number of asbestos workers exposed among the company members from 24 national associations. Altogether about 75% of the factories within the national associations took part in the inquiry, which corresponds respectively to 78% of the asbestos workers. Of course, one should remain very cautious on such an evaluation as there is obviously no one national or international binding rule for a company to become a member or take part in the activities of an industry association. This point is primarily important to consider in connection with some of the small but numerous companies using asbestos at some stage and which are usually not members of the national asbestos association.

As a conclusion of this first part of my presentation I wish to say that our prime objective remains that all the A.I.A. members should be very soon in a position to contribute to the survey.

As we shall see during the second part of my talk, significant progress has already been achieved on the issue. However, as an introductory warning to that second part, I must point out that the results which I am going to present now cannot be extrapolated to become a worldwide picture of the situation and should be cautiously understood within the limited investigations that any national association may undertake in this field.

Also, I would like to mention that an annual detailed report of the survey is distributed by A.I.A. to all its members, disclosing their individual code country number.

Within the limited time which is left now, I shall try to comment on the main findings so far available.

| | | |
|---|---|---|
| ARGENTINA | GERMANY | NIGERIA |
| AUSTRIA | GREECE | REP. OF SOUTH AFRICA |
| BELGIUM | INDIA | SPAIN |
| BRAZIL | IRELAND | SWEDEN |
| CANADA | ISRAEL | SWITZERLAND |
| CHILE | JAPAN | UNITED KINGDOM |
| DENMARK | KENYA | U.S.A. |
| FINLAND | MEXICO | ZIMBABWE |
| FRANCE | NETHERLANDS | |

Figure 1. Countries contributing to the 1986 survey.

## PART TWO: EVALUATION AND RESULTS OF THE SURVEY

Five categories of asbestos activities have been selected and classified into the following groups:

- Manufacturing of asbestos containing products (including asbestos cement, friction materials, textiles and others)
- Asbestos production (mines, mills)

Figure 2 shows the number of factories contributing to the 1984, 1985 and 1986 survey respectively for the various activities described above. Altogether, a significant improvement has been achieved since the initial 1984 survey (130/302/359) and it can be anticipated that this trend will be confirmed through the next inquiries.

Looking now at the corresponding numbers of asbestos workers (Figure 3) whose exposure results will be described later on, more significant progress in the 1986 returns can be observed with 45,696 results available which is a one third increase as compared with the previous year. Most of the results originate from the asbestos production activity, the asbestos-cement and the friction material product group.

## SAMPLING AND COUNTING STRATEGIES

The method used for monitoring of the workplace is always the so-called "membrane filter method" allowing for a fibre counting among the particles deposited onto a filtering media after sampling of a determined air volume during the working time.

Several international initiatives (such as ISO and the EEC) have been undertaken to harmonize the various procedures applied and even though some few divergencies remain, these are in general much less consequent upon the results than variations due to the sampling strategies themselves.

As shown in Figure 4, most samples are personal samples,

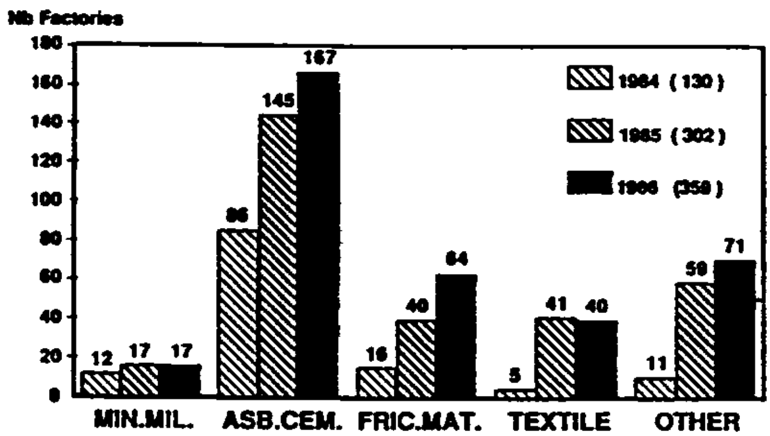


Figure 2. Number of factories covered by the A.I.A. survey (from 1984 to 1986).

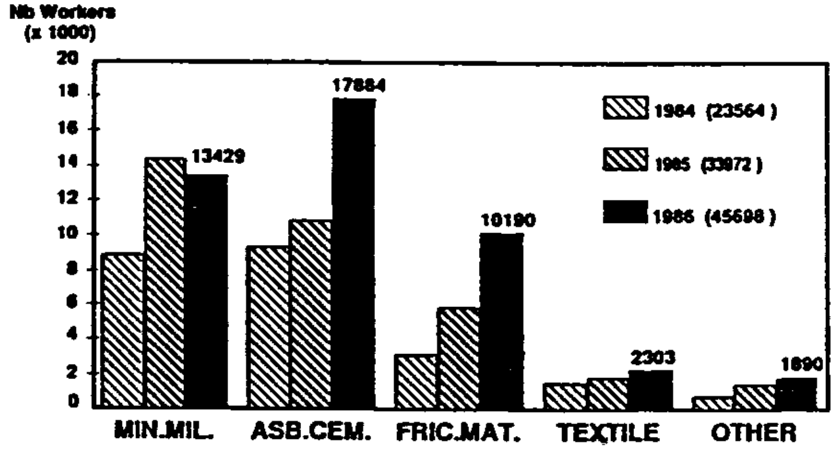


Figure 3. Number of workers covered by the A.I.A. survey (from 1984 to 1986).

but the proportion of static samples still remains rather important mainly for the asbestos-cement group as well as for the mines.

The survey has also revealed further observations pointing out that the sampling strategies have been different among the factories and/or countries. These variations originate mainly from the selection of a workplace to become representative of a job group as well as from the annual sampling frequency in use. In order to reduce the main divergencies on these matters, some recommendations have been prepared by the Dust Advisory Panel of A.I.A.; however, it should be acknowledged that defining and harmonizing the sampling strategies in general remains a rather complex issue.

It is probably through a periodic exchange of views with the main partners involved on the working site that the best practical decision will be achieved in the future.

## RESULTS OF INDIVIDUAL EXPOSURE

Figure 5 illustrates the global situation among 45,696 workers from 359 factories included in the survey.

At this stage no distinction was made between the various product groups and the data were simply distributed within

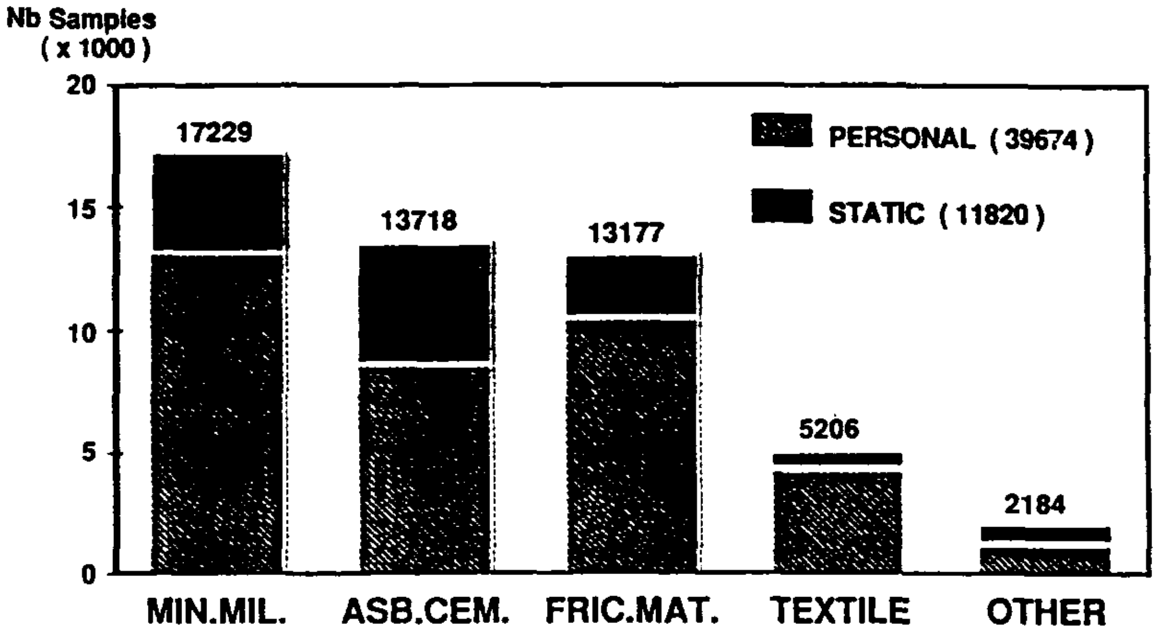


Figure 4. Yearly personal and static samples (total number by product group).

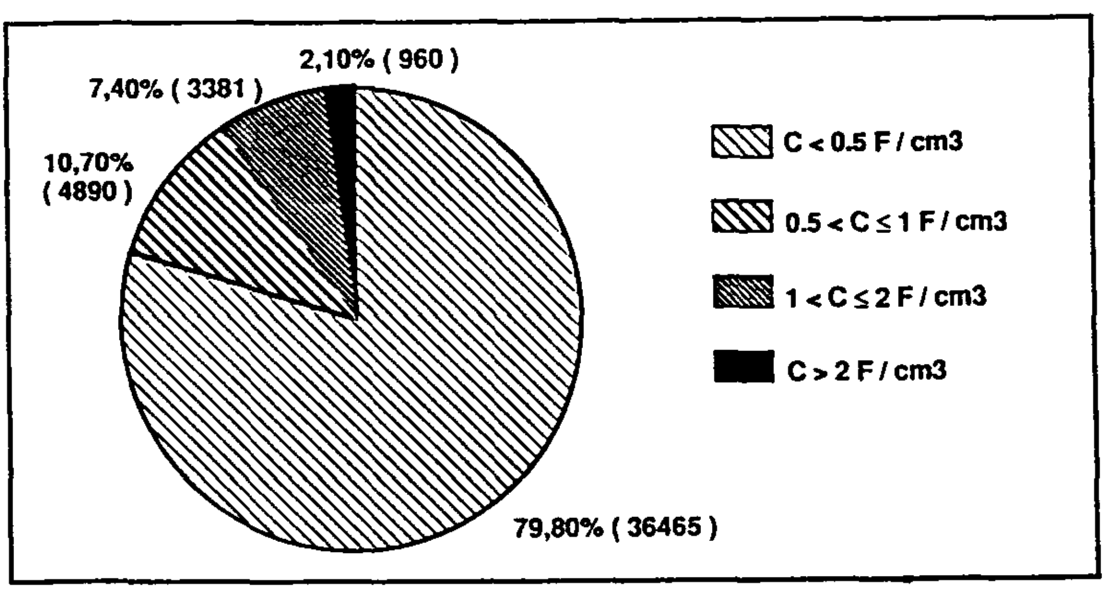


Figure 5. Asbestos worker exposure—1986 (26 countries—45,696 workers under survey).

four ranges.

C < 0.5 f/ml ............................79.8%
0.5 < C ≤ 1 f/ml ........................10.7%
1 < C ≤ 2 f/ml...........................7.4%
C > 2 f/ml...............................2.1%

By reference to a 1 f/ml T.L.V. currently often adopted, it can be seen that it is effectively enforced for more than 90% of the workers.

By reference to a 2 f/ml T.L.V. which had been the first international guideline recommended by an I.L.O. group of experts in 1973, it can be seen that a little more than 2% of the workers have an asbestos exposure above this value.

Figures 6 to 10 evaluate more specifically the mean situation observed in the various industrial activities.

The **mines and mills** group (Figure 6) has provided A.I.A. with results:

— for 13,499 workers,
— in 17 production sites
— from 6 countries

showing:

— 82.6% of results < 1 f/ml
— 16.0% of results between 1 and 2 f/ml
— 1.4% of results > 2 f/ml

The **asbestos-cement** group (Figure 7) has provided A.I.A. with results:

— for 17,884 workers,
— in 167 factories
— from 23 countries

showing:

— 95.5% of results < 1 f/ml
— 3.3% of results between 1 and 2 f/ml
— 1.2% of results > 2 f/ml

The **friction material** group (Figure 8) has provided A.I.A.

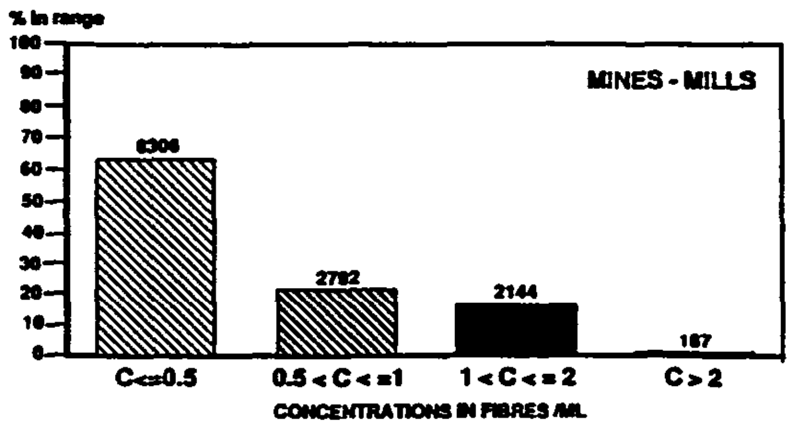


Figure 6. Asbestos exposure of workers under survey (6 countries—17 sites—13,429 workers).

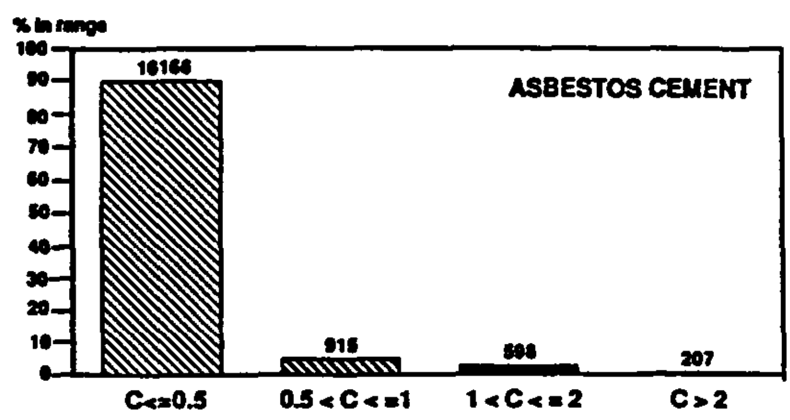


Figure 7. Asbestos exposure of workers under survey (23 countries—167 factories—17,884 workers).

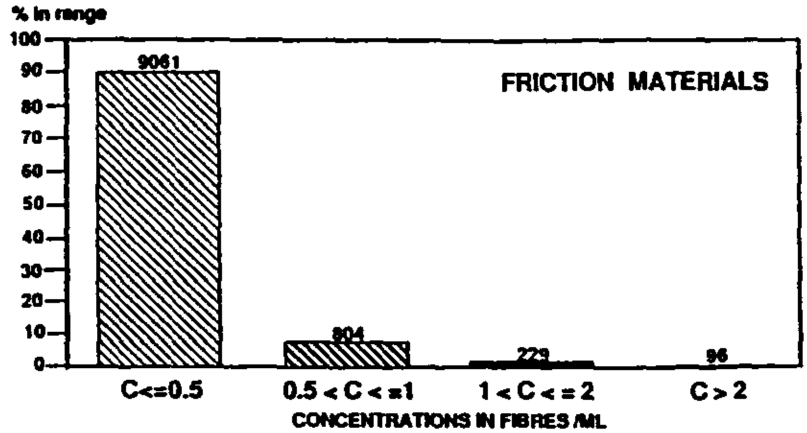


Figure 8. Asbestos exposure of workers under survey (10 countries—64 factories—10,190 workers).

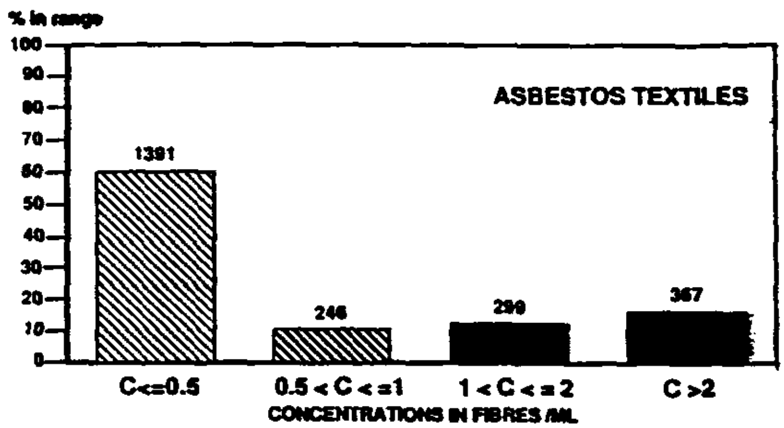


Figure 9. Asbestos exposure of workers under survey (7 countries—40 factories—2,303 workers).

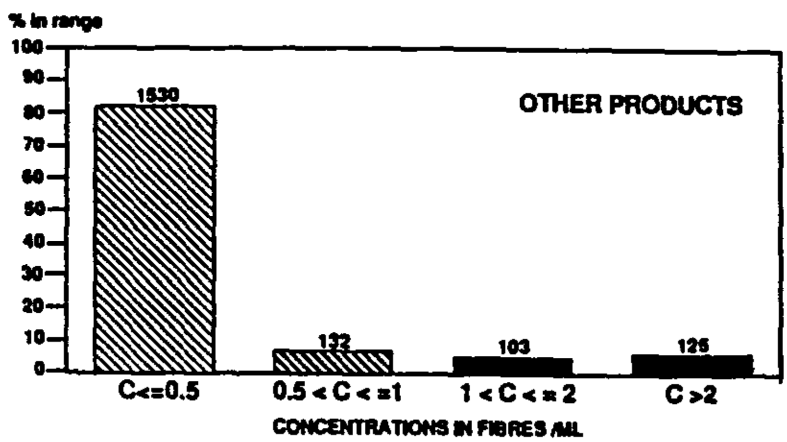


Figure 10. Asbestos exposure of workers under survey (10 countries—71 factories—1,890 workers).

with results:

— for 10,190 workers,
— in 64 factories
— from 10 countries

showing:

— 96.8% of results < 1 f/ml
— 2.2% of results between 1 and 2 f/ml
— 1.0% of results > 2 f/ml

The textile group (Figure 9) has provided A.I.A. with results:

— for 2,303 workers,
— in 40 factories
— from 7 countries

showing:

— 71.1% of results < 1 f/ml
— 13.0% of results between 1 and 2 f/ml
— 15.9% of results > 2 f/ml

The other products group (Figure 10) has provided A.I.A. with results:

— for 1,890 workers,
— in 71 factories
— from 10 countries

showing:

— 87.9% of results < 1 f/ml
— 6.1% of results between 1 and 2 f/ml
— 6.0% of results > 2 f/ml

By comparison, as shown in Figure 11, it can be observed that the textile activities involved in the survey generate the widest distribution of results with a proportion above 1 f/ml about three times higher than the mean (29.9% against 10%) and still much higher when compared with each one of the groups.

In practice, when looking at the textile situation among the limited number of countries which provided results for this product group, it can be assumed that the workers' exposure levels remain highly contrasted in this activity.

With more time available it would have been possible to show more detailed information extracted from this survey. However, I believe that this talk was sufficient to underline the most interesting aspects of such an inquiry. I just wish to add that further work is being carried out in this connection, mainly to improve the reliability of the data collected.

These are relevant on the one hand to the sampling strategies as I mentioned before and to the fiber counting activities on the other hand through an annual microscope international slide exchange and the preparation of specific training slides.

Finally, before closing my speech, I would not like to conclude without pointing out again the most important warning which I made at the beginning: although we feel quite convinced that this A.I.A. report is a major step ahead towards the improvement in the protection against the risks arising from exposure to asbestos, those results are still not complete enough to allow their extrapolation, in one way or the other, to all situations where asbestos can be used in most countries around the world.

The non existence of results might well be an indication that the risks are simply ignored, which should then be imperatively reversed and any further relevant existing results made available to A.I.A. to improve the quality of this survey will certainly be most appreciated and useful.

Thank you for your attention.

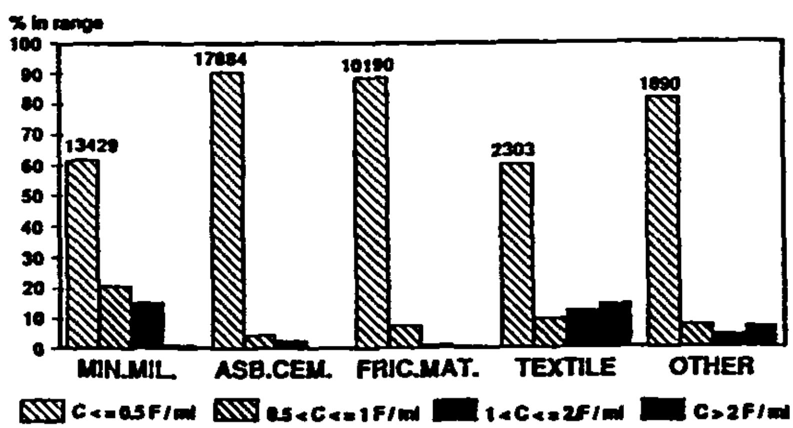


Figure 11. Asbestos exposure of workers under survey (26 countries—359 factories—45,696 workers).

# DISCRIMINATING AMPHIBOLE CLEAVAGE FRAGMENTS FROM ASBESTOS: RATIONALE AND METHODOLOGY

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## INTRODUCTION

Amphiboles, especially tremolite and actinolite, are major rock-forming minerals and are common in many industrial mineral products including crushed stone, vermiculite, industrial talc, playsand, and other special use products. Most epidemiological and experimental data support the conclusion that amphibole cleavage fragments are not carcinogenic[1,2] while it is well established that amphibole asbestos can be a potent carcinogen. Nonetheless, OSHA continues to keep the question of the carcinogenicity of cleavage fragments open.[3] It is my contention that uncharacterized or poorly characterized samples remain at the heart of this disagreement. In this paper I will describe the unique mineralogical properties and dimensions of asbestos, paying particular attention to tremolite-asbestos, actinolite-asbestos and other varieties of these minerals. Despite the fact that mineralogists have urged health scientists to be more precise in the descriptions of minerals used in experiments, there still remains the need to ask again.

## DEFINITIONS

Asbestos is defined by the Glossary of Geology[4] as "a commercial term applied to a group of highly fibrous silicate minerals that readily separate into long, thin, strong fibers of sufficient flexibility to be woven, are heat resistant and chemically inert, and possess a high electrical insulation and therefore are suitable for uses where incombustible, nonconducting or chemically resistant material is required." (p.41) Heat resistance, chemical inertia and high electrical insulation are properties of almost all silicates and are therefore not unique to asbestos. However, long, thin, strong, flexible fibers are limited almost exclusively to asbestos and define the asbestiform habit. This definition is based on the commercial properties that made asbestos use so widespread. Dana, however, defines asbestos based only on mineralogical properties as follows: "Tremolite, actinolite and other varieties of amphibole pass into fibrous varieties, the fibers of which are sometimes very long, fine, flexible and easily separable by the fingers and look like flax. These kinds are called asbestos."[5] Dana also noted that there are varieties of amphibole that are very similar to asbestos but lack the flexibility of asbestos. He called this material byssolite.[5] Byssolite is too stiff to weave into cloth so according to both definitions it is not asbestos.

The word asbestiform has been used in the epidemiological literature and to describe the minerals found in commercial products in many ways. It has been applied to mean asbestos and to describe minerals such as tremolite that are not asbestos but may sometimes occur in nature as asbestos. This contradictory use of the term has rendered it almost useless. This is extremely unfortunate because the mineralogical definition of asbestiform could have great utility in the literature that deals with the carcinogenicity and fibrogenicity of mineral fibers. In fact, until precise mineralogical terminology is employed in describing minerals used in biological experimentation, the results of such experiments cannot be used to generalize about the health effects of mineral size, shape, chemical composition or habit.

In the mineralogical sense, the term asbestiform can be defined under the microscope by the following characteristics:

1. mean aspect ratio of 20:1 or greater for fibers longer than 5 micrometers,
2. very thin fibrils, usually less than 0.5 micrometers in width, and
3. two or more of the following:
   a. parallel fibers occurring in bundles,
   b. fiber bundles displaying splayed ends,
   c. fibers in the form of thin needles,
   d. matted masses of individual fibers, and
   e. fibers showing curvature.

This definition is based on the mineralogical properties and dimensions of both commercial and non-commercial asbestos which are described in the following sections.

## MINERALOGICAL PROPERTIES OF ASBESTIFORM MINERALS

### Fibrillar Structure

Asbestos of all types is composed of bundles of individual fibrils. These fibrils vary in size among the different asbestos types and occurrences. South African and Australian crocidolite has a fibril that ranges in width from about 500 to 2000 A; grunerite-asbestos from South Africa ranges from about 2000-6000 A and chrysotile fibrils from most localities range from about 200 to 500 A in width.[6] Actinolite-asbestos, tremolite-asbestos and anthophyllite-asbestos have fibril widths that are comparable to South African amosite. The width of byssolite fibers may range up to ten micrometers or more.

Asbestos fibrils share a common axis of elongation but are randomly oriented with respect to the other crystallographic directions. There have been reports of other minerals forming between fibrils (talc, brucite), but generally asbestos fibers are monomineralic. The fibrils are held together by weak bonds and the fibrils are easily separated by gentle pressure of the hand. Separation of the fibrils in this manner is not cleavage; no structural bonds are broken.

The fibrillar structure of asbestos hinders the use of single crystal X-ray techniques to study it. Instead of producing a pattern of spots which can be interpreted to determine symmetry and structure, an asbestos fiber with a diameter of about 0.1 mm will produce a pattern consisting of lines derived from spot patterns of thousands of individual fibrils that share only one crystallographic axis in common. For many years, the inability to study asbestos by classical X-ray techniques left the determination of symmetry to the optical properties (which also are affected by the fibrillar structure), and the common amphibole-asbestoses crocidolite and amosite were thought to be orthorhombic rather than monoclinic which they are now known to be.[7]

Monoclinic amphiboles exhibit the property of oblique extinction when viewed under the petrographic microscope. This property arises because the principal optic directions (X, Y, and Z) are not parallel to the principal crystallographic axes (a, b, and c). Oblique extinction is found in minerals that belong to the monoclinic and triclinic crystal systems, but is lacking in minerals that are orthorhombic, hexagonal or tetragonal. Minerals of the latter group exhibit parallel extinction. However, all types of asbestos exhibit parallel extinction, regardless of the crystal system to which they belong. This arises because the individual fibrils are smaller than the resolution of the light microscope so that their properties cannot be examined individually. Instead, a group is always observed. In some samples of asbestos, some individual fibrils approach 1 μm in width. These fibrils should show the properties characteristic of the crystal system to which they belong. In some specimens, notably those with low tensile strength, they do; but in others, they do not. Amosite, for example, has fibrils that approach 5000 A. These are large enough to be seen optically. However, they always exhibit anomalous parallel extinction. {100} twinning is very common in amphibole asbestos, and if pervasive, could account for this anomalous behavior.[8,9,10]

It should be mentioned that the peculiar optical properties of asbestos have been recognized for many years. Deer et al.[11] state that amosite and crocidolite have parallel extinction. Heinrich[12] explains the parallel extinction of asbestos in terms of its fibrillar structure and points out that tremolite-asbestos was originally identified as anthophyllite because of its optical properties.

### Tensile Strength

The high tensile strength of asbestos is clearly related to the fibrillar structure. Asbestos has a 10 to 30-fold increase in tensile strength over nonasbestos forms of the same minerals. In the case of the amphiboles, the tensile strength varies inversely with the fibril width.[7,12] This means that the tensile strength of South African crocidolite is greater than that of the South African amosite which in turn has a tensile strength greater than Finnish anthophyllite.

Zoltai[13] has suggested that the high tensile strength is related to the surface structure of the fibrils as well as to their width. Under the scanning electron microscope, the mirror-like surfaces of asbestos are evident. They lack cracks and other imperfection that contribute to a decrease in the ideal tensile strength. By contrast, cleaved fragments of the same mineral usually have rough, irregular surfaces. It has been known for many years that the strength of a fiber is inversely proportional to the diameter. According to Zoltai[13] this is often related to an increased strength of the surface structure of fibers which becomes increasingly important as diameter decreases.

### Crystal Forms

Cleavage in amphiboles takes place along the {110} surfaces ({210} in the orthoamphiboles). Therefore, most amphibole particles that have been cleaved are bounded by these surfaces. However, some amphiboles may also exhibit parting along {100} and/or {010}. Parting in common amphiboles is not usually well developed so amphibole fragments are bounded by these surfaces only rarely.

By contrast, amphibole asbestos fibrils are frequently bounded by {100}, {010}, and {110} faces with {100} being the most well developed, providing lath-like fibers.[10,14] Dorling and Zussman[10] conclude that these are generally growth surfaces, not cleavage planes, although twinning on {100} is common in amphibole asbestos and parting may contribute to the development of this surface.

## THE SIZE AND SHAPE OF ASBESTOS FIBERS

### Bulk Samples

Length, width, and aspect ratio distributions of populations of bulk samples of many types of asbestos have been determined.[6,16,17,18,19,20,21] To some extent the dimensional characteristics of these populations are dependent on the sample preparation techniques, primarily the degree of grinding. However, except under the most extreme conditions, when grinding has been so prolonged that the particles are reduced to nearly equidimensional masses, certain characteristics of asbestos are retained. For example, sample preparation disaggregates asbestos fibers and, to a greater or lesser degree, separates individual fibrils. However, because the width of a fibril is established during the formation of asbestos and because of the high tensile strength of asbestos, the widths of asbestos fibers are not easily altered. Another dimensional characteristic that is normally unaffected by sample preparation is the relationship between width and length.[22] The width of an asbestos fiber is essentially independent of its length while for populations of cleavage fragments, as the length of a particle increases, so does its width.[17] (Mixed populations will show characteristics between these two.) Aspect ratio has been used frequently to characterize mineral particle populations. However, to be used effectively, aspect ratio comparisons must be restricted to particular ranges in length.

Table I gives the width and aspect ratio distributions of fibers

Table I
Commercial Asbestos—Width Distribution

| | (a) % longer than 5µm | (b) % of (a) with widths < 1.0µm | (c) % of (a) with widths < 0.5µm |
|---|---|---|---|
| crocidolite South Africa | 48 | 98 | 85 |
| amosite South Africa | 73 | 91 | 50 |
| chrysotile Quebec | 38 | 99 | 94 |
| chrysotile (SEM) California | 54 | 98 | 94 |
| chrysotile (TEM) California | 8 | 100 | 98 |

COMMERCIAL ASBESTOS - ASPECT RATIO DISTRIBUTION

| | (a) % longer than 5µm | (b) % of (a) with aspect ratio > 10:1 | (c) % of (a) with aspect ratio > 15:1 | (d) % of (a) with aspect ratio > 20:1 |
|---|---|---|---|---|
| crocidolite South Africa | 48 | 99 | 95 | 89 |
| amosite South Africa | 73 | 98 | 84 | 75 |
| chrysotile Quebec | 38 | 100 | 98 | 96 |
| chrysotile (SEM) California | 54 | 99 | 97 | 94 |
| chrysotile (TEM) California | 8 | 99 | 97 | 96 |

longer than 5 micrometers for four samples of commercial asbestos. These samples have been described by Campbell et al.[6] The small widths and high aspect ratios are the hallmark of asbestos, even for amosite which has the widest widths and lowest tensile strength of the four major commercial asbestos varieties. Similar distributions are found for airborne fibers.[23]

Tables II and III present the width and aspect ratio distributions for tremolite and actinolite samples of several different habits. Only data for particles longer than 5 micrometers with aspect ratios greater than or equal to 3:1 are included. Therefore, the data do not reflect the distribution within the entire population but only for the particles that are elongated. (The data are limited to these dimensions because some of the data were collected only for these particles.)[18,24]

Under the microscope, the two samples of actinolite-asbestos (samples 1 and 2) exhibit all the characteristics of the asbestiform habit and satisfy the commercial definition of asbestos. Sample 3 and sample 6 are both from India but are slightly different. Sample 3 is asbestos while sample 6 is a mixture of both asbestos and byssolite. The differences are most apparent in the percentage of particles with aspect ratios in excess of 20:1 (55 vs.25). The data for samples 4 and 5 come from Atkinson et al.[18] The tremolite is associated with vermiculite at both locations. At Libby, the tremolite is asbestiform (A.M. Langer, personal communication); at Enoree, South Carolina, the tremolite is described as a mixture of both asbestiform fibers and cleavage fragments.[18] Samples 7, 8 and 9 are populations of cleavage fragments. The data for samples 8 and 9 were derived from particles collected on airfilters. These samples lack the characteristics of asbestos. The particles are much wider, shorter, and have smaller percentages with aspect ratios greater than 20:1 than asbestos.

## CONCLUSIONS

In describing mineral samples for biological experiments, hand specimen descriptions, locations, chemical composition, microscopic properties and comprehensive dimensional data should be provided. If these data are available, the differences between cleavage fragments and asbestos fibers are obvious. Even fibrous nonasbestiform byssolite can be distinguished. It is essential if we are to understand what properties of minerals make them carcinogenic, fibrogenic or benign that comprehensive data be published for all minerals used in biological experimentation.

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Table II

Tremolite and Actinolite—Width Distribution—
Particles with AR > 3:1

| | (a) % longer than 5µm | (b) % of (a) with width ≤ 1.0µm | (c) % of (a) with width ≤ 0.5µm |
|---|---|---|---|
| 1. actinolite-asbestos mountain leather locality unknown | 12 | 98 | 90 |
| 2. actinolite-asbestos South Africa | 10 | 96 | 70 |
| 3. tremolite-asbestos India(24) | No data available | | |
| 4. tremolite-asbestos(18) Libby, Montana | 43 | 87 | 54 |
| 5. tremolite (variety?)(18) Enoree, South Carolina | 22 | 81 | 48 |
| 6. tremolite, byssolite & asbestos India | 8 | 61 | 34 |
| 7. tremolite New York | 20 | 9 | 0 |
| 8. actinolite(airborne) Virginia(21) | 29 | 11 | <1 |
| 9. grunerite + actinolite (airborne) Minnesota(21) | 2 | <1 | 0 |

Table III

Tremolite and Actinolite—Aspect Ratio Distribution—Particles AR > 3:1, L > 5 $\mu$m

| | aspect ratio ≥ 10:1 (%) | aspect ratio ≥ 15:1 (%) | aspect ratio ≥ 20:1 (%) |
|---|---|---|---|
| 1. actinolite-asbestos mountain leather locality unknown | 92 | 80 | 63 |
| 2. actinolite-asbestos South Africa | 86 | 70 | 52 |
| 3. tremolite-asbestos India(24) | 80 | - | 55 |
| 4. tremolite-asbestos Libby, Montana(18) | 88 | 70 | 52 |
| 5. tremolite (variety)(18) Enoree, South Carolina | 74 | 57 | 43 |
| 6. tremolite, byssolite & asbestos India | 57 | 31 | 25 |
| 7. tremolite New York | 8 | 4 | 4 |
| 8. actinolite (airborne) Virginia(21) | 11 | 3 | 2 |
| 9. grunerite and actinolite Minnesota (airborne)(21) | 1 | 0 | 0 |

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# A NEW FIBROGENIC DUST SAMPLING METHOD FOR EPIDEMIOLOGY OF PNEUMOCONIOSIS

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## ABSTRACT

Current sampling instruments of respirable dust (RD) may over estimate the inhaled does by up to 400% depending on the size distribution of airborne dust. This limitation and the practice of assigning a single value for RD to all jobs regardless of the level of activity are incompatible with the advances in occupational epidemiology. A new dust sampler designed to estimate pulmonary deposition (PD) was developed to alleviate these limitations. The device consists of a 10 mm cyclone followed by a single-nozzle one-stage impactor. The dust fraction of interest is collected by impaction on a 10 mm diameter microscope cover slip. Estimation of PD is obtained by selecting the appropriate air flow rate and diameter of impactor so that the combined performance will simulate the bell shaped curves of PD at various respiratory frequencies and tidal volumes. This configuration was selected, rather than two impactors in series, to obtain better matching of PD (impactors have sharp cut-off curves). A cyclone can also collect large amounts of dust without overloading. Performance of the sampler was evaluated using monodispersed aerosols 1.1, 2.7, 4.7, 9.8 $\mu$m and geometric standard deviations $<1.2$. The results indicate that PD is estimated very closely by the new sampler.

No Paper provided.

# SYSTEM FOR PROTECTION AGAINST EXPOSURE TO ASBESTOS IN A FACTORY FOR DE-INSULATION OF RAILWAY CARS

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## INTRODUCTION

The Manufacturing of asbestos or the handling of products containing asbestos, provoke contamination of environments both in and out of work areas. The significant efforts made in the last few years, have shown that it is possible to control the work exposure risk within maximum safety limits. In fact, both the use of good procedure regulations and suitable personal protection means, together with constant and detailed instruction of personnel, can reduce professional exposure to levels of only a few fibers for liter of air.

On the contrary, it is not easy to prevent the dispersion of the fibers outside the work sites due to the large quantity of asbestos that moves around the continuous traffic of personnel in some way contaminated. Currently available information does not allow us to establish a threshold limit where the risk of cancer is null; in fact, the W.H.O. and other research agencies' projections require fiber dispersion to be practically null in external environments.

## RESEARCH OBJECTIVES

Our research began by noting that currently existing recommendations and regulations regarding good procedures are not able to assure adequate environmental protection. In our opinion, one of the main causes of environmental contamination is, paradoxically, attributed to the workers means of protection. In fact, in order to achieve maximum safeguarding of workers, we are forced to constantly use personal means of protection, from the semi-protective mask to the positive pressure helmet. This creates the need for frequent breaks in decontaminated and clean areas, where the concentration of fibers is practically the same as the outside environment.

In order to obtain these conditions, the workers must pass through various areas where they remove their overalls, shoes and protective covering; in order to ascertain complete and safe decontamination, it is often compulsory to complete the latter under a shower of water (erf. Circular n. 45, Ministry of Health, Italy). It has been proven that simple, air spraying showers do not assure good decontamination of workers, thus the water shower appears to be indispensable if a perfectly clean rest area is desired. However, it is difficult to require the workers to take several showers, and they most probably will be tempted to pass quickly through, thwarting the efforts made to keep the rest area clean.

## MATERIALS AND METHODS

In order to solve this problem, we thought of creating waterproof overalls that are attached to a sack-like helmet, which in turn is fed by a pump equipped with an absolute filter. The overalls are made of a light-weight polyester fabric (Figure 1) lined with a water vapor, permeable PTFE film. They weigh less than 500 grams. The overalls have a double zipper which closes in the front to assure that they are waterproof (Figure 2). There is also a long, semi-stiff collar (Figure 3) over which the neckline of the helmet is tightened (Figure 4). The inside of the helmet is equipped with an overturned "U" shaped diffusor that prevents the pump's air streams from fogging up the visor and from directly striking the workers face and head. Once the helmet is placed on the head and properly fitted and tightened around the overalls, the air penetrates the overalls slightly inflating them and finally exiting from the wrists and ankles (Figure 5), assuring transpiration from the workers body.

We tested this simple and easy to use personal protection system in a railway car de-insulation industry.

Upon exiting the work area, the workers pass through a multiphase decontamination system.

1. A water filled tank, approximately 20 cm in height, is used for the first washing of the rubber boots;
2. A first stall where a strong blast of air removes the larger fibers;
3. A second stall where a water shower thoroughly cleans the overalls and helmet, removing even the smallest of fibers (Figure 6);
4. A third stall where a stream of air dries the overalls and helmet;
5. By passing through a second water filled tank for an additional boot washing and two air locks, the workers have access to an area where they can remove their overalls, helmet and boots and then move on to the rest area dressed in the cotton clothing that they wear under the overalls.

The first tests we carried out show that with adequate worker training and careful study of work-break cycles, it is possible to limit the environmental concentration of the rest area, where some 50 people pass through, to 1-5 fibers/liter of air. The use of this decontamination system allowed us to reduce the environmental concentration of asbestos fibers. In fact, it was possible to soak the material to be de-insulated in a diluted solution of a tensio-active substance, thus reducing environmental pollution from approximately 200 ff/ml to approximately 5 ff/ml during the highest pollution production phase. With the previous air-spray decontamination system, it was not possible to wet the asbestos. We are currently researching ways to optimize this study, reducing the metabolic charge as much as possible, in order to limit perspiration, thus improving the workers comfort and reducing the frequency of breaks.

Figure 2.

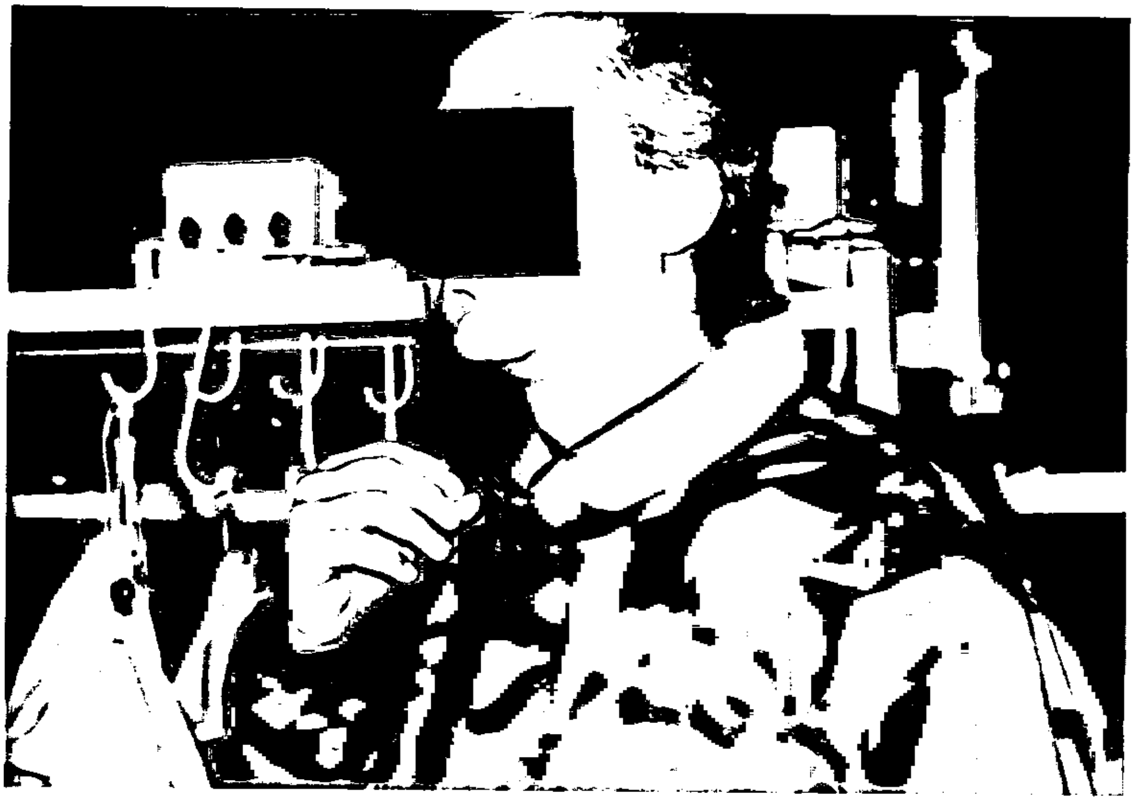

Figure 3.

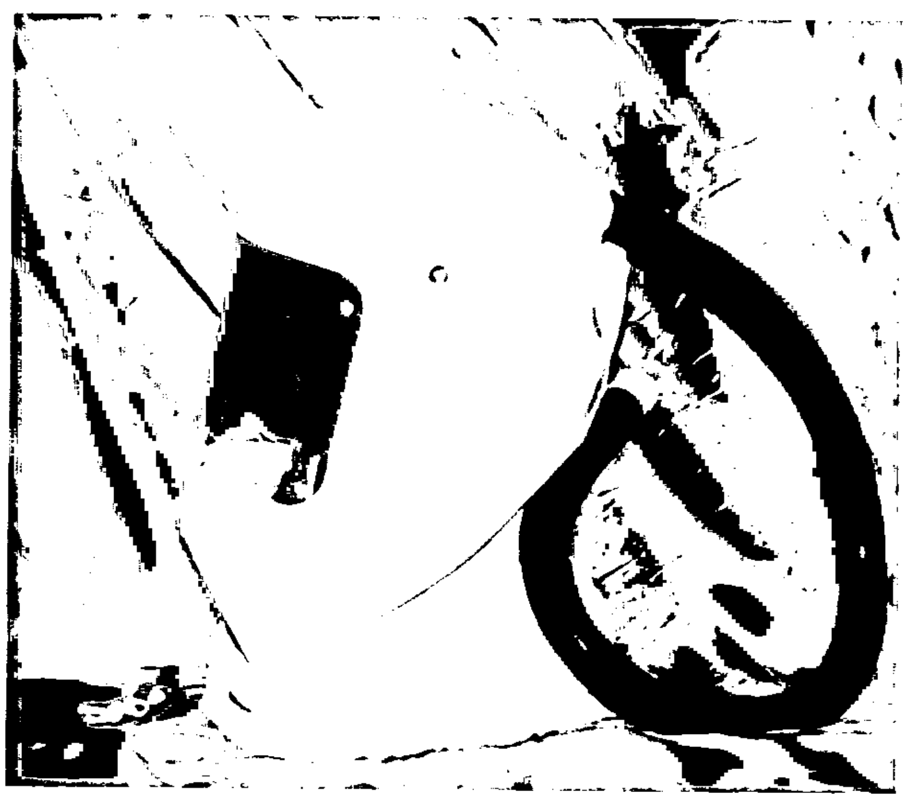

Figure 4.

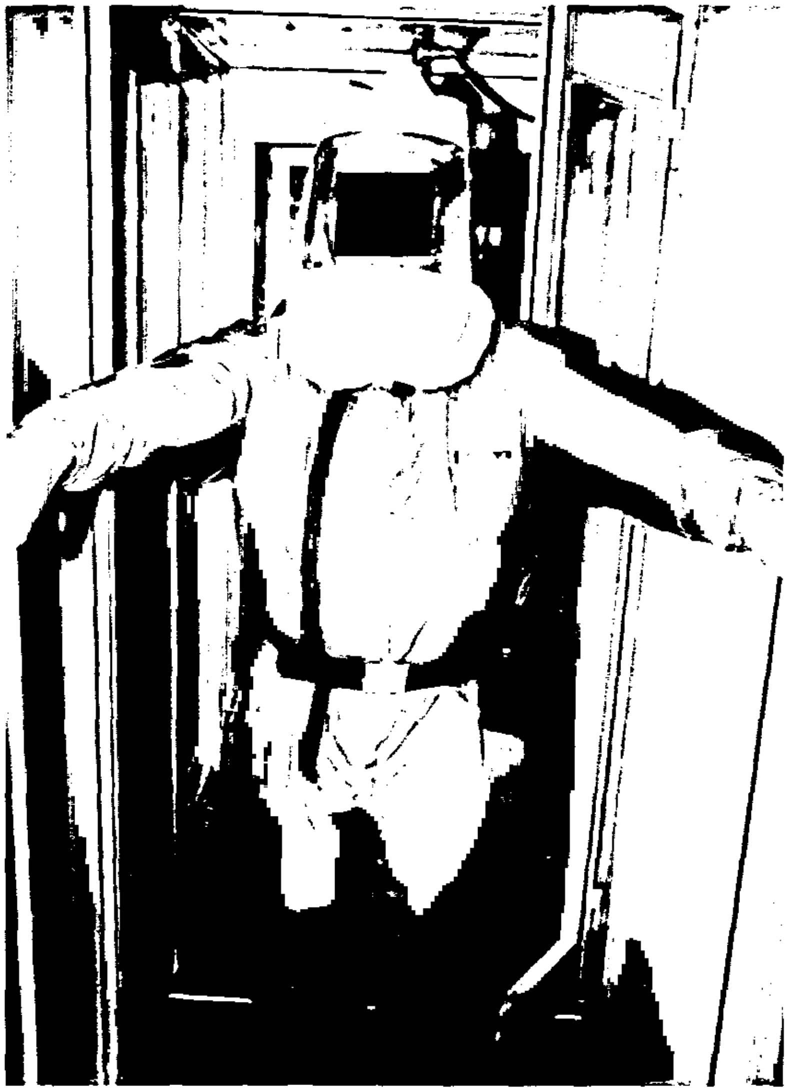

Figure 5.

Figure 6.