U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
CENTERS FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

HEALTH HAZARD EVALUATION DETERMINATION REPORT

MHETA 81-112
NYCO
Willsboro, New York

I. SUMMARY

In 1976 NIOSH performed a health hazard evaluation at a wollastonite mine and mill in Willsboro, New York. A second NIOSH medical-epidemiological evaluation was conducted among 108 current and former workers in January 1982, and the results of that study are reported herein.

The medical evaluation consisted of chest radiography, pulmonary function tests, and administration of a respiratory symptom and occupational questionnaire. Chest x-rays were interpreted by three independent, certified pneumoconiosis readers and pulmonary function tests conformed to criteria recommended for spirometry by the American Thoracic Society. On the basis of total dust data collected between 1976 and 1981 by the Mine Safety and Health Administration (MSHA), company and NIOSH an exposure index was calculated for each worker. For interpretation of lung function a control group of 86 workers employed by a local General Electric plant was used.

Medical testing showed wollastonite workers to have lower values of FEV_1/FVC and peak flow rate when compared with the control group. A dose-response relationship was found between decreasing values of FEV_1, peak-flow, FEV_1/FVC and cumulative long-term exposure to wollastonite containing dust. Three cases of simple pneumoconiosis (category 1/0 or 1/1 small rounded opacities) were found among the 108 wollastonite workers examined. No new cases of pneumoconiosis were found in 1982. Chest x-rays were not obtained for the comparison group of workers. Fifty-seven wollastonite workers were examined by NIOSH both in 1976 and 1982. Analysis of data on these 57 men revealed that workers with higher cumulative exposure to wollastonite had greater peak flow declines than workers with lower cumulative exposure.

The medical data suggest that long term cumulative exposure to wollastonite dust may impair ventilatory capacity as reflected by observed decrements in peak flow rate and FEV_1/FVC ratio. This effect appears to involve the larger airways. While simple pneumoconiosis was observed in three individuals, no comparison group chest films were available to assess the significance of this observation. Further prospective study of this population is recommended.

II. INTRODUCTION

In June 1981, NIOSH received a request from the general manager of NYCO, a Division of Processed Minerals, Inc., Willsboro, New York, for an investigation of their wollastonite mine and mill. A similar request was received by NIOSH in 1976 and an epidemiological survey was conducted (1,2). Since this investigation did not document any increase in the prevalence of respiratory disease, it was suggested that the study be repeated in 1981.

III. BACKGROUND

Wollastonite is a fibrous mineral (i.e., length: diameter aspect ratio greater than 3:1) with multiple uses. The most important one is in the ceramics industry where it is used as a filler and flux in wall time bodies as a compounding agent for binding the bodies, and for glare. It is used as a filler and flux in grinding wheels, refractories, building block, acoustical tiles and wallboard. In wallboard it has been substituted for asbestos as a fire retardant and as insulation. Wollastonite's insulating properties also make it a useful extender in fiberglass insulation and brake linings, and its pure white color makes it a useful extender in paints and marking compounds as well. This wollastonite mine and mill has been in operation since 1951. In that year Cabot Corporation started open-pit mining and operated a small pilot plant. In 1952, underground mining and full-scale milling began. In 1969 the Interpace Corporation bought the operation, and in 1980 Canadian Pacific acquired it and changed the name to NYCO Division.

These wollastonite miners and millers have been studied in the past. In 1964 the New York State Department of Health took x-rays and performed pulmonary function tests on all workers. These tests were repeated by NIOSH in 1976. Few abnormalities were noted in either study.

The current population of the Willsboro operation consists of 114 production workers (22 in the mine, 92 in the mill) and 8 management personnel. In the mine all drilling has been wet since 1952. Ore is transported to the mill where large chunks of wollastonite are reduced to fine fibers. The unique aspects of the mill include methods of removal of impurities, attrition of fibers and a plastic-coating process. The impurities are garnet and diopside, both weakly magnetic, which are removed by a magnetic field. At this point the wollastonite is divided into two types. The first, used for ceramics, requires simple milling and bagging. The second, used for plastics, paints, and asbestos substitutes, require attrition milling which cuts the fibers lengthwise to increase the length-diameter ratio to more than 5:1. Some of this product is bagged or bulk-loaded. Some of it undergoes the process in which plastic coats the wollastonite fibers. The process is largely self-contained and requires only occasional maintenance.

IV. METHODS

The aim of this study was to answer the following questions:

1. Is the wollastonite population characterized by an excess prevalence of respiratory abnormalities when compared with an unexposed population?

2. Is there a relationship between accumulated exposure and the prevalence or respiratory abnormalities determined on the basis of the 1982 cross-sectional survey and on the almost 6 years follow-up of workers examined in 1976?

A. Environmental Methods

In 1976 and 1982, NIOSH investigators conducted an industrial hygiene survey in the Willsboro mine and mill (3). Personal breathing zone samples were collected and time-weighted averages for respirable dust, total dust, wollastonite fibers and free silica were determined. NIOSH industrial hygiene data are supplemented by dust measurements of the company and the Mine Safety and Health Administration (MSHA) obtained the 1977-1981 interstudy period. Based on NIOSH, MSHA, and company total dust data, occupations of wollastonite workers were grouped into 5 exposure categories (Table 1). Since mean dust concentrations from the three sources were similar, all were used to derive a mean concentration representative of each of the five categories. From these exposure estimates and each participant's work hisotry, an index of lifetime cumulative total dust exposure was calculated:

$$\text{Lifetime exposure} = \Sigma \ (k_j \times t_j)$$

Where j = job category
t = time spent in the same job category (in years)
k = geometric mean dust concentration in the job category

B. Medical Methods

Occupational Respiratory Disease Questionnaire

A NIOSH respiratory questionnaire, based upon the British Medical Research Council Questionnaire, was administered by NIOSH personnel to each employee (4). Questionnaires included job history and smoking history. Major respiratory symptoms were defined as follows:

a. chronic cough: cough on most days for as much as three months a year.

b. chronic phlegm: phlegm on most days for as much as three months a year

c. chronic bronchitis: cough and phlegm for as much as three months a year

d. wheezing: ever having wheezing or whistling noises in one's chest

e. attacks of shortness of breath with wheezing: ever having had attacks of shortness of breath with wheezing.

Smoking status was determined according to the following criteria:

Nonsmoker: never smoked cigarettes regularly

Exsmoker: smoked regularly in past but presently does not smoke

Smoker: currently smokes cigarettes

A pack-years estimate was calculated for each worker by multiplying the average amount of cigarettes smoked every day by the years he has smoked and dividing by 20.

Pulmonary Function Tests

Spirometric tests were administered according to standard ATS techniques (5). The test consisted of five blows into an Ohio 840 waterless spirometer, generating a flow-volume curve which was electronically recorded. A minimum of three acceptable maneuvers were obtained on each subject. The spirometry data was corrected for body temperature and pressure saturated with water vapor (BTPS) and was stored on tape. At the NIOSH laboratory, the tapes were edited and for each individual, the largest forced vital capacity (FVC), the largest forced expiratory volume in the first second (FEV_1) and the largest peak flow rate from acceptable curves were used in the analysis. The FEV_1/FVC ratio was calculated. The results for FEV_1 and FVC were compared to predicted values of Knudson and co-workers as percent of predicted values (PPFVC, $PPFEV_1$) (6).

Chest Roentgenograms

Standard 14 by 17 inch posteroanterior and lateral chest roentgenograms were taken by a registered radiology technician. All chest films were independently interpreted by three "B" readers ("B" readers are physicians who have passed a proficiency examination in interpreting chest roentgenograms based on the 1980 ILO U/C classification) (7). For those workers who were examined in 1976 and 1982, paired films were available for comparison, and they were interpreted by the side-by-side method.

V. RESULTS

A. Environmental

During the 1976 and 1982 NIOSH industrial hygiene survey, all time weighted average (TWA) concentrations for respirable dust were below 5 mg/m^3. However, some TWA concentrations for total dust exceeded 10 mg/m^3. Since there is currently no specific occupational health standard for wollastonite, the MSHA standard for inert or nuisance dust is applicable (10 mg/m^3 total dust, based on 1973 ACGIH recommendations) (7).

Airborne fiber concentrations along with fiber sizing were performed by NIOSH in 1976 using both optical phase contrast and electron microscopy. Mean fiber counts by phase contrast microscopy revealed counts of 0.3 fiber per cubic centimeter in the mine and a range of 0.8 to 47.7 in the mill (fibers greater than 5 micrometers)(Table 2). Samples analysed by phase contrast microscopy indicated that 92-97% of the airborne fibers observed had diameters less than 3.5 um. The count median was calculated to be .22 um (range 0.1 - 5.2) for diameters and 2.5 um (range 0.3 - 41.0) for lengths. The x-ray diffraction analysis for free silica showed less than 2% free silica in the bulk samples.

B. Medical

Cross-sectional study

As reported in Table 3, 102 of 114 (89%) production workers participated in the survey. Six of 24 (25%) ex-workers with more than two years tenure in the company were also examined. Average tenure and age of examined current workers and ex-workers were not statistically different from those not examined.

Respiratory Symptoms

The analysis of the prevalence of respiratory symptoms was done with regard to smoking habit (Table 4), and cumulative total dust years. Smokers had a higher prevalence of all groups of symptoms when compared with nonsmokers. For chronic cough (24% vs 0%), chronic phlegm (29% vs 3%) and chronic bronchitis (20% vs 0%), the differences were statistically significant - Fisher's Exact Test, $p < .01$. To evaluate the effect of long term exposure, the workers were divided into groups according to their amount of accumulated dust years. After stratification by smoking status, no significant differences were observed between various exposure categories.

Pulmonary function

Analysis of pulmonary function in wollastonite workers employed multiple regression techniques, and results are summarized in Table 5. After allowing for the effects of age, height, and smoking, FEV_1, FEV_1/FVC ratio, and peak flow rate declined with increasing total dust-years of exposure. The dust-years' coefficients for these lung function indices were significantly different from zero ($p < 0.01$). To avoid a potential interaction between smoking and exposure index, results are also reported for nonsmokers alone. For this group, only the FEV_1/FVC ratio exhibited a significant decline with total dust-years of exposure ($p < 0.01$).

Chest x-ray findings

Two of the three B readers interpreting the x-rays agreed that three of 108 workers demonstrated small rounded opacities of category 1 or greater. Table 6 presents the characteristics of these three workers. They worked with wollastonite from 9 to 23 years, and their estimates for accumulated dust exposure ranged from 66 to 169 dust years. The average tenure for the whole examined population was 9.9 years, and the average amount of accumulated dust years was 45. Two of the workers were current smokers, one was an ex-smoker. All three workers were asymptomatic and their pulmonary function values were 90% or more of predicted.

Comparison of respiratory symptoms and pulmonary function between wollastonite workers and control population.

A comparison group -- of 92 workers who had not been exposed to substances considered etiologic for pulmonary abnormalities -- was selected from a General Electric plant located approximately 150 miles from Willsboro, New York. Eighty-six workers (93%) completed parts of NIOSH's medical screening (respiratory questionnaire and spirometry).

The demographic features of the control group, the total wollastonite group, and the subgroup of wollastonite workers with more than 30 dust-years are presented in Table 7. While the total wollastonite group was younger than the control group, its subgroup of more than 30 dust-years of exposure workers did not vary from the controls with respect to age, height, and smoking habit.

Respiratory symptoms

Comparison of the prevalence of respiratory symptoms in the control group, the total wollastonite group and the subgroup with more than 30 dust-years, revealed a significant excess of shortness of breath with wheezing in the wollastonite population (Table 8). No significant differences were revealed in the subgroups based on the smoking habits of the controls and the wollastonite populations.

Pulmonary function

The comparisons of the $PPFEV_1$, PPFVC and the FEV_1/FVC ratio between controls and wollastonite groups in general and within smoking groups are shown in Table 9. Wollastonite workers had significantly higher PPFVC than control workers. The same pattern was found in the group of exsmokers and smokers. The values of $PPFEV_1$ were similar in controls and wollastonite subgroups. The FEV_1/FVC ratio in wollastonite workers was slightly lower than in control workers. The difference reached a significant level when subgroups of ex-smokers in both populations were compared.

Pulmonary function results of the group of workers with more than 30 accumulated dust years were compared to those of control workers (Table 10). The two groups did not significantly differ with respect to age, height, and smoking habits. The values of FEV_1/FVC, peak flow rate, $PPFEV_1$, PPFVC were compared in both groups. The wollastonite-exposed group had statistically significantly lower values of peak flow rate (8.59 vs 9.30, $p < .05$) and FEV_1/FVC (.73 vs .78, $p < .01$) than workers in the control group.

Follow-up study

Sixty-one of the 82 workers included in the 1976 NIOSH survey were examined a second time in 1982. The 1976 pulmonary function data of three workers and the 1982 data of one worker could not be analyzed due to technical defects (Table 11). For follow-up comparisons the data of 57 workers (71% of 80 who are still alive) was used. Data on those examined and not examined are presented in Table 12. No significant differences were found.

Pulmonary Function

The loss in ventilatory capacity was calculated for each of 57 workers by substracting his 1976 values from his 1982 values. The decrement in FEV_1, FVC and peak flow rate was determined for each of the smoking groups. The mean annual decrement in FEV_1 for workers participating in both surveys was 49 ml for never smokers, and 75 ml for current smokers. For FVC, the mean annual decrement were 47 ml for never smokers, and 73 ml for current smokers. Linear modeling on age, height, smoking habit, and total dust-years was also performed for the 1976-1982 changes in spirometry (Table 31). This analysis showed a significant relationship between the decline in peak flow rate and total dust-years of exposure ($p < 0.02$).

Changes in x-ray findings

All three workers who had pneumoconiosis changes in 1982 had, in opinion of at least two B readers, abnormal radiographs in 1976. The progression rate was different in each of the workers. In one worker three readers had seen no progression. In the second worker two readers observed an expansion of the process from one (right) lung to both lungs; one of them also observed an increase in profusion (from 0/1 to 1/0). In the third worker two readers reported progression in profusion (1/0 to 1/1 and 0/1 to 1/1).

VI. DISCUSSION

There are two studies in the literature describing the health effects of wollastonite. In 1976, Shasby examined 92 workers in the wollastonite mines and mill in Willsboro, New York (2,3). In 1981, Huuskonen conducted a survey of 46 workers in a wollastonite quarry in Finland (9,10). Both studies included respiratory questionnaires, pulmonary function tests and chest roentgenograms. Shasby found a prevalence of chronic bronchitis ranging from 9% in nonsmokers to 23% in smokers and exsmokers. Similar results were obtained by Huuskonen (20% of nonsmokers and 26% of smokers plus exsmokers). There was no relationship between the prevalence of symptoms and long term exposure. In our study, we have not found chronic bronchitis among nonsmokers and exsmokers; we have found a prevalence rate of 20% in our group of smokers.

We found an excess in the prevalence of attacks of shortness of breath with wheezing when wollastonite workers were compared to the unexposed population. This difference could not be attributed to differences between wollastonite workers and comparison workers with regard to age or cigarrette smoking. Neither the study of Shasby nor Huuskonen revealed any severe impairments in the lung function of wollastonite exposed workers. Both investigators evaluated the status of small airways, in addition to FEV_1, FVC, and FEV_1/FVC tests. Shasby found no correlation between decrease in $MMEF_{50}$ and increased years of exposure. Huuskonen found signs indicating small airways disease in 20% of examined workers when he measured closing volumes. In our study, we found that workers with longer tenure had lower values of FEV_1, peak-flow and FEV_1/FVC than those with shorter exposure. Lower values of FEV_1/FVC and peak flow rate were also found when wollastonite workers were compared to the unexposed population.

Some investigators believe that follow-up studies of pulmonary function provide a sensitive measure of the effect of an exposure (11,12). Where there is minimum measurement variability, standardized testing, and stable populations, this is true. We were able to examine only 70% of the population seen in 1976. Our two surveys were performed at different seasons (fall and winter) and it is well-known that seasonal variations occur in pulmonary function (13). Since 1976, methods of data processing have changed, and we had to reprocess the 1976 pulmonary function data according to current requirements. All these factors can be sources of bias. Fortunately, we were able to select an internal control group, and we can assume that, if there is any bias, it will affect all groups to the same extent. For examined wollastonite workers we found that mean annual change was 66 ml (FEV_1), 63 ml (FVC) and 138 ml/s (peak flow rate). Prospective studies of lung function in working and general populations have shown that FEV_1 and FVC in healthy men decrease at a rate of less than 40 ml per year after the age of 25. The rate of decline for smokers is greater than for those who have never smoked. In subjects with chronic obstructive pulmonary disease, the observed rate has been shown to be approximately 80 ml per year (for a detailed review see reference 14). We compared the rate of decline in FEV_1, FVC and peak flow rate for workers with both high and low exposures. The first group declined more than the second, but the only statistically significant difference was the decline in peak flow rate. Detailed analysis, using the method of multiple linear regression, revealed that cumulative exposure had a significant impact on the rate of decline in the peak flow rate.

Chest radiographs of the workers examined in Finland showed slight parenchymal fibrosis in 30% and slight pleural thickening in 28%. Fibrotic changes were mild in profusion (1/0,1/1), opacities were mainly irregular (s,t), and located in the middle and lower lobes of the lungs or in the entire lung. Pleural changes were bilateral. Both the fibrosis and pleural thickening tended to increase with length of exposure and were present in 43% of workers with more than 30 years of work with wollastonite. In both surveys in Willsboro, radiographic changes -- small rounded opacities of category 1/0 or 1/1 profusion -- were found in a small percentage of workers (4% and 3%). No new cases of pneumoconiosis were found during our 1982 survey.

The pulmonary abnormalities found in Willsboro have a different character than those found in the Finnish workers. Changes in closing volumes in Finish workers indicate changes in distal airways. The findings in our study -- reduced FEV_1/FVC, and reduced peak flow rate -- indicate involvement of larger airways. These differences between American and Finish workers are difficult to explain. More information about the size and shape of the wollastonite particles and the concentrations of total and respirable dust found in Finland are needed to explain their reported interaction between wollastonite dust and pulmonary abnormalities.

VII. CONCLUSIONS

1. The wollastonite group of workers was characterized by an excess prevalence of attacks of shortness of breath with wheezing when compared with an unexposed population.

2. Workers with high exposure had lower values of FEV_1/FVC ratio and peak flow rate than the group of unexposed workers.

3. A dose-response relationship was found between decreasing values of FEV_1, peak-flow, FEV_1/FVC and cumulative long term exposure.

4. The follow-up study of pulmonary function of workers seen in 1976 revealed that workers with high exposure had declined more in peak flow rate than those with low exposure.

5. Three cases of simple pneumoconiosis (small rounded opacities) were found among the total exposed group..

6. In general, the character of pulmonary function findings indicate that long term exposure to wollastonite might cause changes in large airways.

VIII. RECOMMENDATIONS

1. A follow-up medical survey is recommended for 1987. All present and former workers should be examined.

2. To establish advantageous conditions for a 1987 NIOSH survey the following steps should be taken:

   a. A register of all present and former workers should be kept and updated every six months. It should include the period the worker was with the company and specifically a list of all jobs and time spent in each.

   b. The present address of former workers should be maintained, and an address and telephone number of each worker separated from the company should be obtained at his departure.

   c. An environmental surveillance program should be established. Total and respirable dust samples should be taken every three months of representative jobs in the mine and mill.

   d. Workers should be advised of the adverse health effects of cigarette smoking. Literature for distribution may be obtained from a local American Lung Association chapter as well as from the National Institute of Health (301-496-4070)

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TABLE 1.

MEAN TOTAL DUST CONCENTRATIONS* (±SD)

EMPLOYED IN THE CALCULATION OF DUST-YEARS, BY JOB CATEGORY

	NIOSH	MSHA AND COMPANY	ALL SOURCES
JOB CATEGORY	1976 and 1982	1977-1981	
1. All mining except crushing	0.90 n=2	0.93 ± 1.94 n=9	0.90 ± 2.16 n=11
2. All administrative activities in mill	2.30 n=2	————	2.30 n=2
3. All milling and crushing	5.24 ± 1.95 n=11	3.33 ± 1.40 n=15	4.10 ± 1.90 n=26
4. Laborer and beneficiator	11.65 ± 1.85 n=8	6.88 ± 1.60 n=9	8.71 ± 1.80 n=17
5. Mill maintenance and packers	10.30 ± 1.93 n=26	9.73 ± 1.99 n=15	10.00 ± 1.94 n=41

* Dust concentrations are reported in mg/M^3 of air.

TABLE 2

MEAN TIME-WEIGHTED AVERAGE (TWA) AIRBORNE CONCENTRATIONS FOR WOLLASTONITE FIBERS

Samples by Job Title		Phase Contrast Miscroscopy 400X Magnification Fibers/cc Mean	Electron Microscopy 10,000X Magnification Fibers/cc > 5mm in length (mean)	Electron Microscopy 10,000X Magnification Fibers/cc total fib (mean)
Mine Driller Loader Utility Man	n=3	0.27	0.33	5.4
Mill Trucker Crusherman	n=1	0.78	0.91.	4.6
Mill Beneficator Mill Helper	n=1	20.0	11.1	33.5
Mill F-1 Miller	n=1	47.7	17.5	51.9
Mill Packer	n=6	32.0	13.1	85.4
Mill Stationary General Area Samples	n=3	15.8	9.7	40.

Source: Industrial Hygiene Study of the Interpace Corporation, Willsboro, New York report prepared by Ralph Zumwalde, 1976.

DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS AND NONPARTICIPANTS BY CURRENT WORK STATUS

	Participants	Nonparticipants
Current Workers:		
Number (% total)	102 (89%)	12 (11%)
Mean tenure ± SD (yrs)	9.9 ± 8.7	7.3 ± 3.7
Mean age ± SD (yrs)	35.6 ± 11.6	36.3 ± 10.5
Former Workers:		
Number (% total)	6 (25%)	18 (75%)
Mean tenure ± SD (yrs)	10.7 ± 8.7	13.3 ± 6.3
Mean age ± SD (yrs)	47.3 ± 12.5	56.4 ± 13.6

TABLE 4

RESPIRATORY SYMPTOMS OF CURRENT AND FORMER WOLLASTONITE WORKERS BY SMOKING HABIT

RESPIRATORY SYMPTOMS	NONSMOKERS		EXSMOKERS		SMOKERS		TOTAL	
	N	%	N	%	N	%	N	%
Number of Workers	32	100	27	100	49	100	108	100
Chronic Cough	0	0	2	7	12	24*	14	13
Chronic Phlegm	1	3	2	7	14	29*	17	16
Chronic Bronchitis	0	0	0	0	10	20*	10	9
Wheezing	5	16	3	11	15	31	23	21
Shortness of Breath with Wheezing	3	9	0	0	5	10	8	7
Mean Age	34.2±12.2		40.6±11.9		35.2±11.3		36.2±11.9	

*$p < .01$ compared to nonsmokers

TABLE 5

COEFFICIENT ESTIMATES FROM REGRESSION ANALYSIS

FOR LUNG FUNCTION OF WOLLASTONITE WORKERS

	TOTAL POPULATION (N=108)			
	FEV_1 (L)	FVC (L)	FEV_1/FVC	PFR (L/s)
Intercept	-1.2102	-2.7407	0.9370	-1.5000
Age (yr.)	-0.0252**	-0.0233**	-0.0014	-0.0326*
Height (cm)	0.0357**	0.0512**	-0.0007	0.0700**
Smoking Status				
sm	0.0000	0.0000	0.0000	0.0000
ex	-0.1032	-0.1023	-0.0037	-0.0433
non	0.0600	-0.2060	0.0525	0.2674
Dust-years†	-0.0037*	-0.0019	-0.0005**	-0.0088**
	NONSMOKERS (N=32)			
Intercept	-2.9127	-8.9240	1.6816	-8.5478
Age (yr.)	-0.0098	-0.0240**	0.0022	-0.0086
Height (cm)	0.0433**	0.0848**	0.0051**	0.1072**
Dust-years†	-0.0060	0.0057	-0.0022**	-0.0052

† (mg-yrs./M^3)

* $p<0.02$

** $p<0.01$

TABLE 6

CHEST X-RAY READINGS, THREE WORKERS WITH PNEUMOCONIOSIS

			WORKERS WITH PNEUMOCONIOSIS X	Y	Z
Chest x-ray reading by B readers	B_1	Profusion	1/0	1/0	1/0
		Shape	qt	qt	qt
		Location	L&R	L&R	L&R
	B_2	Profusion	1/1	1/0	1/0
		Shape	qt	qt	qt
		Location	L&R	L&R	L&R
	B_3	Profusion	1/1	0	0
		Shape	qt	-	-
		Location	L&R	-	-

L - left lung
R - right lung
q - small rounded opacities with diameter 1.5 - 3 mm
t - small irregular opacities with width 1.5 - 3mm

TABLE 7

DEMOGRAPHIC FEATURES OF CONTROL GROUP, TOTAL WOLLASTONITE GROUP, AND WOLLASTONITE GROUP WITH MORE THAN 30 DUST-YEARS

	CONTROL	WOLLASTONITE TOTAL	WOLLASTONITE > 30 DUST YEARS
Number of workers	86	108	52
Av. Age	41.52 ± 10.59	36.23 ± 11.91*	40.98 ± 11.66
Av. Height	172.82 ± 5.88	172.32 ± 6.72	172.58 ± 6.05
Av. Pack-years	17.90 ± 17.27	14.61 ± 16.44	20.28 ± 18.41
% Nonsmokers	28	30	25
% Exsmokers	24	25	33
% Smokers	48	45	42

* $p < .05$ compared to controls

TABLE 8

PREVALENCE RATES OF RESPIRATORY SYMPTOMS IN THE CONTROL GROUP, THE WOLLASTONITE GROUP AND THE WOLLASTONITE SUBGROUP WITH MORE THAN 30 DUST YEARS

RESPIRATORY SYMPTOMS	CONTROL		WOLLASTONITE TOTAL		WOLLASTONITE > 30 DUST YEARS	
	N	%	N	%	N	%
Number of workers	89	100	108	100	45	100
Chronic cough	19	21	14	13	6	13
Chronic phlegm	21	24	17	16	7	16
Chronic bronchitis	9	10	10	9	4	9
Wheezing	26	29	23	21	11	24
Shortness of breath with wheezing	0	0	8**	7	4*	9

* $p < .05$

** $p < .01$

TABLE 9

PULMONARY FUNCTION OF CONTROL AND WOLLASTONITE WORKERS BY SMOKING HABIT

		CONTROL	WOLLASTONITE
TOTAL	N	86	108
	$PPFEV_1$	100 ± 14	102 ± 18
	PPFVC	103 ± 12	109 ± 13**
	FEV_1/FVC	.78 ± .08	.76 ± .10
NONSMOKERS	N	24	32
	$PPFEV_1$	105 ± 13	106 ± 16
	PPFVC	107 ± 14	108 ± 11
	FEV_1/FVC	.81 ± .06	.81 ± .09
EXSMOKERS	N	21	27
	$PPFEV_1$	102 ±11	97 ± 16
	PPFVC	108 ±10	108 ± 12
	FEV_1/FVC	.77 ± .07	.72 ± .10*
	Pack-years	22.15 ± 17.57	20.89 ± 19.65
SMOKERS	N	41	49
	$PPFEV_1$	96 ± 15	102 ± 19
	PPFVC	100 ± 12	111 ± 14**
	FEV_1/FVC	.76 ± .09	.74 ± .90
	Pack-years	23.91 ± 12.67	20.69 ± 13.82

* $p < .05$
** $p < .01$

TABLE 10

LUNG FUNCTION AND RELATED DATA OF CONTROL PLANT AND WOLLASTONITE WORKERS WITH > 30 DUST-YEARS OF EXPOSURE

	Comparison Workers	Wollastonite Workers > 30 Dust-Years
Number	86	52
Mean age, yrs (SD)	42 ± 11	41 ± 12
Mean height, cm (SD)	173 ± 6	173 ± 6
Smoking status:		
% nonsmokers	28	25
% ex-smokers	24	33
% current smokers	48	42
mean pk-yrs. (SD)	18 ± 18	20 ± 18
FEV_1 (L), SD	3.68 ± .69	3.56 ± .73
FVC (L), SD	4.73 ± .68	4.87 ± .67
FEV_1/FVC, SD	.78 ± .08	.73 ± .09**
Peak Flow (L/s), SD	9.30 ± 1.89	8.59 ± 1.76*

* $p<0.05$

** $p<0.01$

TABLE 11

1982 STATUS OF WORKERS SEEN IN 1976

STATUS IN 1976	SEEN IN 1976	NOT SEEN IN 1982				UNACCEPTABLE QUALITY OF DATA	TOTA INCL IN D ANAL
		DECEASED	RETIRED	QUIT	STILL EMPLOYED IN NYCO		
Employees	77	2	1	7	6	4	57
Exworkers	5	-	5	-	-	-	0
Total	82*	2	6	7	6	4	57

*Total seen in 1976 - 92, 10 excluded due to incompleted examination or no exposu

LUNG FUNCTION AND RELATED DATA OF WORKERS EXAMINED IN 1976 AND 1982 AND ONLY IN 1976

STATISTIC	EXAMINED IN 1976 AND 1982	EXAMINED ONLY IN 1976
Number of workers	57	25
Age	36.16 ± 10.22	39.64 ± 14.06
Tenure	9.04 ± .76	8.4 ± 8.58
PPFVC	113 ± 15	113 ± 15*
$PPFEV_1$	106 ± 16	111 ± 17*
FEV_1/FVC	.76 ± .08	.80 ± .08*

* The data of only 14 out of 25 workers were available for the comparison of pulmonary function data.

TABLE 13

REGRESSION ANALYSIS OF CHANGE IN PULMONARY

FUNCTION FOR WOLLASTONITE WORKERS EXAMINED IN 1976 AND 1982 (N=57)

	FEV_1(L)	FVC (L)	FEV_1/FVC	PFR (L/s)
Intercept	1.1135	1.2216	0.0316	6.9140
Age (yr.)	-0.0034	-0.0100	0.0005	-0.0237
Height (cm)	-0.0079	-0.0070	-0.0004	-0.0369
Smoking Status				
sm	0.0000	0.0000	0.0000	0.0000
ex	0.0323	0.1264	-0.0143	-0.1061
non	0.1240	0.1191	0.0079	0.1984
Dust-years†	-0.0003	0.0001	0.0001	-0.0053*

† (mg-yrs./M^3)

* $p<0.02$