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Radiological survey of past and present vermiculite miners exposed to tremolite

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Radiological survey of past and present vermiculite miners exposed to tremolite

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ABSTRACT Chest radiographs taken by a standard technique were obtained from 173 current employees (164 men, 9 women) of a vermiculite mine in Montana, from 80 of 110 past employees resident within 200 miles, and from 47 men from the same area without known exposure to dust. In 43 of the 80 and 24 of the 47 an earlier chest *x* ray film was retrieved from the hospital archives. All 367 films were assessed blind and independently by three experienced readers using the ILO 1980 classification. Median radiographic assessment scores were analysed in relation to estimated cumulative exposure to the amphibole fibres that contaminate the vermiculite. Logistic regression analyses showed independent effects of age, smoking, and exposure on the prevalence of small opacities and of age and probably of exposure on pleural thickening. Overall, the data suggest that by retirement age the increase in prevalence of small opacities ($\geq 1/0$) lies between 5% and 10% per 100 f/ml years. This gradient may be somewhat steeper than for chrysotile miners and millers, but not much so.

The survey described in the present paper is one of a series of studies undertaken to assess the health effects of work in a vermiculite mine in Libby, Montana. Two complementary programmes of research were initiated by NIOSH and ourselves, primarily because of contamination of the ore body with fibrous amphibole deposits in the tremolite series. A history and description of the mining and milling processes were given in our report on a cohort mortality study in this group of workers.[1] These data showed substantial excess mortality compared with United States white men from respiratory cancers (SMR = 2·45), non-malignant respiratory disease (SMR = 2·55), and malignant mesothelioma (proportional mortality = 2·4%). The NIOSH mortality study of a more broadly defined cohort obtained similar results from independently assembled data.[2]

Vermiculite, a micaceous mineral that expands on heat treatment has many uses in construction industries, agriculture, and packaging. The largest known vermiculite deposit, at Libby, Montana, has been commercially mined since 1923. At first it was on a small scale but, after 1939, when two companies merged, production increased: 20 000 tons were shipped in 1940, 150 000 in 1950, and, since 1972, about 200 000 annually.

The Libby deposit is mined using the open pit mining technique incorporating rubber tyre loaders and trucks for both ore and waste removal. Waste is discharged at the perimeter of the mined area whereas the ore is hauled to a transfer point for blending and wet beneficiation. During early years of the operation, all functions of mining and milling were performed in a dry state, leading to very dusty conditions. A series of process improvements resulted in present mine personnel operating from within enclosed air controlled cabs and a totally wet beneficiation process. Vermiculite concentrate is graded into five size fractions before shipment to expansion plants in various parts of the United States.

Fibrous tremolite has little commercial value and only one or two small mines in northern Italy produce it. On the other hand, it is a fairly common contaminant in various exploited minerals, notably some talc deposits of New York State and in the Quebec chrysotile mines where it is present in trace amounts. There has been no previously published radiological survey of tremolite miners as such but several studies of talc miners and millers exposed to varying concentrations of mineral fibre and silica.[3] Pleural thickening was frequently found in these workers but parenchymal opacities much less so. These observations are not easily interpreted in terms of tremolite fibre because of the other components in the airborne dust.

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Table 1 *Percentage of radiographic changes by age*

Age (years)	*Current employees*					*Past employees*				
	No	*Mean cumulative exposure (f/ml y)*	*Small opacities (≥ 1/0)*	*Pleural thickening (chest wall)*	*Pleural calcification*	*No*	*f/ml y*	*Small opacities (≥ 1/0)*	*Pleural thickening (chest wall)*	*Pleural*
20–39	80	13·4	*2·5*	*7·5*	*1·3*	1	6·0	—	—	—
40–59	69	57·3	*13·0*	*20·3*	*5·8*	30	160·2	*33·3*	*40·0*	*16·7*
≥60	15	103·5	*26·7*	*40·0*	*6·7*	49	96·1	*40·8*	*61·2*	*36·7*
All	164	40·1	*9·1*	*15·9*	*3·7*	80	118·9	*37·5*	*52·5*	*28·8*

Table 2 *Age standardised prevalence of abnormalities by cumulative exposure*

Cumulative exposure (f/ml y)		*No in group*	*Small opacities (≥ 1/0)*		*Pleural thickening of chest wall*	
Group	*Mean*		*No*	*Prevalence %**	*No*	*Prevalence %**
<10	4·1	92	7	*10·6*	15	*23·3*
10–<20	17·5	64	12	*18·4*	14	*21·7*
20–<100	53·9	53	10	*15·4*	22	*38·7*
100–<200	144·4	16	8	*31·3*	6	*22·2*
≥200	495·8	19	8	*27·9*	11	*38·5*
Total	65·9	244	45	*18·4*	68	*27·9*

*Directly age standardised, total study group taken as standard.

Table 3 *Prevalence of abnormalities in men aged 60 or more by cumulative exposure*

Cumulative exposure (f/ml y)		*No in group*	*Small opacities (≥ 1/0)*		*Pleural thickening of chest wall*	
Group	*Mean*		*No*	*Prevalence %*	*No*	*Prevalence %*
<10	6·5	15	2	*13·3*	7	*46·7*
10–<20	19·0	17	6	*35·3*	9	*52·9*
20–<100	56·7	16	6	*37·5*	10	*62·5*
100–<200	153·4	8	6	*75·0*	5	*62·5*
≥200	463·4	8	4	*50·0*	5	*62·5*
Total	97·9	64	24	*37·5*	36	*56·3*

Table 4 *Logistic regression analysis of exposure response relations*

Test for	*In the presence of*	*Small opacities (≥ 1/0)*		*Pleural thickening of chest wall*	
		χ^2 *(df)*	*p*	χ^2 *(df)*	*p*
Cumulative exposure	Age, smoking	10·9 (1)	p < 0·001	5·9 (1)	p < 0·025
Smoking	Age, cumulative exposure	8·2 (2)	p < 0·025	4·6 (2)	p ≃ 0·10
Age	Cumulative exposure smoking	27·2 (1)	p < 0·001	28·1 (1)	p < 0·001

Estimated coefficients:

Small opacities: $\text{Log}\ \frac{P}{1-P} = -7{\cdot}27 + 0{\cdot}0035\ (\text{cum exp}) + 0{\cdot}084\ (\text{age}) + \begin{cases} 0{\cdot}82 \text{ if ex-smoker} \\ 1.72 \text{ if current smoker} \end{cases}$

Pleural thickening: $\text{Log}\ \frac{P}{1-P} = -5{\cdot}62 + 0{\cdot}0024\ (\text{cum exp}) + 0{\cdot}088\ (\text{age}) + \begin{cases} -0{\cdot}41 \text{ if ex-smoker} \\ 0{\cdot}42 \text{ if current smoker} \end{cases}$

0·1 f/ml, no excess of radiological change should be detectable after a working life of 40 years. The imprecision associated with radiological technique and reading error would be far greater than the expected level of risk.

There are few other data sets against which these findings may be compared. Our original studies of Quebec chrysolite miners[6] gave a slope of about 0·6% per 100 fibre years and a later analysis,[7] confined to men aged 60–69 with an average gross service of 42·3 years, gave a lower estimate (0·2%). Both these estimates were based on men still at work and it was concluded that the true gradients were probably steeper. A more recent study of the Quebec workers (JC McDonald *et al*, paper presented at XXI international congress on occupational help, Dublin, 1984) was based on current and past employees, used *x* ray films taken with a similar technique to that at Libby, and one of the three readers took part in both studies. That study gave a slope of 4% per 100 fibre years, about half that in the present survey.

The radiographic study by NIOSH was based on the most recent chest *x* ray films (188 in all) available in the local hospital for men employed five or more years and at some time since 1974.[2] These men were all current employees at the time of the *x* ray examination, were somewhat younger than those in our sample, but had been employed nearly four years longer and at a slightly higher average level of exposure. Despite this, and the fact that one of the readers was common to both studies, the prevalence rates of both parenchymal and pleural changes were substantially higher in our study than theirs. The slope of the logistic regression line for small opacities ($\geq$ 1/0) and cumulative exposure was also somewhat steeper in our data. We believe that these differences were due to better film quality and perhaps to the inclusion of ex-employees in our survey. This underlines the problems and imprecision of radiographic estimates of exposure response in dust exposed workers.

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