potential is high (> 10) the positive ion appropriates one or more oxygen ion, freeing the hydrogen and forming an oxyanion, which is generally soluble; this is characteristic of the nonmetals in the upper right corner of the periodic table.

If life began in the primitive terrestrial oceans, elements whose abundances in the aqueous phase are high should have a high representation in living material. In Fig. 1, the enrichment factor for a number of elements—that is, the ratio of the concentration of the element in an organism to its concentration in the earth's crust (*7*)—is plotted against ionic potential. A similar curve is seen for all major groups of organisms, as we proceed up the evolutionary scale from bacteria to fungi to plants to land animals, and for the ocean (Fig. 2).

A general pattern is observed for all living organisms: (i) For elements of low ionic potential values ($IP < 3$) the log of the enrichment factor (EF) is in the range of -1 to +1 indicating small enrichment or small depletion relative to the crust. (ii) For intermediate IP values ($3 < IP < 10$) log EF is -3 to -4 indicating large depletion in living organisms. (iii) For large IP values ($IP > 10$) log EF increases as the ionic potential increases and varies from -4 to +4. It should be noted that the elements mentioned by Crick and Orgel as showing anomalous distribution patterns—Mo, Ni, and Cr—also follow this general pattern. Specifically, Mo does not show any significant enrichment in living organisms as compared to the earth's crust. Obviously, taking each element and each group of organisms separately, we may expect many exceptions to the rules; still, the general pattern is strikingly similar for all the groups of organisms investigated.

According to Oparin (*8*), some combinations of biochemical reactions are characteristic of all contemporary organisms. These are combinations of patterns acquired by the emerging living matter in its very early stages of development, before further specialization and differentiation took place. Thus the basic similarity of the elemental composition pattern of all groups of living organisms (Fig. 1) indicates that the pattern was determined at the initial steps of the development of life.

It should be noted that in the range of ionic potentials higher than 10, where the major biochemical elements sulfur, carbon, and nitrogen are found, organisms have a very significant enrichment of 10 to most 10,000 relative to the ocean. This

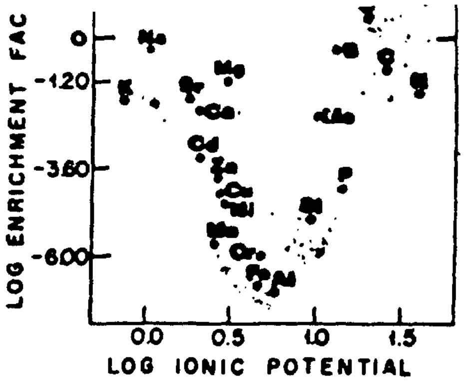

Fig. 2. Elemental enrichment factors in seawater, related to the ionic potential of the elements.

may be taken as a clue to a more exact location for the origin of life. It can be speculated that life began at the interface of the primitive atmosphere and the ocean, in the thin microlayers at the surface of the ocean where large enrichments of the atmospheric constituents (mainly nitrogen and carbon at that stage) may occur. Various other elements may also be concentrated in these microlayers because of the effects of surface-active materials, surface tension, and the transfer processes between the liquid and the gaseous phase. In any event, it is evident that a chemical environment similar to the earth's ocean is sufficient to explain the elemental abundance relationships in living materials. A nonterrestrial explanation, especially one that has in-

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11 March 1975

Exposure to Asbestos in the Use of Consumer Spackling, Patching, and Taping Compounds

Abstract. *Analysis of representative samples of spackling, patching, and jointing compounds, purchased at retail stores in the New York City area, has shown that some contain asbestos minerals as well as other biologically active substances. Measurements suggest that home repair work involving the use of such materials may result in exposure to dust at concentrations sufficient to produce disease.*

Spackling and drywall taping compounds consist of extremely fine-grained white powders or premixed pastes. Plaster of Paris is supposedly the major constituent, but other light-colored materials including clays, micas, quartz, talc, and ground limestone, supplement or replace the plaster in many formulations. Chrysotile is added to some products, apparently because these minute fibers act as reinforcing agents. The presence of amphibole asbestos in some products results from its natural occurrence in talc, carbonates, and other rocks used as raw materials (*1*).

Fifteen samples of consumer spackling and patching compounds were purchased at hardware stores in the New York City area, four in 1972 or earlier and the remainder in January 1974. We analyzed the samples for mineral phases by polarized light microscopy, x-ray powder diffraction, and transmission electron microscopy, with particular attention to quantitative determination of asbestos minerals. The spackling and taping compounds consist mainly of particles smaller than 3 μm in average diameter or length (Fig. 1). Particles of this size are generally too small to

Table 1. Mineral content of consumer spackling and patching compounds and industrial drywall taping compounds.

Mineral phase	Frequency of occurrence of mineral phases: In 15 consumer spackling and patching compounds	In 10 industrial drywall taping compounds
Chrysotile	3 (5–10%)	9 (5–12%)
Tremolite	1 (4– 6%)	1 (5– 7%)
Anthophyllite	1 (10–12%)	
Talc	2	2
Quartz	9 (5–70%)	6 (10–30%)
Feldspar	1	
Pyrophyllite	2	
Mica	8	9
Kaolinite	5	7
Calcite	11	4
Dolomite	3	4
Plaster of Paris	7	6

be individually studied by polarized light microscopy, and identification is further confounded because these compounds commonly are mixtures of four or more different materials. The analytical use of the optical microscope with its limited resolution allows large numbers of fibers to go undetected. The asbestos minerals, in particular, are usually too fine-grained to identify. In such circumstances, x-ray powder diffraction may be used to identify and quantify the individual crystalline phases present in the mixtures.

In this investigation the amounts of asbestos present in spackling compounds was determined by comparison with dilution standards (*2*). Binary systems of chrysotile, tremolite, and anthophyllite asbestos in plaster of Paris ($CaSO_4 \cdot {}^1/_2H_2O$) were prepared at varying dilutions on a weight-to-weight basis. Diagnostic reflections for each of the asbestos minerals were selected. These reflections were step-scanned by x-ray diffraction at increments of 0.02° 2θ, where θ is the dispersion angle, over a goniometric interval sufficient to define a peak-to-background ratio for the diagnostic reflections. A digital printout of elapsed time in a fixed-count determination was used to prepare precise positions and profiles of the diagnostic reflections. The area above background, determined with a compensating polar planimeter, was taken to be proportional to the concentration. Details of the method have been presented elsewhere (*2*). Samples of spackling and taping compounds were prepared, analyzed, and measured under the same conditions as the dilution standards. Comparison of the results of known dilution standards with the samples permitted the amounts of asbestos to be estimated with approximately 20 percent reproducibility.

The presence of certain minerals may interfere with the detection or quantitation of chrysotile in spackling and taping compounds. For example, chrysotile and kaolinite have similar crystal structures and consequently similar x-ray diffraction patterns (*3*). However, electron microscopy can be used to corroborate the results of x-ray diffraction and to directly estimate the asbestos content of materials, since each mineral type has a characteristic morphology and electron diffraction pattern.

The results of the analyses of 15 consumer spackling and patching compounds are given in Table 1. Three of the samples were found to contain chrysotile asbestos, and two others contained tremolite and anthophyllite asbestos. Talc was a major con-

Fig. 1 Electron photomicrograph of a c spackling product. Large numbers of c fibers and fiber bundles are present. particulates are clay, mica, and carbor erals.

stituent in two samples and pyroph two. The crystal structure and properties of pryrophyllite are identical to those of talc; pyrophyll be considered the aluminum analog Its biological activity is presen known. Quartz was a major consti seven of the samples, and it was pr two others in lesser concentrations. basis of the x-ray intensities of seve jor quartz reflections, including t 4.26, 3.34, and 1.817 Å, the am quartz present is estimated to be than 10 percent in the seven sample cal and transmission electron mic have shown essentially all the quar of respirable size (< 5 μm). Both and talc can produce pulmonary (silicosis, talcosis) (*4*). One samp sisted largely of quartz with lesser a of feldspar and anthophyllite. This dicate that the source material product was an anthophyllite sch combination of talc with some t and quartz in another sample repr common mineral association ty commercial talc ore bodies.

Both optical and electron mic analyses showed that the asbestc present in the samples ranged in from 0.25 to 8.0 μm. Most were than 5 μm in length, which is re size, yet they were not generally by optical microscopy.

The possibility of asbestos expo ing home construction and repa dicated by the fact that drywall c tion workers are exposed to si concentrations of asbestos a tamination. Mineralogical analyse industrial drywall taping compour that nine contain chrysotile, in co tions ranging from 5 to 12 per weight) (Table 1).

Table 2. Asbestos fiber concentrations during use of taping compounds containing asbestos minerals. Multiplication of the number of fibers per milliliter by 10⁶ gives the number of fibers per cubic meter of air, an amount which may be inhaled during 1 hour. An unstudied proportion of these fibers is retained and others are exhaled. Current (interim) regulations of the OSHA prohibit concentrations of 5 fibers per milliliter or more, longer than 5 μm, as a time-weighted average for workers. Concentrations above 2 fibers per milliliter will be illegal after 1976. Current regulations set a ceiling concentration of 10 fibers, longer than 5 μm, per milliliter of air.

Operations	Number of samples	Peak fiber concentration (fibers per milliliter): Mean	Range
Pole-sanding (1 to 1.5 m)	10	10.0	1.2 to 19.3
Background (2.5 m), same room	3	8.6	3.5 to 19.8
Background (7.5 m), adjacent room	2	4.8	0.7 to 8.8
Hand-sanding (1 to 1.5 m)	11	5.3	1.3 to 16.9
Background (2.5 m), same room	2	2.3	2.1 to 2.5
Background (4.5 m), adjacent room	2	4.3	1.5 to 7.1
Dry mixing (1 to 1.5 m)	2	47.2	35.4 to 59.0
Background (3 to 6 m), same room	3	5.8	0.5 to 13.1
Background (5 to 10 m), adjacent room	2	2.6	2.1 to 3.1
Sweeping floor (3 to 15 m)			
15 Minutes after sweeping	1	41.4	
35 Minutes after sweeping	1	26.4	

We made measurements of peak asbestos air concentrations in the breathing zone of drywall construction workers, utilizing the standard technique of the National Institute for Occupational Safety and Health (NIOSH) for asbestos sampling and analysis (phase-contrast optical microscopy at × 430) (*5*). These air samples were also analyzed by transmission electron microscopy. Air samples were taken at various building jobs and job sites and included such operations as hand-sanding, pole-sanding, mixing of dry spackle with water, and sweeping after completion of such operations. Personal air samples were also taken in adjacent areas; such air samples, taken in the breathing zones of the operators, constitute measurements of their exposure to dust.

Table 2 shows that airborne concentrations of 5 fibers per milliliter of air or more, longer than 5 μm, are common during the use of drywall taping compounds containing asbestos. This exceeds the interim legal standard excursion set by the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor. The OSHA standard calls for an 8-hour time-weighted average. The discontinuous nature of these operations suggests that the 8-hour sampling is inappropriate in that peak exposures in the present instance, under a range of application and cleanup operations, greatly exceed the maximum allowable excursions of 10 fibers per milliliter for a 15-minute interval.

These concentrations, determined by the NIOSH method, are only suggestive of the total asbestos exposure. Comparison of optical microscopic and electron microscopic analyses of asbestos fiber counts of identical samples showed that, for every fiber visible by light microscopy (×400 magnification), there were from 200 to almost 1000 that could be seen only at electron microscopic magnifications of ×25,000.

The background measurements in Table 2 suggest that in home repair work involving sanding of spackling compounds, members of the entire household or other occupants of a building may inhale asbestos fibers. This could occur during mixing, sanding, or cleaning up of debris. During mixing of drywall taping compounds, spackle is gradually poured from a bag into a bucket of water and the mixture is stirred until the desired consistency is attained. Fiber counts measured during mixing were found to be from 7 to 12 times greater than the current occupational standard. Detectable fiber concentrations were found in adjacent rooms during mixing, and fibers were still suspended in the room air at least 15 minutes after mixing had ceased. Personal air samples were taken after sanding was completed. The floors of the rooms and halls were swept with a hand broom, which raised a cloud of dust. Fiber counts could not be made on floor sweeping samples because the filters were too heavily laden to count. Samples were taken after 15 minutes had elapsed, and, in one case, 15 m away in another room. Measurements showed that significant concentrations of asbestos remained suspended and could pervade living quarters for a considerable duration of time after sweeping had ceased.

In summary, our analysis of 15 representative samples of consumer spackling, patching, and taping compounds has shown that five contained appreciable amounts of chrysotile or other asbestos minerals. Many contained substantial amounts of quartz, talc, and other minerals with disease potential. Optical microscopic analysis of personal air samples obtained during the use of asbestos-containing compounds showed concentrations frequently in excess of the current occupational standard of 5 fibers per milliliter, longer than 5 μm. Use of these materials in home repair work (for example, mixing, sanding, and cleanup) may expose the user (and other members of the household) to significant concentrations of asbestos.

Even more important, none of the 25 industrial and consumer spackling and taping compounds examined had warning labels or indication that they might contain toxic or hazardous materials. It is, therefore, recommended that potentially toxic or hazardous materials be eliminated from consumer spackling, taping, and wall-patching compounds as soon as feasible. As an interim measure, labels should be required on such products stating their content and providing instructions for the use of appropriate respirator protection and for safe cleanup procedures, including the disposal of waste materials.

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7 March 1975

Water Wells as Possible Indicators of Tectonic Strain

Abstract. *Coseismic water level changes associated with the Izu-Hanto-oki earthquake of 9 May 1974 were recorded in 59 among 95 observation wells located in the districts of Tokai and Kanto, Japan. The spatial distribution of wells in which the groundwater level rose or fell is rather systematic. The areas in which these wells are located closely coincide with the areas of contraction and dilatation expected by the faulting. This strongly suggests a possible correlation between the observed changes in groundwater level and the tectonic strain. The results may indicate that the water level of wells is able to monitor at least acute coseismic strain changes.*

A destructive earthquake occurred on the southern tip of the Izu Peninsula, Japan, at 08:33 hours on 9 May 1974. The seismological data (*1*) are: epicenter, 34° 34′N, 138°48′E; depth of focus, 10 km; and magnitude, 6.9. The focal mechanism of the earthquake was a quadrant type with the maximum pressure axis in a nearly north-south and horizontal direction. Distinct earthquake faults appeared along the preexisting, dextral strike-slip faults trending in a northwest-southeast direction (*2*).

Coseismic changes in groundwater level caused by the earthquake were examined in 95 observation wells (*3*), located 50 to 210 km from the epicenter. These wells were drilled originally for the protection of groundwater resources and measurement of land subsidence. Most of the wells range in depth from 100 to 300 m, the shallowest and the deepest being 35 and 2150 m deep, respectively. Groundwater level changes were continuously monitored, in most cases, with recorders manufactured by the Nakaasa Sokki Co. The practical sensitiv-

File · Asbestos

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INSULATION HYGIENE PROGRESS REPORTS

FROM THE INSULATION INDUSTRY HYGIENE RESEARCH PROGRAM

Irving J. Selikoff, M.D., Program Director

Vol. 6 No. 1 Spring 1975

The Asbestos Exposure of Insulation Workmen

ASBESTOS STANDARD TO BE REVIEWED

On December 7, 1971 an Asbestos Standard was promulgated that prohibited workmen's eight-hour average asbestos exposures to exceed 5 fibers per milliliter (f/ml) of air. A milliliter is about a thimbleful of air and only fibers longer than five microns (about 1/25,000 of an inch) are to be counted. This level is mandated to go to 2 f/ml during June, 1976.

Last year, the U.S. Court of Appeals ordered portions of the current U.S. standard to be reviewed by the Department of Labor. Of interest to insulators, the court specifically stated that in those industries where a dust level of 2 f/ml was feasible, it should be implemented before 1976.

Because of this pending review of the standard, a summary of all research on the asbestos exposure of insulation workers has been prepared for submission to the Dept. of Labor by the Insulation Industry Hygiene Research Program. Because of the importance of achieving a safe U.S. Asbestos Standard and the interest of asbestos workers in this goal, we are publishing the full report in this issue.

Extensive information has been developed on the mortality experience of insulation workers. It would, thus, be of considerable value to have quantitative information on the asbestos dust levels to which these workers were exposed. Because of the long lapse period between exposure and clinical appearance of disease, the dust estimates of greatest concern are those of 20, 30, 40 or more years ago.

While historical data are scant and fragmentary, insulation work practices have changed relatively little, prior to 1970, either in the U.S. or abroad. Thus, measurements taken prior to 1970 will also provide data of use in assessing earlier exposure.

United States Data

The only early work of note is the 1945 study of Fleischer and his colleagues[1] who reported asbestos dust levels during insulation application in four U.S. shipyards. In this study, dust levels were assessed using a konimeter (an instrument widely used at the time but no longer employed), and both total dust levels and fiber levels were recorded. This study gains importance in that one of the yards studied by Fleischer was resurveyed during 1965 and 1966 by personnel of the Department of Industrial Hygiene, Harvard School of Public Health[2,3] and a comparison of levels is possible.

During 1964, additional data were published by Marr[4] on exposure levels at the Long Beach Naval Shipyard (Local 20, IAHFIAW). However, detailed numerical data on dust concentrations are only given for particles. If fibers were present, but the count revealed less than 1 million particles per cubic foot (mppcf), they were reported only as a trace. Thus, no average fiber concentrations can be derived from this study.

(Continued on page 2)

TABLE I

Shipyard asbestos fiber concentrations by Konimeter count—1945, 1965-66

Yard	A fiber conc.		B fiber conc.		C (1945) fiber conc.		C (1965-66) fiber conc.		D fiber conc.	
	MPPCF	f/ml	MPPCF	f/ml	MPPCF	f/ml	MPPCF	f/ml	MPPCF	f/ml
Shop Activity										
No. of men exposed (1945)	84		50		51		—		8	
Layout and cutting	0.35	12.4	0.23	8.1	2.2	78	1.76	62	0.63	22
Sewing and fabrication	0.03	1.1	0.1	3.5	0.62	22	0.27	9.5	0.03	1.1
General room air	0.08	2.8	0.01	0.4	0.8	28	0.3	10.6	0.02	0.7
The following shop activities were done at infrequent intervals and involved only one or, at most, two men:										
Band saw cutting	0.12	4.2	3.0	106	6.19	218	0.7	24.7	—	—
Mixing cement	0.2	7.0	1.7	60	3.1	109	0.23	8.1	0.01	0.4
Scrap grinding	0.47	16.6	—	—	—	—	—	—	—	—
Aboard Ship										
No. of men exposed (1945)	467		700		123		—		160	
Avg. exposure, all activities	0.02	0.7	2.8	98	1.1	39	0.17	6.0	0.03	1.1
Time-Weighted Average Exposure (All fibers visible)		1.1		90		35				1.1

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Average Exposures Low

1945 Results Available

Table I lists the fiber exposure data obtained from over 200 dust counts by Fleischer in 1945 and also those obtained by Murphy[3] during 1965 and 1966. Using data supplied on the number of individuals engaged in the various work activities, a time-weighted (actually man-weighted) average asbestos exposure is calculated.

A detailed analysis of the results, however, presents difficulties. In each yard, a worker's average exposure was dominated by insulation activities aboard ship. For such activities, the average asbestos dust levels reported in the different shipyards varied by nearly one hundred times.

It should be recognized that these fiber counts represent all fibers enumerated in the field of view of a konimeter. These would include fibers perhaps as short as 1.5 microns. Supplementary data[5] on the size distribution of amosite aerosols in shipyards suggest that this overestimates the number of fibers longer than five microns by a factor of two.

Taking this factor into account, the average of the eight-hour concentrations of fibers longer than five microns in the four U.S. shipyards studied by Fleischer in 1945 would be from 15 to 20 fibers per milliliter (f/ml). It must be emphasized, however, that such averages are highly subjective and depend strongly upon the vagaries of the particular work practices selected for sampling and conditions present at that time.

Similar considerations would yield a value of 4 f/ml for the shipyard survey by Murphy in 1965-66.

New Techniques Used

The first research that quantified asbestos insulation exposures using membrane filter techniques was that of Balzer and Cooper published in 1968[6] and extended in a report at the Dresden Conference on the Biological Effects of Asbestos in 1969.[7]

Their initial publication, however, enumerated fiber concentrations in marine and commercial insulation work in terms of all visible fibers, including those shorter than five microns. The later subsequent publication also provided data on fiber concentrations longer than five microns. Table 2 summarizes these results.

Using the information provided on dust concentrations and the percentage of time a worker is engaged in a particular practice, a time-weighted average of 2.7 f/ml was obtained for exposures during asbestos insulation work in light and heavy construction, and 6.6 f/ml in marine construction and repair.

Cooper and Balzer noted that at the time of their study, approximately 55% of the work time of insulation workers was spent using materials other than asbestos. Thus, eight-hour time-weighted average exposures for asbestos workers during 1968 in the western United States would have averaged less than 1.5 f/ml in light and heavy construction. Moreover, it is noteworthy that Cooper and Balzer state their samples were "deliberately taken under conditions where the highest dust concentrations representative of a particular job were being developed."

Union Cooperation Obtained

The environmental evaluation of insulation work that was undertaken by the Mount Sinai School of Medicine under the auspices of the Insulation Industry Hygiene Research Program[3] revealed asbestos air concentrations somewhat higher than those measured by Balzer and Cooper. Again using information supplied by union members and from observation of work practices, estimates were made of the percentage of time workmen were engaged in various activities in commercial and industrial construction.

The information on measured asbestos air concentrations obtained during these work activities is shown in Table 3. They were used as indicated to arrive at the estimated time-weighted average exposure of about 6 f/ml for insulators *when working with asbestos*.

On the average, in the eastern United

Insulation Hygiene Progress Reports

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from the Insulation Industry Hygiene Research Program

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PURPOSES OF THE INSULATION INDUSTRY HYGIENE RESEARCH PROGRAM

1. To develop improved methods for minimizing exposure of insulation workers to dusts and fumes encountered in their work.
2. To disseminate knowledge of these improved methods of dust control wherever they may be applied advantageously and to offer cooperation, advice and assistance toward their universal adoption.

TABLE II

Asbestos fiber concentrations by membrane filter techniques

Job Classification	Percentage of work with asbestos	Light and Heavy Industrial Fibers/cc mean: All Lengths	Light and Heavy Industrial Fibers/cc mean: Length > 5μ	Marine Construction and Repair Fibers/cc mean: All Lengths	Marine Construction and Repair Fibers/cc mean: Length > 5μ
Prefabrication	10%	10.1	6.6	30.4	20.0
Application	40%	12.4	8.0	24.8	16.8
Mixing	5%	2.4	1.6	10.6	7.1
Finishing	30%	2.7	1.8	1.8	1.2
Tearing Out	10%	12.8	8.4	31.5	20.2
General	5%	0.8	.5	.2	0.1
Time-Weighted Average Exposure		4.1	2.7	9.9	6.6

IIHRP Results Reported

States during the 1960's, over half of the work activities of these men were with materials other than asbestos. Thus, the over eight-hour time-weighted average asbestos exposure was approximately 3 f/ml.

In the research that led to these data, it was reported that peak exposures could be extremely high. It was not uncommon, for example, for two to five-minute concentrations of asbestos to range between 50 f/ml and 100 f/ml during the mixing of cement. This mixing, however, would consume only a few minutes time and be done perhaps once an hour. Thus, exposures measured over that hour, including the mixing, would seldom average over 5 f/ml.

Peak High, Average Low

Similar experiences were subsequently reported by Cooper[8] at Lyon who stated that, "Peak concentrations may be high for brief periods, while time-weighted averages are often deceptively low."

In a continuation of the work of the Department of Industrial Hygiene of Harvard University in assessing asbestos exposure in Naval Shipyards, Ferris *et al*[9] reported on the results obtained by J. Lynch and W. Burgess from 81 shipyard asbestos air samples taken during 1969. Using fiber counting techniques they determined a mean asbestos concentration of 0.3 f/ml in land fabrication shops and 2.9 f/ml in shipboard installation work.

3 f/ml Exposure

Three research programs in the United States point to the conclusion that the time-weighted average exposure of insulators between 1965 and 1969 was *less than 3 fibers longer than five microns per milliliter*.

We have direct information on asbestos fiber concentrations, measured using the currently prescribed analysis procedures, during recent years only. Insulation materials have changed from earlier years. Fibrous glass has found extensive use while work with cork is seldom seen today. Moreover, changes in the asbestos composition of insulation products have taken place. Pipe covering and insulation block may have had twice the asbestos content in past years as exists today.

During this period, however, work practices were virtually identical to those of past years and during the period of those measurements, few controls of significance were in use.

TABLE III

Asbestos concentrations during various work practices

Type of Work	Measured Fiber Concentration (f/ml) (greater than 5 microns)	Percentage of Time Practice Occurs When Asbestos is Used	Column One times Column Two
Mixing and Applying Cement and Cloth Covering to Insulation Material			
Good Ventilation	2.5	17.5	44
Poor Ventilation	4.6	17.5	81
Cutting and Applying Insulation Block or Sections of Pipe Covering			
Good Ventilation	5.2	20	104
Poor Ventilation	11.5	20	230
Pre-Fabrication work including Cutting Materials for later use	7.6	10	76
			535

Time-weighted average = 535/85 = 6.3 f/ml

The above practices, which occupy 85% of the work time in asbestos insulation work, give rise to a time-weighted average exposure of 6.3 f/ml. As the majority of the other activities of insulation work (supervision, collection of materials, movement and installation of equipment, etc.) are relatively clean, the overall exposure may be lower. (In the U.S., sweeping and dusty cleanup are done by members of the Laborers Union.)

In a review of work activities in commercial and industrial construction, it was found that little removal of insulation was conducted and asbestos spray applications were very rarely undertaken by insulators. (Asbestos workers applied spray insulations only to powerhouse turbines.) It is estimated that less than two or three percent of nonmarine insulation work by members of the Asbestos Workers Union is in these continuously dusty operations. Even if average exposures here were 50 f/ml and the men wore no respirators, their overall average exposure would be increased only to 7 f/ml when working with asbestos.

Insulators Still Exposed to Asbestos

While much of new insulation material contains no asbestos, pipe-coverers may still be exposed to high asbestos concentrations during removal and demolition. In such work, safe procedures and personal protective equipment must be used. Thus, obtaining an effective and safe Asbestos Standard remains of paramount importance.

Thus, dust concentrations measured under these conditions have relevance for the estimate of levels of past years.

Considering the possible doubling of asbestos content of insulation materials and considering that workers may have used asbestos materials more often in the past than now, the data from these three studies would suggest that the upper limit on insulator's exposures in the United States during past years would be about 10 f/ml.

British Data

At the Devonport Naval Dockyard in Plymouth, England, extensive measurements of asbestos dust concentrations during the application and removal of insulation aboard ship have been reported by Harries.[10] These are listed in Table 4. During the application of insulation material, fiber concentrations from 2.1 to 22.4 f/ml were found, not unlike those found in U.S. studies.

However, during the removal of pipe and machinery insulation, mean dust concentration in various compartments ranged from 88 to 257 f/ml, and in the removal of sprayed crocidolite asbestos, fiber concentrations ranged from 20 to 500 f/ml, with short-term breathing zone samples showing concentrations exceeding 1000 f/ml. Moreover, the spread of asbestos from the site of removal can be extensive. Concentrations of 30 f/ml were found at hatchway openings to decks from the area of crocidolite stripping.

High Dust During Ripout

Additionally, short-term fiber concentrations measured during the variety of specific application and removal techniques are reported. High levels, exceeding 200 f/ml, occurred while mixing asbestos cement. The cleaning of debris (155 f/ml) and the sawing (55 f/ml), fitting (43 f/ml), or removing (52 f/ml) of calcium silicate sections also produced high dust concentrations.

A subsequent publication by Harries[11] of long-term area sampling in var-

Adequacy of Standard Questioned

ious circumstances indicated a mean concentration of 226 f/ml during the removal of spray; of 152 f/ml during the removal of pipe insulation; and of 8.9 f/ml during the application of pipe lagging.

As with the Mount Sinai research and the Balzer-Cooper study, short-term dust concentrations during specific insulation practices can be extremely high, while samples taken over long periods of time yield concentrations that are relatively low when compared with current and past asbestos standards.

Summary

Studies on asbestos concentrations from 1965 through 1971 by five different research groups in two countries are summarized in Table 5, along with estimates made of earlier insulation asbestos exposures. They indicate that recent average exposures of insulation workers to asbestos are from 3 to 9 f/ml when working with asbestos.

As asbestos workers in the United States in the period these measurements were taken used asbestos materials in their work less than 50% of the time, their eight-hour average exposure to asbestos was less than 3 f/ml. It is noteworthy that these exposures existed prior to the implementation of the current 5 f/ml standards in the U.S. As extensive substitution of non-asbestos materials has subsequently taken place in insulation work, current exposures are now considerably lower.

The estimate of from 10 to 15 f/ml obtained for past exposures in non-marine insulations work does not offer much confidence that 5 f/ml, or even 2 f/ml, is sufficient to protect asbestos workmen. Forty percent of insulators' deaths can be attributed to their past occupational exposure to asbestos at such levels. A standard set at two, or even five times lower, is unlikely to offer significant protection to asbestos workmen.

Asbestos Workers Have High Peak but Low Average Asbestos Exposures

The high peak exposures of asbestos workers measured by different groups can be deceptive. These often are of short term and may involve few men. Average exposures have universally been found to be low, usually less than current standards. This result leads to two conclusions: 1) Current standards may be inadequate to protect workers, and 2) Easily accomplished control of peak exposures can significantly reduce the long-term average exposures.

TABLE IV

Asbestos dust concentrations during the fabrication, application and removal of insulation materials

Location	General Atmosphere			Breathing Zone		
	No. of samples	Mean fibers/cm³	Range	No. of samples	Mean fibers/cm³	Range
Application of pipe and machinery insulation:						
Boiler rooms	17	22.4	1-61	14	16.8	0 1-68
Engine rooms	28	2.1	0.1-14	16	7.3	0 04-40
Accumulator room	5	16.5	2.5-46	17	9.6	1 -47
Mattress fabrication:						
Old shop	12	12.7	0-126	15	1 5	0- 7
New shop	11	16.3	2-83	25	3.7	0-17
Removal of pipe and machinery insulation:						
Boiler room	153	171	0.04-1062	20	97	25-220
Engine room	45	88	0.16-3021	25	91	2-490
Brick stowage space	13	257	9-592	—	—	—
Removal of asbestos acoustic panels:	6	413.5	30-684	6	131	48-271

TABLE V

Summary of average asbestos air concentrations during insulation work

Research Group	Average Fiber Concentration: Light and Heavy Construction	Marine Work
Mount Sinai (IIHRP)	6.3	
Balzer-Cooper	2.7	6.6
Murphy, Harvard		8.0*
Burgess-Lynch		2 9
Harries		8.8
Estimates of early exposures		
Fleischer		15-20
Mount Sinai	10-15	

These concentrations were those measured or estimated for workers while using asbestos. Eight hour average exposures, considering the use of other materials, would be as little as half the above values.

* Fiber count includes all visible fibers.

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