Asbestos Exposure, Smoking, and Neoplasia

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Asbestos insulation workers, as a group, have a high risk of dying of bronchogenic carcinoma (about seven or eight times expected). We have observed 370 such workmen from Jan 1, 1963 to April 30, 1967. Our findings indicate that asbestos exposure alone is not the entire explanation. Of 87 noncigarette smokers, none died of bronchogenic carcinoma. Of 283 workmen with a history of regular cigarette smoking, 24 died of bronchogenic carcinoma, although only three were expected to die of this disease. Calculations suggest that asbestos workers who smoke have about 92 times the risk of dying of bronchogenic carcinoma as men who neither work with asbestos nor smoke cigarettes. We conclude that asbestos exposure should be minimized, that asbestos workers who do not smoke should never start, and that those now smoking should stop immediately.

In 1964, we reported on deaths occurring between Jan 1, 1943, and Dec 31, 1962, among 632 members of the International Association of Heat and Frost Insulators and Asbestos Workers.[1] All of these men had been occupationally exposed to asbestos dust for many years. Their death rate from lung cancer was found to be 6.8 times as high as that reported for the general white male population of the United States during the same years, with age taken into consideration. Three of the men died of diffuse pleural mesothelioma and one died of a neoplasm histologically suggestive of peritoneal mesothelioma. This was of interest since mesothelioma is a very rare disease in the general population but is reported to be associated with exposure to asbestos dust.[2] In addition, their death rate from cancer of the stomach, colon, and rectum was higher than expected; but this may have been due to chance, the number of such deaths being small. During the latter part of the study, we obtained information on the smoking habits of most of the survivors, but we could not obtain reliable information on the smoking habits of those who had died at an earlier date. Therefore, we could not at that time investigate death rates in relation to smoking habits and exposure to asbestos dust which were considered both separately and jointly.

There is abundant evidence that cigarette smoking leads to a high rate of death from lung cancer in the absence of occupational exposure to asbestos dust.[3-7] Our findings outlined above suggested (but did not prove) that exposure to asbestos dust may lead to a high rate of death from lung cancer in the absence of cigarette smoking. If the latter be so, then the combined effect of both types of exposure might or might not be equal to or greater than the sum of the two effects. On the other hand, it was possible that exposure to asbestos dust increases the risk of lung cancer among cigarette smokers but does not lead to lung cancer among nonsmokers.

The present study was undertaken primarily to investigate these possibilities. In addition, we wished to obtain more information on the occurrence of mesothelioma and gastrointestinal cancer among asbestos workers.

Material

From records of New York Local 12 and Newark, NJ, Local 32 of the International Association of Heat and Frost Insulators and Asbestos Workers, a list was made of every man who was a member of either one of these locals on Dec 31, 1942, or who joined between that date and Dec 31, 1962. No one was omitted regardless of his subsequent work history.

Personnel data from union records indicated that of the 632 on the union rolls on Jan 1, 1943, 339 of the men had first been occupationally exposed to asbestos dust prior to 1922, and an additional

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293 men had first been exposed between the beginning of 1923 and the end of 1942. All of these men were successfully traced through Dec 31, 1962, and 262 of them were found to have died up to that time. Of the 262 deaths, seven occurred prior to the 20th anniversary of the man's first exposure to asbestos dust and 255 occurred after the 20th anniversary. Thus, of the 632 men, 370 were still living on Jan 1, 1963.

These 370 men were the subjects of the present investigation. Table 1 shows their age distribution as of Jan 1, 1963, and the lapsed time from first exposure up to that date. All of them have been traced, and 94 of them were found to have died during the four-year and four-month interval from Jan 1, 1963, to April 30, 1967.

Table 1.—Subjects Classified by Age as of Jan 1, 1963, and by Years From First Occupational Exposure to Asbestos Dust up to Jan 1, 1963

Age, Yr	Total No. of Subjects	No. of Years Since First Exposure to Asbestos							No. of Deaths, 52 Mo
		20-24	25-29	30-34	35-39	40-44	45-49	50+	
35-39	2	2	...	...	...	...	...	...	...
40-44	13	12	1	...	...	...	...	...	1
45-49	32	17	2	13	...	...	...	...	2
50-54	109	...	1	80	28	...	...	...	18
55-59	60	...	1	16	34	8	1	...	11
60-64	42	...	1	3	11	19	8	...	16
65-69	49	...	...	1	10	18	18	2	17
70-74	38	...	...	...	3	12	6	17	18
75-79	21	...	...	...	...	1	5	15	8
80-84	4	...	...	...	...	1	1	2	3
Total	370	31	6	113	86	59	39	36	94

Table 2.—Subjects Classified by Age and by Smoking Habits on or about Jan 1, 1963

Age, Yr	Total No.	Never Smoked Regularly	Pipe, Cigar Only	Ex-cigarette Smokers*	Current Cigarette Smokers*			
					1-9 a Day	10-19 a Day	20-39 a Day	40+ a Day
35-39	2	1	...	1	...	...	...	...
40-44	13	2	...	2	...	...	5	4
45-49	32	2	1	5	...	...	12	12
50-54	109	12	6	26	3	5	33	24
55-59	60	6	5	16	...	3	20	10
60-64	42	7	4	15	1	...	11	4
65-69	49	6	8	17	...	4	9	5
70-74	38	7	7	12	1	4	4	3
75-79	21	3	7	6	...	1	3	1
80-84	4	2	1	1	...	...	...	...
Total	370	48	39	101	5	17	97	63

*Includes cigarette smokers who also smoked pipes or cigars.

Beginning in October 1962, we made arrangements to examine these men periodically, once every six to twelve months; the interval depended upon age and physical condition. The examinations include chest x-ray films as well as physical examination and cover past and present smoking habits, occupational history, medical history, and current physical complaints. Altogether, we have examined 338 (91.4±) of the men at least once and have repeatedly examined most of those who are still living.

Information on smoking habits was obtained by personal interview with the 338 men who were examined. Of the 32 men who were not examined, six told us their smoking habits by telephone and five gave us the information by mail. The local union secretaries (who personally knew these men well) ascertained the smoking habits of 18 men, and family members supplied the information on the remaining three men. This accounts for all of the 370 men. Table 2 shows their smoking habits on or about Jan 1, 1963, the men being classified by their ages on that date, even though some changed their smoking habits between 1963 and 1967.

Of the 370 men, 48 never smoked regularly, 39 smoked or had smoked pipes or cigars but never smoked cigarettes regularly, and 283 had smoked cigarettes regularly. Some of those with history of cigarette smoking also smoked pipes or cigars. Of the 283 with a history of regular cigarette smoking, 101 were excigarette smokers, five currently smoked one to nine cigarettes a day, 17 smoked 10 to 19 cigarettes a day, 97 smoked 20 to 39 cigarettes a day, and 63 smoked 40 or more cigarettes a day.

The smoking habits of the 370 subjects were compared with the smoking habits of a large number of men selected from the general population.[7] There were proportionally more cigarette smokers among the 370 subjects than were found in the general population sample; age was taken into consideration.

Causes of Death.—A copy of the death certificate was obtained for each of the 94 deaths. In addition, we examined hospital records, postmortem findings (41 cases), as well as the surgical and pathologic reports when surgery was performed (39 cases). We also reexamined histologic specimens. It was found that the death certificate was inaccurate in 14 instances. However, this did not alter the picture as much as might have been expected since there were several compensating errors. For example, in one instance the death certificate indicated bronchogenic carcinoma as the cause of death while a review of the histologic specimen showed that death was due to pleural mesothelioma; but in another instance exactly the reverse was found. Likewise, review in one instance resulted in changing the reported cause of death from bronchogenic carcinoma to cancer of the stomach with metastasis to the lungs while review in another instance resulted in exactly the oposite change. The 94 deaths were ascribed to the following causes: bronchogenic carcinoma, 24; pleural

Table 3.—Observed and Expected Number of Deaths Among 370 Asbestos Workers During the 52-Month Period

Cause of Death	Observed Deaths	Expected Deaths*
Total, cancer (all sites)	49	8.6
Cancer of lung, pleura, bronchus, and trachea	27	2.3
Bronchogenic carcinoma	24	†
Pleural mesothelioma	3	‡
Peritoneal mesothelioma	7	‡
Cancer of stomach	3	0.6
Cancer of colon and rectum	5	1.2
Cancer of all other sites combined	7	4.5
Asbestosis	15	...
Heart and circulatory disease including stroke	22	28.5
All other causes of death	8	10.4
Total, all causes	94	47.5

* Based upon US mortality data disregarding smoking habits.
† United States data not available, but figure should be only slightly less than 2.3.
‡ United States data not available, but these are rare causes of death in general population.

mesothelioma, three; peritoneal mesothelioma, seven; cancer of the colon, four; cancer of the rectum, one; cancer of the stomach, three; cancer of the pancreas, two; cancer of buccal cavity and pharynx, two; cancer of bladder, one; cancer of undetermined primary site, two; asbestosis, 15; cor pulmonale, one; cornary heart disease, 17; congestive heart failure, one; cerebral vascular lesion, two; aortic aneurysm, one; cirrhosis of the liver, three; bronchopneumonia, one; encephalopathy, one; acute pancreatitis, one; Wegener's granulomatosis, one; and accidental fall, one.

Expected Deaths.—For purposes of comparison, we wished to ascertain how many of the 370 subjects would have died during the 52-month period (Jan 1, 1963, to April 30, 1967) if their age-specific death rates had been exactly the same as for the general white male population of the United States. For this purpose, we made use of the United States 1964 life table for white males; this provided the most stable basis for comparison. It should be noted that for white males total death rates and death rates from respiratory cancer were slightly higher in the industrial states of New York and New Jersey than in the United States as a whole.[3] On the other hand, respiratory cancer death rates in white men aged 20 to 64 are reported to be a trifle lower than average among laborers, not elsewhere classified employed in construction work.[4]

From the life table we determined for each of the 370 men the probability of his dying within a period of 52 months, considering his age on Jan 1, 1963, and assuming that the life table probability applied to him. Summing these probabilities for the 370 men yielded an estimate of the "expected" number of deaths under the null hypothesis that the age-specific death rates of these asbestos workers are the same as for United States white males in general. The computation indicated that 47.5 deaths would have been expected.

Next, we wished to estimate the expected number of deaths from each of several causes. For this, we made use of the percentage distribution of deaths by cause of death among United States white males of various ages during the year 1964 as reported by the National Center for Health Statistics. These percentages were then standardized for age according to the age distribution at time of the 47.5 expected deaths. The results are shown in Table 3.

Expected vs Observed Deaths.—As shown in Table 3, there were 94 observed deaths (ie, 94 of the 370 asbestos workers died) as compared with 47.5 deaths expected on the basis of the age-specific death rates of all white males in the United States in 1964. Thus, there were 94 minus 47.5 = 46.5 excess deaths. The excess deaths were due to bronchogenic carcinoma, mesothelioma of the pleura and peritoneum, asbestosis, and cancer of the stomach, colon, and rectum.

Cancer of Lung, Pleura, and Trachea.—In published mortality data for the United States showing deaths each year from various causes by age, sex, and race, the following diseases are combined: cancer of the lung (including sarcoma of the lung), cancer of the bronchus, cancer of the pleura, and cancer of the trachea. For this group of diseases, there were 27 observed deaths and only 2.3 expected deaths, a ratio of nearly 12 to 1.

It is well known that, for the United States as a whole, all except a very few of the deaths reported in the combined category are due to bronchogenic carcinoma. Thus, it may be assumed that there were close to 2.3 expected deaths from this cause as compared with 24 observed deaths, a ratio of over 10 to 1.

Mesothelioma.—Ten of the 94 observed deaths were due to mesothelioma, three were due to pleural mesothelioma, and seven were due to peritoneal mesotheliomas. This is such a rare disease that if the 370 subjects had been selected as a random sample from the general population, one would not have expected any of them to die of mesothelioma within a period of 52 months.

All three of the men who died of pleural mesothelioma had a history of regular cigarette smoking. Of the seven who died of peritoneal mesothelioma, one never smoked regularly, one smoked only pipes and cigars, and five had a history of regular cigarette smoking.

Cancer of Stomach, Colon, and Rectum.—In our earlier study of asbestos workers,[1] there were more deaths than expected from cancer of the stomach, colon, and rectum (9.4 expected, 29 observed). As compared with a total of 1.8 expected deaths from these causes, there were eight observed deaths in this study, due to cancer of the following sites: stomach, three; colon, four; and rectum, one. Although this bears out our earlier findings, the number of deaths from these causes was so small that we still refrain from drawing any conclusion at this time.

Asbestosis.—Asbestosis accounted for 15 of the 94 deaths. While it is not surprising that deaths from this disease occur among men exposed to asbestos dust, attention must be called to the fact

that these subjects were primarily insulation workers. While all of them were occupationally exposed to asbestos dust, their degree of exposure was light as compared with the degree of exposure of asbestos miners, processors, and weavers in earlier times.

Bronchogenic Carcinoma.—Bronchogenic carcinoma accounted for 24 deaths while only about 2.3 were expected on the basis of general United States mortality data for white males. However, as previously mentioned, evidence at hand suggests that there were proportionally somewhat more cigarette smokers among the 370 subjects than among white males in the United States as a whole, age being taken into consideration. This might have partially accounted for the high bronchogenic carcinoma death rate of the subjects. For this and other reasons we made estimates of the expected number of bronchogenic carcinoma deaths, the smoking habits of the men being taken into consideration. This was done as follows:

Table 4.—Estimated Number of Lung Cancer Deaths Expected to Occur During a Period of 52 Months per 10,000 Men Living at the Start of Period: by Age and by Smoking Habits*

Age, Yr (Jan 1, 1963)	Never Smoked Regularly	Pipe, Cigar Only	Excigarette Smokers‡	Current Cigarette Smokers‡			
				1-9 a Day	10-19 a Day	20-39 a Day	40+ a Day
35-39	0	...†	5	...	...	...	...
40-44	2	...	7§	...	...	15	15
45-49	2	2	10	...	...	39	46
50-54	7	12	22	28	44	69	90
55-59	6	15	53	...	91	117	185
60-64	16	31	71	80	...	190	256
65-69	14	32	97	...	157	305	350§
70-74	12	52	100	103	206	288	450§
75-79	28	53	100	...	185	341	329
80-84	25	32	148	...	...	...	...

Based upon data from a prospective study with adjustment for US mortality experience.
†Ellipses indicate rates omitted for categories with no subjects in this study. See Table 2.
‡Includes cigarette smokers who also smoked pipe or cigar. Men with a history of only cigarette smoking have higher lung cancer rates than shown here.
§Rates obtained by smoothing the data.

Data are available on lung cancer deaths in relation to the smoking habits of 440,000 men enrolled by American Cancer Society volunteers in a prospective epidemiological study between October 1959 and March 1960 and traced through Sept 30, 1964. Causes of death were ascertained from death certificates, but whenever cancer was mentioned on a death certificate inquiry was made of the physician who signed the certificate. In case of disagreement between the two sources of information, the physician's statement was accepted. For the purpose at hand, we only made use of data covering the 52-month period beginning on June 1, 1960, and ending on Sept 30, 1964. The number of lung cancer deaths occurring during the 52-month period was divided by the number of men alive at the beginning of the period. This was done by five-year age groups for men in each of the following smoking categories: (1) never smoked regularly (nonsmokers and occasional smokers being combined); (2) history of regular pipe or cigar smoking, past or present, but never smoked cigarettes regularly; (3) excigarette smokers (including those who had smoked or currently smoked pipes or cigars); and (4) current regular cigarette smokers (including those who also had smoked or currently smoked pipes or cigars). The last of these categories was further divided by current number of cigarettes smoked per day: (4a) one to nine cigarettes a day; (4b) 10 to 19 cigarettes a day; (4c) 20 to 39 cigarettes a day; and (4d) 40 or more cigarettes a day. Since the men were divided into seven groups by smoking habits and further subdivided into many five-year age groups, some of the subgroups contained only a small number of men. In consequence, the lung cancer death rate was statistically unstable in some of the very small subgroups. In three instances where the observed rate in a small subgroup appeared to be badly out of line, we arbitrarily made an adjustment to bring it more into line with adjacent figures in the table. These adjusted figures which are indicated with symbols in Table 4 carry very little weight in the final calculation. All of the rates were then adjusted as follows:

Lung cancer death rates in the United States have risen steadily year by year and were higher in 1964 than during the period 1960 to 1964 as a whole. Furthermore, in the study described above, we avoided enrolling seriously ill people and, as of the cut-off date for preparing the computer tape, we had not yet received death certificates for all of the men now known to have died during the specified period of time. For these reasons, lung cancer death rates in the study population were appreciably lower than those reported for white males in the United States in 1964. To compensate for this, we raised the rate of each individual smoking category so that the total lung cancer death rate (disregarding smoking habits) in each five-year age group would be the same as that of all United States white males (based upon the 1964 life table and the 1964 distribution of deaths by causes of death). The results of these computations are shown in Table 4. (It should be noted that Table 4 shows only such rates as were required for further calculations.)

The rates shown in Table 4 were then applied to the number of asbestos workers shown in each of the corresponding internal cells of Table 2. This yielded an estimate of the number of lung cancer deaths expected to occur during a 52-month period among the 370 asbestos workers classified by their smoking habits. By "expected" number, we here mean an estimate of the number of lung cancer deaths which would have occurred under the null hypothesis that asbestos workers do not differ from other men in respect to their lung cancer death rates, both age and smoking habits being taken

Table 5.—Observed and Expected Bronchogenic Carcinoma Deaths by Smoking Habits* for 370 Asbestos Workers

Smoking Habits	Observed Deaths	Expected Deaths
Never smoked regularly	0	0.05
History of pipe, cigar smoking only	0	0.13
History of regular cigarette smoking†	24	2.98
Total	24	3.16

*Based upon data in Table 2 and Table 4.
†Includes cigarette smokers who also smoked pipe or cigar.

Table 6.—Expected and Observed Deaths Among 632 Asbestos Workers Exposed to Asbesto Dust 20 years or Longer

	1943-1962	1963-1967	Total 1943-1967
Total deaths: all causes			
Expected	203.5	47.5	251
Observed	255	94	349
Total cancer: all sites			
Expected	36.5	8.6	45.1
Observed	95	49	144
Cancer of lung, trachea, pleura			
Expected	6.6	2.3	8.9
Observed	45	27	72
Cancer of stomach, colon, rectum			
Expected	9.4	1.8	11.2
Observed	29	8	37
Cancer all other sites combined			
Expected	20.5	4.5	25
Observed	21	14	35
Asbestosis			
Expected	0	0	0
Observed	12	15	27
All other causes			
Expected	167	38.9	205.9
Observed	148	30	178

into consideration. The results are summarized in Table 5 which shows the expected and observed number of lung cancer deaths in each of three smoking categories.

Taking smoking habits as well as age into consideration (Table 5) a total of 3.2 bronchogenic carcinoma deaths were expected whereas taking only age into consideration 2.3 deaths were expected from this cause (Table 3). Thus, perhaps one of the excess bronchogenic carcinoma deaths might be attributed to the fact that there appear to have been proportionally somewhat more cigarette smokers among the 370 subjects than among men of the same ages in the general population.

The following statements are based upon the data shown in Table 5. Twenty-four deaths from bronchogenic carcinoma occurred among the 370 subjects compared with only 3.16 expected, a ratio of about 7.6 to 1. This is slightly higher than found in our earlier study which indicated a ratio of 6.8 to 1 (not taking smoking habits into consideration). It should be noted in this connection that the 370 subjects in this study had been exposed to asbestos dust somewhat longer than the subjects of our previous study (the present 370 subjects are survivors as of Jan 1, 1963, of subjects in the previous study).

Of the subjects who never smoked regularly and those who smoked only pipes or cigars, none died of bronchogenic carcinoma whereas 0.18 of these men were expected to die of lung cancer. This suggests that exposure to asbestos dust does not increase the risk of bronchogenic carcinoma among men who never smoked cigarettes regularly. However, considering the small number of such subjects in this study, we only conclude that exposure to asbestos dust does not *greatly* increase the risk of bronchogenic carcinoma among men who never smoked cigarettes regularly.

Twenty-four of the men with a history of regular cigarette smoking died of bronchogenic carcinoma whereas only 2.98 were expected to die of it, a ratio of 8.05 to 1. From this it appears that exposure to asbestos dust greatly increases the risk of lung cancer among cigarette smokers.

Now we may ask how greatly is the risk of bronchogenic carcinoma increased by the combined effects of cigarette smoking and exposure to asbestos dust. To answer this question, we applied rates shown in Table 4 for nonasbestos workers who never smoked regularly to the number of subjects with a history of regular cigarette smoking as shown in Table 2. This indicated that only 0.26 of the subjects with a history of regular cigarette smoking would have been expected to die of bronchogenic carcinoma if they had never smoked regularly and had never been occupationally exposed to asbestos dust. Since 24 of them actually died of this cause, the ratio of observed to expected deaths is 92 to 1 (ie, 24 divided by 0.26=92). This appears to indicate that cigarette smoking plus occupational exposure to asbestos dust increases the risk of bronchogenic carcinoma by a factor in the order of magnitude of 92 to 1. It should be noted that this estimate does not take current amount of cigarette smoking into consideration.

Comparison With Earlier Findings.—As explained, we started with a cohort of 632 asbestos insulation workers, the entire membership of the union locals on Jan 1, 1943. We have now traced each man through April 30, 1967. Table 6 shows the observed and expected number of deaths for each of two periods (the first, 1943 to 1962, being previously reported[1]) and for the entire period. In respect to respiratory cancer (lung, trachea, and pleura) and in respect to cancer of the stomach, colon, and rectum, the findings in the two periods are in close agreement.

Comment

The increased risk of neoplasia (mainly bronchogenic carcinoma and mesothelioma) among insulation workers reported here should be evaluated in the knowledge that these men have comparatively light exposure as asbestos trades go. Primarily employed in construction work, many of the materials they use contain little or no asbestos and others have only 5% to 15%. Conditions of work vary: these men often work outdoors unlike asbestos operators in factory work. Comparatively few dust-exposure surveys have been made in this trade but their results have generally been within the 5 million particles per cubic foot permissible limits currently accepted by the American Conference of Governmental Industrial Hygienists.[9,10] Nor have

additional potentially carcinogenic substances been identified among the other materials used.[10]

Heavier or even lighter exposure may result in different degrees of risk of neoplasia. Heavy factory exposure in the past has in some instances resulted in considerable lung cancer risk.[11] In others, paradoxically, little lung cancer was seen because asbestosis was so common and so severe as to cause death of the exposed workers before they could live long enough to develop lung cancer. Once exposure was reduced by improved industrial hygiene practices, early death from asbestosis sharply diminished and lung cancer became common.[12]

In any case, heavy exposure is not likely to be the most important problem in the future, unless there be sheer carelessness or unconcern. Rather, light exposure, similar to that in insulation work, will be much more common, both in direct asbestos working trades and as the result of indirect occupational exposure, as in the construction and shipbuilding industries.

There is another type of "light exposure" which may affect many more people than those industrially exposed. In the past several years, it has been demonstrated that asbestos bodies can be found in the lungs of 25% to 50% of adults examined at autopsy in large cities, such as Belfast, Northern Ireland, Capetown, Republic of South Africa, Miami, Fla, Pittsburgh, and Montreal. This is presumably due to "asbestos air pollution" by fibers derived from industrial "spillover" (as dust from construction sites or factory wastes) or from end-product use. Such community asbestos air pollution may be important since there is already evidence that in certain circumstances, as living within half mile of an asbestos plant or in the household of an asbestos worker, intimate environmental contamination can be associated with some risk of mesothelioma.[13] What is not now known is whether the minimal amounts inhaled by the general public carry a similar risk.[14]

Nor do we know whether inhalation of the very small amounts of asbestos present in the air of some communities is associated with a special lung cancer risk in cigarette smokers (or, conversely, whether cigarette smoking makes the inhalation of very small amounts of asbestos particularly hazardous). It will be important to ascertain whether such cocarcinogenic or potentiating or precipitating relationships exist because, with the rapid growth of asbestos use (500,000 tons per year world production in 1930 has risen to over 4,000,000 tons per year now), it may be difficult for cigarette smokers to avoid inhaling air contaminated with asbestos.

It may not be easy to unravel the interrelationships which might exist between community asbestos air pollution and cigarette smoking. Both asbestos exposure and cigarette smoking have a long-lapsed period between onset of exposure and occurrence of neoplasia, yet for current smokers these two exposures may not have begun simultaneously; there was much less asbestos used 20 to 40 years ago. Youngsters who start smoking now have a much greater chance of having both exposures simultaneously.

Significance of Findings for Asbestos Workers.—The import of the data reported here seems clear. There is an extraordinary risk of developing and dying from lung cancer for asbestos workers who smoke cigarettes regularly. In the group studied, the combination of asbestos exposure and cigarette smoking increased the risk approximately 90 times compared with men who neither work with asbestos nor smoke!

Of 283 asbestos workers who had a history of cigarette smoking, 78 died within a period of 52 months whereas only 32.4 would have been expected to die within that length of time if their age specific death rates had been the same as for the general white male population of the United States. Of the 78 deaths, 24 (31%) were due to bronchogenic carcinoma. It is estimated that if these men had smoked cigarettes but had not been exposed to asbestos dust, only 2.98 would have died of bronchogenic carcinoma within the same length of time. If they had neither smoked nor been exposed to asbestos dust, only 0.26 would have been expected to die of the disease within a period of 52 months.

Of 87 asbestos workers who never smoked cigarettes regularly, none died of lung cancer within the 52-month period (although three died of asbestosis and one died of peritoneal mesothelioma). This finding, being based upon the experience of only 87 men, does not prove that exposure to asbestos dust has no influence on the risk of lung cancer among nonsmokers. However, it suggests that exposure to asbestos dust does not lead to an extremely high risk of lung cancer among nonsmokers.

The conclusions are evident:

1. Occupational exposure to asbestos dust should be reduced to as low a level as possible; but there may be an irreducible minimum level if asbestos, a very useful material, is to be used at all. Such reduction in exposure will benefit asbestos workers of the future. However, we are also concerned with workers who have already been exposed at significant levels for many years. Asbestos fibers will remain in their tissues for the remainder of their lives.

2. All people incur a great increase in risk of lung cancer if they smoke cigarettes; for asbestos workers the increase in risk is tremendous. Asbestos workers who do not now smoke cigarettes should never begin. Those who do smoke, should stop immediately. We may hope that the decrease in risk which results from cessation of smoking among the general public will be the good fortune of the asbestos workers as well.

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Many, possibly most, of the words in the dictionary stand there as representatives of a whole family of forms. Not even the timidest of the linguistically timid will run to the dictionary for encouragement when, for instance, they want to refer to a spell of "hiccuping," provided they are certain that Webster does know "to hiccup."

All the tense forms, the participles, the gerunds are assumed to be authorized by implication the moment the infinitive is known to exist. The plurals of nouns are similarly taken for granted, and the forms of comparison and the adverbial forms of adjectives.

This phenomenon is generally covered by the assertion that a dictionary is not a grammar and that each individual entry in a dictionary stands simultaneously for all its grammatically possible forms. (For details, consult your grammar.)

But is a gerund a grammatical form? Or is it a suffix-derived noun?

I am not really looking for an answer. I ask those questions to suggest that the dividing line between grammatical form and derived neologism is both hard to define and artificial. If I distinguish—among men—the "hunting" from the "hunted," I have done no more than form (grammatically) two nouns from two adjectives which are forms (grammatically) implied in the existence of "to hunt." But if "hunting" is implied, why not "hunter"? Why not "huntee" and "huntable" and "huntabiiize"?

The question of when a new word is a new word and when it is merely an "implied" form of a conventional term is indeed more complex than is grossly apparent. Take "dehairability" as an example. Can I claim the word is implied in the existence of "hair," or must I assume the responsibility for having spawned a monster?

Or take "unequivocably," which indeed was the starting point of all this reasoning and wondering, for it was spotted as a bold neologism in *JAMA* in the sentence, "Research at the Public Health Service Hospital at Lexington, Ky, has unequivocably proven that methadone has all of the euphoric properties of morphine. . . ."

Now, clearly, the adverb "unequivocably" is grammatically implied in the adjective "unequivocable," and this in turn is implied—grammatically of semi-grammatically or otherwise—in "equivocable." If we grant further that formations in "-able" of "-ible" are likewise legitimate without special dispensation, we shall conclude that "unequivocably" is in no sense a bold departure since "to equivocate" is a firmly established, standard English word.

But there is a hitch and a flaw in the argument. "To equivocate" means "to use ambiguous language" and (by extension) "to render ambiguous." Hence, "equivocable" can only suggest the trait of "being apt or able to be made ambiguous," and that, I fear, was not intended. Which means, by (nongrammatical) implication, that the discrepancy between the obviously intended meaning of "unequivocably" and its structurally supported significance was the cause of the unpleasant jolt experienced by the spotting reader.

PS.—It is of course possible, and even likely, that "unequivocably" was just a typo for "equivocally."

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Carcinogenicity of Amosite Asbestos

Irving J. Selikoff, MD; E. Cuyler Hammond, ScD; and Jacob Churg, MD, New York

Few data exist concerning the comparative neoplastic potential in man of the several kinds of asbestos. In particular, there has been no evidence concerning whether the amosite variety is carcinogenic. The matter is of practical importance, since amosite use in the United States has sharply increased. The mortality experience of a group of 230 men previously employed in an amosite asbestos factory was studied during the years 1960 through 1971. Total deaths were more than twice the number anticipated: 46.4 were expected, and 105 occurred. Some 14 deaths were due to asbestosis. Both lung cancer and mesothelioma were found in considerable excess. Two or three deaths from lung cancer were expected, and 25 occurred. There were five deaths from mesothelioma. Occupational exposure to amosite asbestos can be associated with serious cancer hazard; its continued industrial use requires rigorous control.

Possible differences in the disease potential of the several common, commercially available varieties of asbestos fiber (chrysotile, amosite, crocidolite, anthophyllite) have been sought, since the use of asbestos might be guided accordingly.[1] Experimental studies were undertaken to seek such information. These have not indicated any critical differences; mesothelioma can be produced easily by intrapleural inoculation of various types of asbestos.[2] There is less information concerning experimental lung cancer.[3]

Few data exist concerning the comparative neoplastic potential of the several kinds of asbestos in man. Some information is available for chrysotile,[4] crocidolite,[5] and anthophyllite.[6] However, there has been no evidence to indicate whether or not the amosite variety is also carcinogenic.

In large part this has been the result of epidemiological difficulties. Since there is often admixture of fiber varieties under industrial circumstances, the experiences of employed populations are not always readily attributable to a single fiber variety. Diligent efforts have been made to investigate the occurrence of disease in the Transvaal in South Africa, the only area in which amosite is mined, and where populations exposed only to amosite could be identified. Environmental studies in this area, reported in 1964, showed no instance of mesothelioma in amosite miners and only isolated instances of carcinoma of the bronchus, although asbestosis was found.[7] This survey has since been complemented by a study of miners in the area. No attempt was made to study the Bantu workmen who are in the majority, since labor turnover is very high, and ". . . records kept are such that follow-up of individuals over a period of time is impossible."[8] The fate of white miners employed between 1954 and 1958 was investigated. Unfortunately, the records turned out to be imperfect and incomplete, since the white work force in these mines was unstable. Only 147 white miners could be followed at all, and only 20 of these were observed for more than 20 years after first exposure to asbestos. Among these 20, there was one instance of lung cancer and none of mesothelioma. Elsewhere, comment is made

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that "The position of amosite is not clear . . ." with only one pleural mesothelioma stated to be known in the Transvaal.[9]

Increasing Use of Amosite in the US

Whether or not amosite is carcinogenic is of some practical importance. Because this variety of asbestos has not been reported to cause cancer, there has been a tendency in Great Britian, for example, to substitute it for other kinds of asbestos, especially crocidolite. Moreover, increasing amounts of amosite have been sent to the United States from South Africa. There is no record of amosite being imported before 1930, and as late as 1940, only small amounts were received. Since the Second World War, the situation has changed. Annual imports have risen from less than 500 tons in 1935 to 4,500 in 1945, 18,000 in 1955, and 21,400 tons in 1965 (Table 1).

The US Department of Commerce has reported imports of amosite and crocidolite into the United States (in tons per year) as follows:

	Total Amosite and Crocidolite
1930	1,907
1931	823
1932	212
1933	233
1934	152
1935	501
1936	1,432
1937	2,928
1938	3,282
1939	6,129

These data should be considered with appreciation of the long-lapsed period between onset of asbestos exposure and appearance of asbestos cancer—usually 20 to 30 years or more.[10] Cancers that may be associated with the amosite now being imported will not become clinically evident until the 1990s or after the year 2000.

Current Investigation

We have investigated the mortality experience of a group of workmen occupationally exposed solely to amosite whose employment started between June 1941 and December 1945. This cohort has been observed through June 30, 1971.

Employed Population.—Nine hundred thirty-three men were employed for varying periods of time in an asbestos products factory in an eastern city of the United States, starting work some time between June 1941, when the factory began production, and December 1945. The plant continued production until November 1954, when it closed its doors. It manufactured amosite asbestos insulation, primarily for use in shipbuilding and ship repair.

We have sought to trace each of these men and have successfully done so in 868 instances so far (93%). In 65 instances, tracing is still incomplete. Data concerning date of birth, onset of employment, duration of employment, and type of work are known.

For the purpose of this report, we have investigated the mortality experience of those individuals who had at least one year of employment. There were 333 such men who began work sometime between 1941 and 1945: 88 died by Dec 31, 1959; 15 were lost to follow-up; and 230 were alive on Jan 1, 1960, and each of these men has been followed since. Table 2 provides an analysis of man-years of experience for these 230 men, by age category.

We have calculated expected death rates for these men in the Jan 1, 1960 through June 30, 1971 category, using age, year, and sex specific rates for US white men. Expected deaths were then compared with those observed.

Amosite Exposure.—No information is available concerning dust levels in this plant. Although exhaust ventilation was used, discussions with surviving workmen and plant management indicate that dust exposure, at least in some circumstances, could have been high. Respirators were issued to the work force but were inconsistently used.

We have ascertained that only amosite asbestos was used in this factory in several ways:

1. Review with plant management indicated that only this fiber variety was purchased and utilized. This is consistent with the ship insulation specifications under which the products were made.

2. We have obtained samples of the products made; examination of these samples by polarized light microscopy, electron microscopy, electron diffraction, and electron microprobe analysis showed only amosite to be present.

3. Asbestos was still present in the factory building's storeroom. When retrieved and examined, the material was found to be amosite, by employment of the same analytical methods.

4. Several workmen had kept their own respirators, dating back to their period of employment. The filters in these respirators were studied. Fibers retained on the filters were

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Table 1.—Estimated US Asbestos Fiber Consumption (Tons)

Year	Crocidolite	Amosite	Canadian Chrysolite	Other	Total
1920	No data	No data	152,000	4,000	156,000
1925	No data	No data	200,700	4,100	204,800
1930	1,907*		198,200	8,500	208,407
1935	501*		154,200	20,500	175,201
1940	8,068*		225,900	36,300	270,268
1945	8,700	4,500	355,800	9,000	378,000
1950	8,500	5,400	687,400	27,400	728,700
1955	11,700	18,000	699,100	11,600	740,400
1960	19,600	19,500	605,800	24,600	669,580
1965	17,100	21,400	661,100	20,100	719,700

* Amosite and crocidolite combined; not separately recorded.

Table 2.—Man-Years of Experience Among 230 Amosite Factory Workers (1/1/60—6/30/71)

Age	Jan 1, 1960 Through Dec 31, 1964	Jan 1, 1965 Through June 30, 1971
Under 40	471.7	54.8
40-44	528.8	438.3
45-49	501.9	619.5
50-54	415.2	565.2
55-59	347.3	472.2
60-64	285.2	352.4
65-69	198.4	272.9
70-74	204.0	163.9
75-79	89.7	134.1
80-84	38.0	47.0
85+	8.0	25.0
Total	3088.2	3145.3

Table 3.—Causes of Death Among 230 Amosite Asbestos Factory Workers (1/1/60—6/30/71)*

Cause of Death	Observed Deaths	Expected Deaths†
Total cancer, all sites	43	3.5
Cancer of lung, pleura, bronchus, trachea	27	2.4
Lung cancer	25	‡
Pleural mesothelioma	2	§
Peritoneal mesothelioma	3	§
Cancer of stomach, colon, rectum	5	1.6
Cancer of all other sites	8	4.5
Asbestosis	14	§
All other causes	48	37.9
Total deaths	105	46.4

* Analysis of lifetime work experience indicates that, for large majority, this was only occupational asbestos exposure.
† Expected deaths 1960-1964 are based on US age-specific rates for white men in 1962. For 1965-1971, rates for 1968 were utilized. Smoking habits are disregarded.
‡ US data not available, but figure should be only slightly less than 2.4.
§ US data not available but these are rare causes of death in general population.

removed and analyzed. They were invariably amosite.

5. We have extracted mineral fibers from the lungs of individuals in this cohort who had died. Large numbers of fibers were present. Electron diffraction and electron microprobe analysis showed them to be amosite,[11] except for the occasional chrysotile fibril expected to be present in the lungs of urban dwellers in this area.[12]

Results

The mortality experience of this group of workmen, 1960 through 1971, demonstrates that a serious health hazard was associated with this industrial use of amosite. Table 3 records expected and observed deaths.

Total deaths were more than twice the number anticipated: 46.4 were expected and 105 occurred. This excess death rate was limited to two categories: cancers of various sites and asbestosis.

Fourteen deaths were due to asbestosis, when virtually none was expected. That amosite can result in asbestosis has been previously recognized.[7] In physiological studies of a select group of workmen at this particular factory from 1954, serious pulmonary insufficiency had been demonstrated.[13]

Both lung cancer and mesothelioma were also found in considerable excess. It was anticipated that 2.4 deaths from lung cancer would eventuate; 25 occurred. The calculation of expected rates disregarded smoking habits, since the smoking habits of individuals not examined by us are not accurately known. In prospective studies from this point on, smoking habits will be taken into account.[14]

Mesothelioma caused five deaths: two pleural and three peritoneal. Each has been histologically verified in material obtained during operations in two instances and at autopsies in three. In one case, there had been prior chrysotile exposure; in four, only amosite asbestos exposure had occurred. Parenthetically, additional instances of mesothelioma have occurred among men working in this plant, other than in the cohort reported here.

It may be of interest that more deaths from cancer of the stomach, colon, and rectum have occurred than expected. The increase is only threefold, however. As with similar previous experiences, further observations are required before this association can be regarded as clearly established.[15]

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Field investigations were carried out by Dorothy Perron, Shirley Levine, Rayla Margolies, and Charles V. Nolan.

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