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The Correlation of Chest Radiograph and Pulmonary Function Tests in Asbestos Miners and Millers

S.K. Dave, L.J. Bhagia, P.K. Mazumdar, G.C. Patel, P.K. Kulkarni and S.K. Kashyap

National Institute of Occupational Health, Meghani Nagar, Ahmedabad

An environmental-cum-medical survey was carried out in asbestos mines and milling units at Pullivendalla, Cuddaph (A.P.) India. This was done in two mines and six milling units with 95% of the total work force being surveyed. Out of a total of 633 registered workers, 329 (52%, all males) were employed in mines while 135 (21.4%) workers of whom 114 (84%, all females) were employed in the milling units All subjects underwent limited medical examination, spirometry and chest radiographs.

The levels of asbestos fiber concentration was much below threshold limit value (TLV) in underground mines but several times higher than TLV in milling units. The percentage of workers with abnormal pulmonary function tests (PFT) and chest radiographs increased with duration of exposure in smokers as well as non-smokers. Restrictive pattern of lung functions (159 workers-16.27%) was more common than obstructive (33 workers-5.21%) and combined type (22 workers-3.4%). Similarly, the parenchymal changes (156 workers-24.6%) were more common than pleural (27 workers-4.3%). As most of the males were employed in mines, where the fiber levels were much below TLV, the number of male workers with normal PFT and chest radiographs were ten times (61.3%, more than male workers with both the parameters abnormal (6.3%). As most of the females (114 our of 120 95%) were employed in milling units, where the levels of fibers were several times higher than TLV, the number of females having both the parameters normal 29 (24.1%) or abnormal 35 (29.2%) were similar.

***Key words :** Asbestos mines, asbestos mills, chest radiograph, pulmonary function tests.*

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The results of extensive epidemiological and toxicological studies have confirmed that respiratory morbidity due to asbestos exposure is related to the dose and duration of exposure, the processes of work and type of fiber[1-3].

While studying respiratory morbidity due to asbestos exposure attempts were being made to find out the relationship of chest radiographs and pulmonary function tests in work environment. Attempts were also made to observe the interdependency of these two objective parameters with each other. While such efforts do not throw direct light on, for

Correspondence : Dr S.K. Dave, Deputy Director and Head, Occupational Medicine and Epidemiology Division, National Institute of Occupational Health Meghani Nagar, Ahmedabad-380 016.

instance, the prevalence of health effects of hazards, they have lead to some interesting speculation regarding the sensitivity of such tests in detecting the early changes in health status[4].

In India, more than 30 mines are located in Andhra Pradesh and Rajasthan. The serpentine (Chrysotile-17,000 metric ton) variety is available in Andhra Pradesh and amphibole (Tremolite-25,000 metric ton) in Rajasthan. The latter variety is technically of very poor grade. As per the directives of the Indian Council of Medical Research (ICMR), New Delhi, the National Institute of Occupational Health (NIOH), Ahmedabad initiated "Intervention study in asbestos mines and milling units in India" at the national level. The findings presented here are the part of overall observations made from the entire study whose objectives were (*i*) to measure the asbestos fiber levels in mines and milling units, (*ii*) to assess the health status of workers in asbestos mining and milling units, (*iii*) to correlate the effects of work environment on respiratory system in reference to two objective parameters, *i.e.* chest radiograph and pulmonary function tests and (*iv*) to find out the interdependency of two objective parameters, *i.e.* chest radiography and pulmonary function tests on each other.

Material and Methods

Environmental Evaluation. The environment was evaluated in two mines and six milling units at Pullivendalla, Cuddaph in Andhra Pradesh, India.

(*a*) *Collection of samples.* As recommended by the Bureau of Indian Standards (BIS)[5], the millipore membrane filter method (MMFM) was used. The minimum number of samples taken were four. A total of 157 samples were collected from the breathing zone of workers by personal samplers at various locations. The dust was collected on cellulose membrane filter with 25 mm diameter and 0.8 μm pore size at the flow rate of 1.5 L/min.

(*b*) *Counting.* A phase contrast microscope (x 400) with Walton-Becklet graticule specially designed for asbestos fiber counting was used. One hundred fibers or 100 fields were counted with minimum count of 20 fields. All fibers with length ≥ 5 μm and diameter (width) ≤ 3 μm and length to diameter ratio 3 : 1 or more were counted. Fiber concentration was calculated by using the following equation:

$$(A/a) \times (1/r) \times (1/t)$$

where A is for effective area, *i.e.* 325.88 mm^2, a for graticule area, *i.e.* 0.006936 mm^2, r for flow rate, *i.e.* 1.5/min, t for sample duration (min), N = total number of fibers counted, and n for number of graticule area counted (≤ 100).

Health Status Study. This study comprised of 633 (513 males and 120 females) workers (95% of the work force) of the asbestos mines and milling units at Pullivendalla, Cuddaph, A.P., (India).

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(*d*) *Chest roentgenog*
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Results

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Table 1.

Semi-Mechanic

Operation

Jaw crusher

Decorticator

Loader

Fiber room

Vibrator

Hand screening

Figures in parenthesis m

(*a*) *Questionnaire.* A standard questionnaire administered by trained interviewers included a medical section, a section on occupational history and smoking habit[6]. To avoid bias non-smokers were defined as those who had no exposure to tobacco and remaining were considered as smokers.

(*b*) *Limited physical examination.* Auscultation was performed on site to determine the presence of infra-axillary crepitations heard at the full inspiration especially after a short period of breath holding at the low lung volumes.

(*c*) *Spirometry.* Spirometry was performed by Vitalograph (7.1 L). Each subject performed a minimum of three technically satisfactory forced expiratory manoeuvers. The reading of the forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) were used for analysis. Predicted normal values were obtained from the data of Kamat *et al*[7].

(*d*) *Chest roentgenograms.* All workers underwent a full size postero-anterior chest roentgenogram as per the recommendations made by ILO (1980). The films were read by three chest physicians and common agreement was taken for analysis[8-9].

Results

In mines, the levels of asbestos fibers were much below the threshold limit value (TLV) for chrysotile fiber [*i.e.*, $\leq$ 2 f/ml] which is accepted by the Government of India in Model Rule 123-A under Section 112 of the Factories Act 1948 as ammended in 1987 which is also applicable to chrysotile mine and milling environment[10].

Table 1. *Mean asbestos fiber concentration in two types of mills*

Semi-Mechanic		Semi-Automatic	
Operation	(f/ml)	Operation	(f/ml)
Jaw crusher	244.14 (6.69-40.79)	Fiberision	21 43 (3.32-41.92)
Decorticator	52.27 (12.49-141.9)	Primary screening	33.27 (8.4-60.97)
Loader	45.92 (30.0-63.9)	Fiber collection	75.28 (19.07-54.77)
Fiber room	148.96 (91.05-220.79)	Tailing plant (Feeding)	144.42 (2 05-26.76)
Vibrator	224.33 (96.77-488.05)	Tailing plant (collection)	3.98 (1.36-6.60)
Hand screening	101.30 (51.54-214.71)	—	—

Figures in parenthesis indicate range; TLV = $\leq$ 2/ml

The mean asbestos fiber concentration in two types of mills have been shown in table-1. Mean asbestos fiber concentration at various locations of the semi-mechanic mill was higher as compared to the location of the semi-automatic mills. However in both the type of mills, the fiber levels were several times higher than TLV (≤ 2 f/ml) at all locations. The mean fiber level was highest near the vibrator (224.23 f/ml) in semi-mechanized mill. In semi-automatic mill, the highest level was observed near the tailing plant (Feeding-144.42 f/ml).

The distribution of workers according to the nature and duration of exposure and smoking habit in both the sexes is shown in table-2. The directly exposed group included workers working either in mining and/or milling, while those working as supervisor, mechanic, electricians, helpers, drivers etc have been included in indirect exposure group. Out of a total of 633 workers, 341 (53.8%) had less than 10 years exposure, 186 (29.3%) with 11 to 15 years and 106 (16.7%) with more than 15 years. Out of the total work force, 329 workers (52%, all males) were employed in mining, 199 (31.4%) in milling, 23 (3.6%) in mining and milling and 82 (12.9%) in indirect exposure processes. Out of a total of 513 male workers, 282 (54.9%) were smokers while 22 (18.3%) of the 120 females smoked.

Table 2. *Distribution of workers according to nature and duration of exposure and smoking habits in both sexes*

Duration of exposure (yrs)	Sex	Direct exposure group				Indirect exposure group				Total
		Mining		Milling		Mining +		Milling		
		NS	S	NS	S	NS	S	NS	S	
≤ 10 341 (53.8%)	M	115 (22.41)	95 (18.51)	20 (3.89)	26 (5.06)	4 (0.78)	5 (0.97)	17 (3.31)	17 (3.31)	299 (47.1)
	F		–	32 (26.6)	8 (6.06)	–	–	2 (1.6)	–	42 (6.6)
11-15 186 (29.4%)	M	34 (6.62)	40 (7.79)	7 (1.36)	17 (3.31)	3 (0.58)	6 (1.16)	7 (1.36)	20 (3.89)	134 (21.2)
	F		–	41 (34.16)	8 (6.66)	–	–	3 (2.5)	–	52 (8.1)
≥ 16 106 (16.51%)	M	15 (2.92)	30 (5.84)	3 (0.58)	12 (2.33)	2 (0.38)	3 (0.58)	4 (0.77)	11 (2.14)	80 (12.6)
	F	–	–	19 (15.83)	6 (5.00)	–	–	1 (0.83)	–	26 (4.1)
Total		164 (25.9)	165 (26.06)	122 (19.27)	77 (12.16)	9 (1.42)	14 (2.21)	34 (5.37)	48 (7.58)	633

NS = Non smoker, S = Smoker; Figures in parenthesis indicate percentages
Male smokers = 282 (54.9%), Female smokers = 22 (18.3%)

Table 3. *Pulmonary function impairment in different operation groups*

Operation group	Sex	Pulmonary function impairment				Total
		No. of workers	Restrictive	Obstructive	Combined	
Direct exposure						
Mining	M	329	26 (7.9)	25 (7.6)	10 (3)	61 (18.5)
	F	–	–	–	–	–
Milling	M	85	14 (16.5)	2 (2.3)	2 (2.3)	18 (21.2)
	F	114	48 (42.1)	2 (1.8)	4 (3.5)	54 (47.3)
Mining and milling	M	23	1 (4.3)	1 (4.3)	-	2 (8.7)
Indirect exposure						
	M	76	12 (15.8)	3 (3.9)	6 (7.9)	21 (26.7)
	F	6	2 (33.3)	–		2 (33.3)
Total		633	103 (16.27)	33 (5.2)	22 (3.4)	158 (25)

Figures in parenthesis indicate percentages

Impairment of lung functions in workers in both directly and indirectly exposed groups of both the sexes is shown in table 3. It was observed that restrictive pattern was more common (103 workers-16.27%) as compared to the obstructive (33 workers-5.21%) while a mixed pattern was observed in 22 workers (3.4%). As compared to miners (61 workers-18.5%), the prevalence of lung function impairment was more common in millers (72 workers-36.2%) and in workers in the indirect exposure group (23 workers-28%). In female workers of the indirect exposure group and milling units, the prevalence of restrictive impairment was nearly two to two-and-half times more common than their male counterparts.

The radiological changes were more common in workers in the milling units (109 workers-54.8%) than mining units (64 workers-19.5%) (Table 4). Amongst radiological changes in direct as well as indirect exposure group, parenchymal changes were more common (166 workers-26.2%) than pleural one (27 workers-4.3%). Pulmonary tuberculosis was detected in 6 workers (1%), all of them were male smokers.

In milling units and in the indirect exposure group the prevalence of parenchymal changes were more common in females (milling units-28 males, *i.e.* 33% out of 85 and 62 females, *i.e.* 54.38% out of 114; indirect exposure group 13 males, *i.e.* 17.1% out of 76 and one female, *i.e.* 16.6% out of 6). Thus, the radiological changes also had a similar pattern as the pulmonary function tests.

Correlation of chest radiographs and pulmonary function tests in asbestos miners and millers of both the sexes is summarized in table 5. Out of the total of 513 male workers, 317 (61.3%) were having both the parameters normal while 31 (6.3%) had both the parameters abnormal. Of the 120 female workers, 29 (24%) had both the parameters normal while 35 (29.2%) had both parameters abnormal. In case of male workers, 71 (13.8%) were with abnormal PFT and normal chest x-ray and 94 (18.4) had normal PFT and abnormal chest x-ray. In female workers the corresponding figures were 21 (17.5%) and 35 (29.2%), respectively. Here, it is worthwhile to note that males were employed mainly in mines (underground) due to prohibition of employment of females on such locations. Thus, the females were largely employed in milling units (95% out of 120 females) and indirect

Table 4. *Radiological changes in different operation groups*

Operation group	Sex	No. of workers	Radiological changes: Parenchymal changes IO	RO	CO	Pleural changes PT	PCa	Pulmonary tuberculosis	Total
Direct exposure									
Mining	M	329	31 (9.4)	1 (0.3)	18 (5.5)	6 (1.8)	3 (0.9)	5 (1.5)	64 (19.4)
	F	–	–	–	–	–	–	–	–
Milling	M	85	28 (32.9)	–	7 (8.2)	4 (4.2)	–	1 (1.2)	40 (47.1)
	F	114	42 (36.8)	–	20 (17.5)	4 (3.5)	3 (2.6)		69 (60.5)
Mining and milling	M	23	3 (13.1)	–	2 (8.7)	1 (4.37)	–	–	6 (26.1)
	F	–	–	–	–	–	–	–	–
Indirect exposure	M	76	8 (10.5)	1 (1.3)	4 (5.3)	6 (7.9)	–	–	19 (25)
	F	6	–	–	1 (16.6)	–	–	–	–
Total		633	112 (17.7)	2 (0.3)	52 (8.2)	21 (3.3)	6 (1.0)	6 (1.0)	

I.O. = Irregular opacities, R.O. = Regular opacities, C.O. = Combined opacities, P.T. = Pleural thickening, P. Ca. = Pleural calcification
Figures in parenthesis indicate percentages

Table 5. *Correlation of ch millers*

Pulmonary function tests

Normal

Abnormal

Figures in parenthesis inc

exposure process. As a re. females to much higher le in Model Rule 123-a und which is also applicabl conclusion, that when the the levels are comparative

Discussion

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In the milling units, i locations the fiber levels v Government of India in M ammended in 1987 and is be mainly due to three reas and safety act and (c) low and milling units, total pro milling units. Such a low the reason for their resist. prevailing lack of awaren absence of low cost indige contribute to an extreme Countries like Canada (Qu profitable asbestos mines w

Table 5. *Correlation of chest radiographs and pulmonary function tests in asbestos miners and millers*

Pulmonary function tests	Chest radiographs			
	Males (513)		Females (120)	
	Normal	Abnormal	Normal	Abnormal
Normal	317 (61.7)	94 (18.4)	29 (24.1)	35 (29.2)
Abnormal	71 (13.8)	31 (6.3)	21 (17.5)	35 (29.2)

Figures in parenthesis indicate percentages

exposure process. As a result males were exposed to very low levels (*i.e.*, $\leq$ 0.5 f/ml) while females to much higher levels than the TLV ($\leq$ 2 f/ml) accepted by the Government of India in Model Rule 123-a under Section 112 of the Factories Act 1948 as ammended in 1987, which is also applicable to chrysotile mine and milling environment. However, the conclusion, that when the fiber levels are too high, chest radiographs are affected and when the levels are comparatively low, pulmonary function tests are affected can't be derived.

Discussion

The fiber levels were much below TLV in mines due to wet drilling and low content of the fiber in parent rock ($\leq$ 3%). Underground mining does play a significant role in the reduction of the fiber levels to a significant extent. In the South African mines, Gibbs and Du Toit[11] also observed the levels of asbestos fiber were two to three times higher in surface mining as compared to underground one.

In the milling units, in the general work environment, as well as at various other locations the fiber levels were much higher than TLV ($\leq$ 2 f/ml) which is accepted by the Government of India in Model Rule 123-A under Section 112 of the Factories Act 1948 as ammended in 1987 and is applicable to chrysotile mine and milling environment This can be mainly due to three reasons : (*a*) obsolete technology, (*b*) inadequate compliance to mines and safety act and (*c*) low content of asbestos fiber in parent rock. In Pullivendalla mines and milling units, total production of chrysotile is approximately 17,000 metric ton by six milling units. Such a low yield gives poor economic returns to mine/mill owners which is the reason for their resistance in investing in environmental engineering controls. The prevailing lack of awareness about health risks due to asbestos in miner and millers and absence of low cost indigenous technology aggravate the problem further. All these factors contribute to an extremely dusty working condition in these asbestos milling units. Countries like Canada (Quebec)[12], Cyprus[13], Italy[14] and South Africa[11] have economically profitable asbestos mines which contribute nearly 30% of the total world production. Studies carried out in these countries reported significantly high levels in general mill environment. However, records maintained since 1940 in South Africa, Canada and Italy documented significant decrease in the environmental concentration of asbestos fibers over the past 40 years[11,12,14].

We observed that the percentage of male workers with both parameters normal (61.3%) was ten times more than the percentage of workers with both the parameters abnormal (6.3%). However, in cases of female workers there was not much difference in the percentage of workers having both the parameters normal (24%) and abnormal (29%). This could be due the fact that in underground mines only males are permitted legally to work and the fiber levels were much below TLV in these mines. This results in females being predominantly employed in milling units and other indirect processes where the fiber levels were several times higher than TLV. Thus, the highly significant difference in fiber levels between mining and milling units kept male work force healthier than their female counterpart. Similarly restrictive pattern of PFT and radiological parenchymal changes mainly in the form of irregular linear opacities were more common in milling workers than in miners.

A study carried out in British Columbia reported decreased levels of forced vital capacity in those working in the mill area known for its high levels of exposure to asbestos fibers[15]. Similar magnitude of deficit of FVC (8.9%) has also been reported in a Quebec study[16]. We noted parenchymal changes on radiology in 12.2% of the workers studied which was in conformity with similar studies in asbestos mines and milling units in Quebec[4,16], Cyprus[17], Italy[13] and British Columbia[15] where parenchymal changes observed were 8%, 5%, 29% and 11%, respectively. The figures for pleural changes varied from 2 to 7% in all these studies except in an Italian study where it was 13%[13]. Studies of lung function and radiography have been reported from Quebec[4] and Italy[13] and in both the studies levels of lung function was noted to be related to the abnormalities observed radiologically. The analysis of these studies also revealed that inter-relationship of the two objective parameters, *i.e.* chest radiograph, spirometry and their dependence on environmental levels of asbestos fiber. It also depends to a major extent on pre-employment health status and individual host susceptibility[4,15,16].

References

1. Irwing RS, DuToit J, Sluis-Cremer GK, Solomon A, Thomas R. Risk of asbestosis in crocidolite and amosite in South Africa. *Ann N Y Acad Sci* 1979; **330** : 35-52.

2. Rossister CE, Bristol LJ, Cartier PH, *et al.* Radiographic changes in chrysotile asbestos mine and mill workers of Quebec. *Arch Environ Health* 1972; **24** : 388-400.

3. Felton, Jean Spencer. Radiographic search for asbestos related disease in a naval shipyard. *Ann NY Acad Sci* 1979; **330** : 341-352.

4. Becklake MR, Fournier-Massey G, McDonald JC, Siemiatycki J, Rossister CE. Lung function in relation to radiographic changes in Quebec asbestos workers. *Proceedings of the International Conference on Pneumoconiosis*, Johannesburg, SA. 1970; 233-239.

5. *Bureau of Indian*
fiber concentratior

6. *American Lung A*
adults and childrei

7. Kamat SR, Tyagi
I : 11-21.

8. International Lab
Pneumoconiosis (1
fice, Geneva, Swit

9. Rossister CE, Har
Proceedings of the

10. Exposure limits in
Labour Office, 198

11. Gibbs GW, DuToi
Scientific Publicati

12. McDonald JC, Be
chrysotile asbestos

13. McDonald JC. Asb
Scientific Publicati

14. Vigalani EC. Asbe
Conference on Pne

15. Enarson DA, Emb
miners in British C

16. Becklake MR, Fou
asbestos mine and r

5. *Bureau of Indian Standards IS 11450-1986.* Method of determination of airborne asbestos fiber concentration in work environment by light microscopy.

6. *American Lung Association.* Recommended respiratory disease questionnaire for use with adults and children in epidemiological reasearch.

7. Kamat SR, Tyagi NK, Rashid SSA. Lung function in Indian adult subjects. *Lung India* 1982; **1** : 11-21.

8. International Labour Office : ILO/UC International Classification of Radiographs for *Pneumoconiosis* (1979). *Occupational Safety and Health Series XX*; International Labour Office, Geneva, Switzerland.

9. Rossister CE, Harris PG. Choice of radiography for assessing effects of asbestos exposure. *Proceedings of the International Conference on Occupational Health* (*Abstract*); 1975 : p. 128.

10. Exposure limits in various countries (Appendix-A) : Safety in use of asbestos. *International Labour Office*; 1984 : 94-96.

11. Gibbs GW, DuToit RSJ. Environmental data in mining : Biologic effects of asbestos. *IARC Scientific Publication No. 8 IARC-Lyon, France*; 1973 : 138-144.

12. McDonald JC, Becklake MR, Gibbs GW, McDonald AD, Rossister CE. The health of chrysotile asbestos mine and mill workers of Quebec. *Arch Environ Health* 1974; **28** : 61-68.

13. McDonald JC. Asbestosis in chrysotile mines and mills : Biological effects of asbestos. *IARC Scientific Publication No. 8. IARC-Lyon, France*; 1973 : 189-194.

14. Vigalani EC. Asbestos exposure and its results in Italy. *Proceedings of the 2nd International Conference on Pneumoconosis*, Johannesburg, SA. 1970; 192-196.

15. Enarson DA, Embree V, Maclean L, Grzybowski Respiratory health in chrysotile asbestos miners in British Columbia : A longitudinal study. *Br J Med* 1988; **45** : 459-463.

16. Becklake MR, Fournier-Massey G, Rossister CE, McDonald JC. Lung function in chrysotile asbestos mine and mill workers of Quebec. *Arch Environ Health* 1972; **24** : 401-408.