

Radiographic and Physiologic Patterns Among Workers Engaged in Manufacture of Asbestos Cement Products

A Preliminary Report

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Although two-thirds of all asbestos fiber imported into this country is used in the manufacture of asbestos cement products, little information is available concerning health effects associated with asbestos exposure in this industry. Asbestos cement products which contain asbestos fiber, free silica and cement include shingle, pipe, roofing and siding. Although chrysotile is the primary type of fiber utilized in this industry, several products contain small amounts of crocidolite because of its strength and resistance to acid corrosion.

Methods

An investigation of health effects associated with dust exposure in this industry was begun in November, 1969, with a study of currently employed and retired workers of two plants in the New Orleans Area. Over 95% of actively employed workers participated. Although shortly after the study began, a major work reduction occurred at one plant, 70% of the 184 employees laid off prior to their participation in this study were recruited. Of the retired workers residing in the New Orleans vicinity, 50% could be contacted and were able and willing to participate. A total of 908 workers

were studied, 871 men and 37 women. Their mean age was 36 years and they had been in the industry up to 40 years, the mean period of exposure being 17.3 years.

Workers were given time off by the companies and spent one-half day in the laboratory where a respiratory and occupational questionnaire was administered by a trained interviewer. PA and both oblique chest x-ray films were obtained and a brief physical examination performed. Studies of pulmonary function included spirometry to determine maximum expiratory flow rates, total lung volume and its compartments using helium equilibration, gas transfer utilizing the single breath carbon monoxide pulmonary diffusing capacity, and gas exchange during light and moderate levels of exercise, with determination of total ventilation and ventilatory equivalent for oxygen. Complete plant records were made available and each worker's job history was abstracted. Exposure assessments were based on dust measurements provided by company industrial hygienists, the State Health Department, and the U.S. Public Health Service. An estimate was made of dust level in million particles per cubic foot at each job site for each year. Improvements in dust suppression were reflected in decreased estimates. The constitution of the dust in terms of chrysotile, crocidolite and silica contents was also assessed. For each man, five exposure indices were calculated from his detailed industrial history. These were total time employed, total dust exposure, the total of all exposure levels multiplied

by the corresponding periods of exposure; total chrysotile exposure calculated as for total dust but chrysotile proportion only; crocidolite; and total silica exposure.

Chest x-ray films were read using new UICC Cincinnati Internal Classification for the Pneumoco. These films have been read by or expert member of the committee developed the classification. Fil 69 nonindustrially exposed individuals matched as closely as possible to and age were interspersed among films of exposed workers. These were not identifiable as controls reader.

Working Environment

Because of the importance of working environment to biological response, the manufacture of a cement products will be described briefly. Bags of asbestos fiber in compressed form are delivered by car and stored in the plant. Although improvements in packaging have been made, bags occasionally tear with subsequent dust emission. The bags of asbestos are opened, the block broken up and, finally, the compartment charged with the material. The fibers are "opened" by means of a blower and cyclone and, in the process, fibers are then discharged by a beater and mixed into the cement. Silica enters a dry mix by way of a shaker and reground scrap is stored. It also enters the new mix after being dumped by wheelbarrow or hopper after which it enters the

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and is blended into the slurr. The slurr is molded and solid particles collected on a screen, which is then transferred to a felt where the stock accumulates on a roller. After a series of transfers, a wet sheet is formed. Cutting of the wet sheet into appropriate sizes is not associated with significant dust production. The dust-sized sheets are then cured for a week and, after the sheet is considerably drier, it enters the punch press for more precise sizing and introduction of nail holes into the shingle. Energy applied to this relatively dry product during the operation is associated with dust. Cutting of corrugated sheeting also results in the dust production. Final curing is performed in large autoclaves. Important dust exposures occur either early in the process where the fiber is unpacked, the conveyor loaded and fiber discharged into the beater, and later when the dry product is sawed or punched for sizing to commercial specifications.

Results

With this mixed dust exposure to asbestos and silica, radiographic patterns have included small rounded as well as irregular or linear opacities. The new radiographic classification separates the type of small opacity into rounded or irregular and is, therefore, suitable to characterize patterns encountered in this industry. Profusion of these small opacities is graded by 12 categories ranging from 0- to 3+.

Preliminary analysis of the type and profusion of diffuse opacities in relation to dust exposure reveals that higher cumulative exposures are associated with higher rates of both types of opacities in this industry. For small rounded opacities, definite radiographic changes, of 2.1 category or above, begin to appear after cumulative exposure of 1,000 million particles per cubic foot-months (Fig 1). There is an increase in rates of abnormal radiographic patterns as this exposure rises. Except for two individuals in low dust exposure categories read as having category 2 irregular opacities, a similar pattern is seen for this type of radiographic change (Fig 2). One of these workers had bilateral basilar pneumonia with appropriate symptoms and there might be differences of opinion regarding the profusion classification in the other, however, they were left in the profusion category designated on the first reading. Finally, when rounded and irregular

PROFUSION	Total Dust Exposure (MILLION PARTICLES PER CUBIC FOOT - MONTHS)					
	≤ 250	251-500	501-1000	1001-2000	2001-4000	4001 +
% and %	98	94	97	93	88	77
%	2	5	1	4	4	9
1/2, 1/2 and 1/2	0	1	2	1	4	8
2/1 +	0	0	0	2	4	6

(161) (67) (105) (122) (209) (231)

Fig 1. — Rates (%) of small rounded opacities for total dust categories.

small opacities are combined, the prevalence of any diffuse parenchymal change can be related to total exposure (Fig 3).

Since these changes result from both asbestos and silica exposure, an attempt

was made to determine if predominant type of exposure influences radiographic pattern. A clear association between expected silica exposure and rounded opacities or irregular opacities and asbestos exposure was not seen (Fig 4).

PROFUSION	Total Dust Exposure (MILLION PARTICLES PER CUBIC FOOT - MONTHS)					
	≤ 250	251-500	501-1000	1001-2000	2001-4000	4001 +
% and %	97	97	96	89	82	82
%	2	2	3	7	11	9
1/2, 1/2 and 1/2	0	0	1	2	2	5
2/1 +	1	1	0	2	5	4

(161) (67) (105) (122) (209) (231)

Fig 2. — Rates (%) of small irregular opacities for total dust categories.

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perhaps because the range of exposures to these two materials was limited in these plants. Increasing protrusion of rounded opacities was associated with increasing total dust, silica and asbestos exposure, this pattern being better related to dust exposure than were irregular opacities. Although it is difficult in any study of this type to separate clearly years of exposure from total dust exposure, it can be seen that the presence of diffuse changes on the chest x-ray correlated better with total exposure than simply with years in the industry. Analyses to date have not considered size of either type of opacity. Readings of the 69 control x-rays included 66 with a 0.0 category and three with a 0.1 category.

Anticipating that those individuals with small rounded opacities might have different pulmonary function patterns than those with irregular opacities, mean values for lung volumes, gas transfer and expiratory flow rates are expressed in percent of predicted where indicated and compared in groups with irregular opacities, rounded opacities, and negative chest films. Although emphasis will be placed on groups exhibiting "definite" or category 2 changes mean values in category 1 protrusion are also plotted. In the category 2 groups, total lung capacity and vital capacity differ significantly from the 0 group; mean values for both these volumes are considerably lower in the group with irregular opacities than in the group with rounded change (Fig 5). Residual volume was significantly higher in the rounded group than in the irregular group with residual volume to total lung capacity ratio differing in the same direction but not reaching statistical significance. The category 2 rounded opacity group had a mean RV/TLC which differed significantly from the 0 group. Pulmonary diffusing capacity in both groups with category 2 opacities was significantly lower than in the group with no radiographic changes (Fig 6) and mean D_L was considerably lower in the irregular group than in the rounded. This difference was not statistically significant. Alveolar volume was lower in those with irregular opacities while diffusion constant (K) was lower in the rounded group. In neither case was this difference between groups statistically significant. K in the rounded group, and alveolar volume in the irregular group,

MAXIMUM PROTRUSION	Total Dust Exposure (MILLION PARTICLES PER CUBIC FOOT - MONTHS)					
	≤ 250	251-500	501-1000	1001-2000	2001-4000	4001
% and %	95	93	94	81	70	60
%	4	6	4	11	16	17
% 1/4 and 1/2	0	0	2	3	6	13
3/4 +	1	1	0	5	8	10
	(161)	(67)	(105)	(122)	(209)	(231)

Fig 3. — Rates (%) of rounded or irregular small opacities for total dust categories.

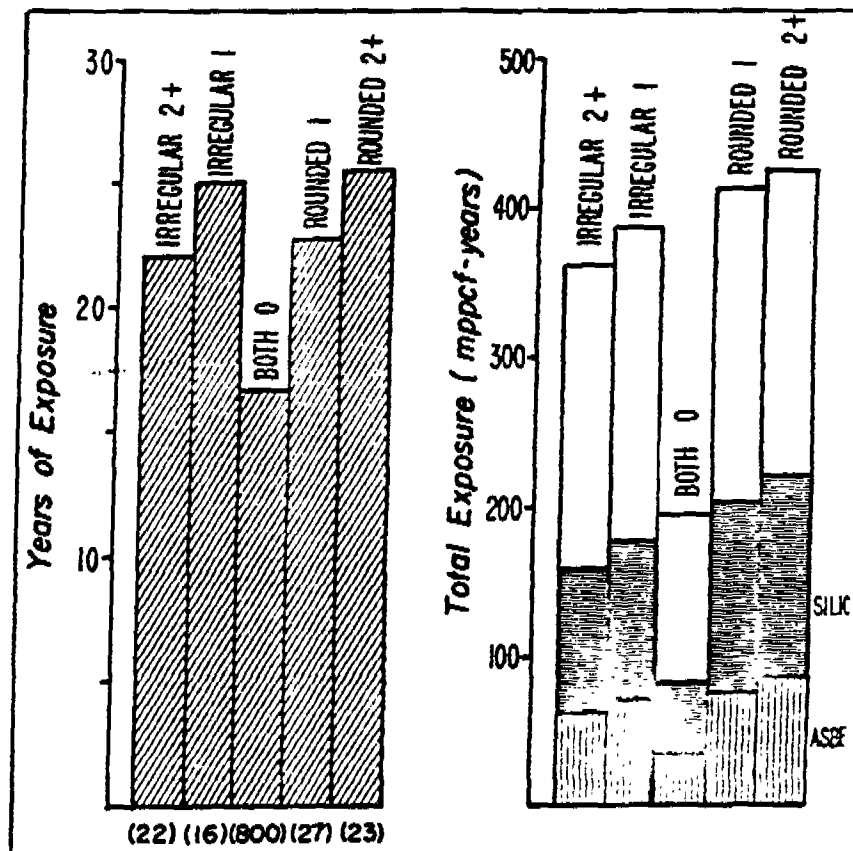


Fig 4. — Radiographic changes and exposure.

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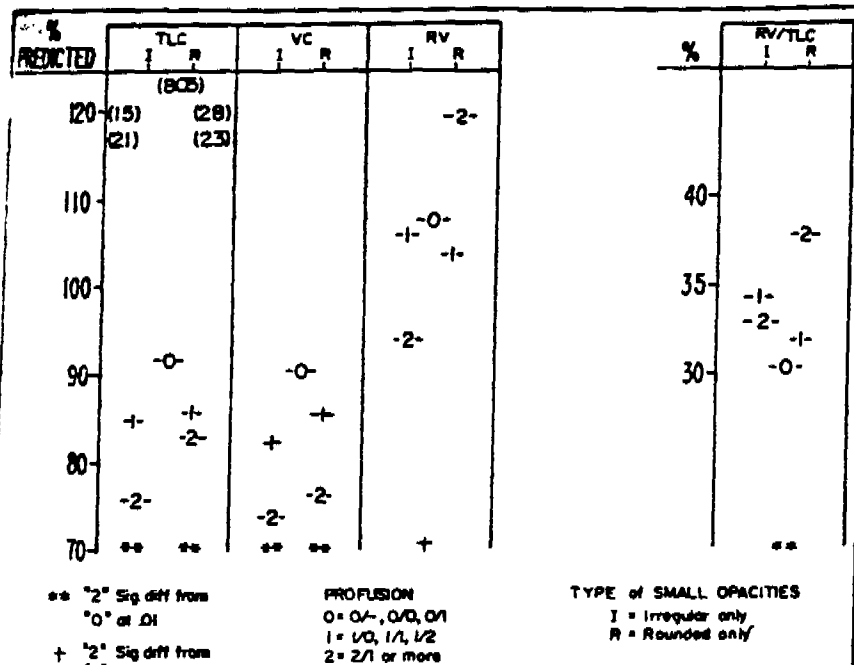


Fig 5. — Lung volumes.

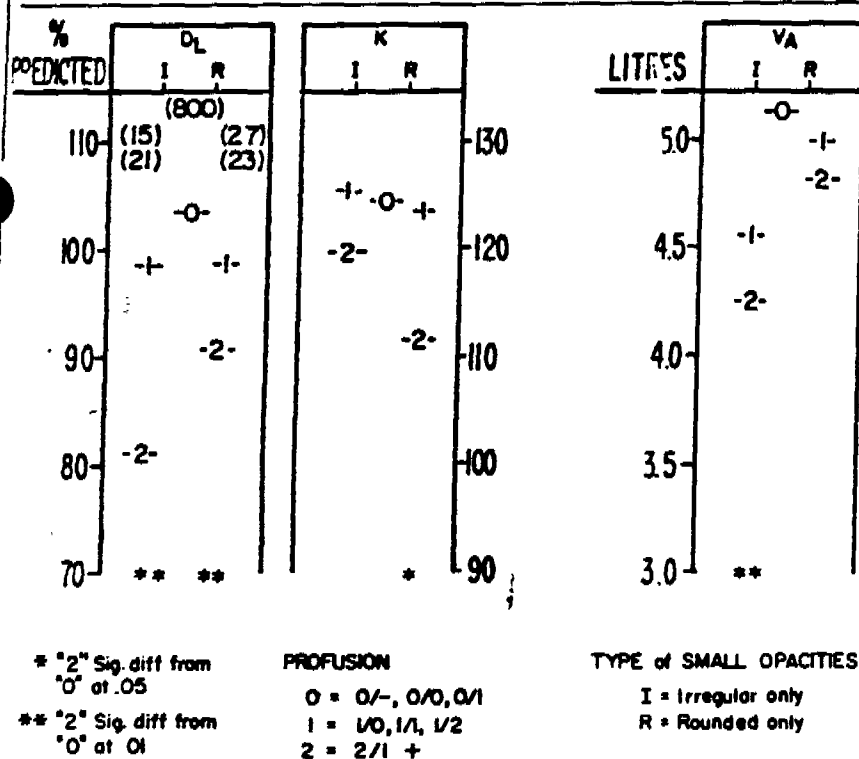


Fig 6. — Gas transfer.

did differ significantly from this mean value in the normal x-ray group. FEV₁, FEF₂₅₋₇₅ and FEV₁/VC were significantly lower in the two groups with definite radiographic changes than in the normal x-ray group (Fig 7). None of the expiration flow rates, however, separated the irregular from the rounded opacity group. The additional effect of pleural changes on selected parameters of lung

function is displayed for the same groups with and without parenchymal changes (Fig 8). In the irregular and rounded opacity groups, further reduction of vital capacity, forced expiratory volume and residual volume is observed in the presence of radiographically apparent pleural change. This effect for vital capacity and FEV₁ is also present in those without parenchymal changes. The

pleural effect on lung volumes is slightly greater in those with category 2 irregular changes than in the same profusion group with rounded opacities. Pulmonary diffusing capacity is reduced by the presence of pleural changes in the rounded opacity group, unchanged in those with category 2 irregular changes and paradoxically increased in the few subjects with irregular category 1 changes.

In summarizing this part of the analysis it appears that individuals with moderately advanced profusion or irregular opacities tend to have lower lung volumes and pulmonary diffusing capacity than those with rounded opacities. Hyperinflation is associated with rounded nodular changes but spirometric flow rate measurements which are generally affected by lung volume changes, do not separate the groups. These associations for lung volume reduction changes in pulmonary diffusing capacity and hyperinflation are consistent with the hypothesis that the small rounded opacities are primarily due to silica exposure while irregular opacities indicate predominant asbestos effect. Any anticipated additional ventilatory disturbance associated with silica exposure was not detected in these individuals, perhaps because of the high prevalence of airways disease in a smoking population and the recently demonstrated changes in small airways or in individuals exposed to asbestos dust.

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Comments

In the first phase of this investigation we were concerned with radiographic and physiologic evidence of diffuse pulmonary change due to dust exposure in the manufacture of asbestos cement products. These changes were related to indices of exposure but our data allow conclusions only concerning morbidity. In the next phase, information on mortality, particularly in relation to carcinogenesis, will be obtained. We have been describing biologic changes related to exposures beginning 20 or 30 years ago for most workers who demonstrate disease at this time. These exposures were much higher prior to the introduction of modern dust control methods. One can conclude tentatively that there is a cumulative level of ex-

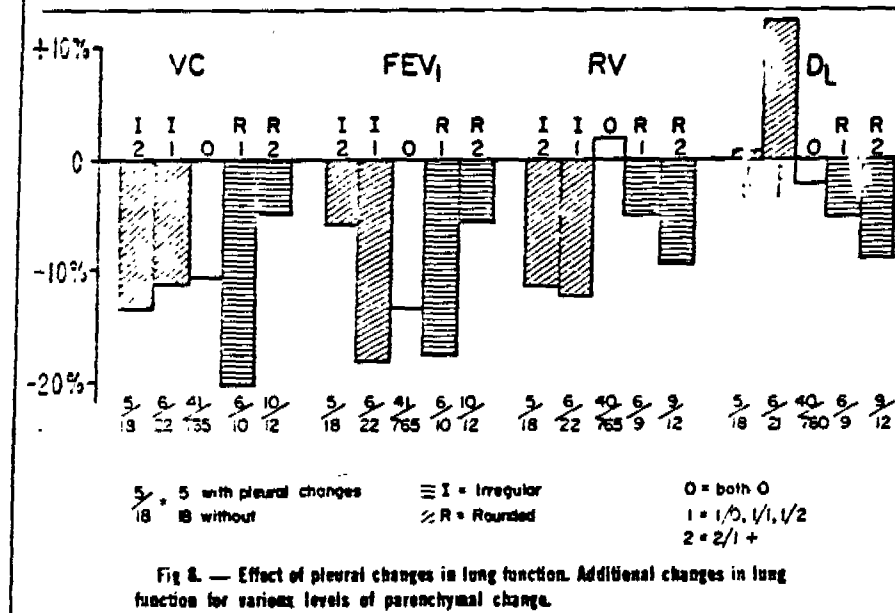
% PREDICTED	FEV ₁		FEF ₂₅₋₇₅		% PREDICTED	FEV ₁ /VC	
	I	R	I	R		I	R
90	-0-		(16) (22)	(28) (23)			
80		-1-	-0-			-0-	-1-
70	-1-	-2-		-1-		-2-	-2-
60	-2-		-2-	-2-			
50	**	**	**	**		*	**

* "2" Sig diff from "0" at .05
 ** "2" Sig diff from "0" at .01

PROFUSION
 0 = 0/0, 0/0 or 0/1
 1 = 1/0, 1/1 or 1/2
 2 = 2/1, or more

TYPE of SMALL OPACITIES
 I = Irregular only
 R = Rounded only

Fig 7. — Flow rates.



posure in this industry at fibrogenic effects associated with dusts are unlikely to occur. Perhaps level will have been reached where is universal conformance to the established TLV of 5 fibers per milliliter simultaneous impedance to count air sampling data are not available to allow for reliable conversion of total dust expressed in million per cubic foot to fibers per milliliter. Based on the limited available information, a conservative conversion ratio might be 10 fibers per milliliter for one MPPCF. The limit of our third dust category is equivalent to somewhat more than 1 MPPCF for a working lifetime of 40 years. This would conform with recent emergency TLC of 5 fibers per milliliter. Again, this relates to the risk of developing pneumoconiosis. The TLV provides no information concerning the excess risk of neoplasm. Finally, there appear to be differences in pulmonary function patterns between groups with small irregular and small rounded opacities. Although we have not been able to distinguish between consequences of exposures of asbestos and silica in these groups, the physiologic patterns suggest that rounded nodules seen on chest x-rays may represent a predominant effect while irregular or linear opacities are associated with an asbestos effect. At this time, reasons why individuals in this industry with seemingly similar exposures develop such different radiographic and physiologic patterns are not clear.

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