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ASBESTOSIS AMONG MAINTENANCE WORKERS IN THE CHEMICAL INDUSTRY AND IN OIL REFINERY WORKERS

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INTRODUCTION

Clinical field examinations of several large groups of workers in various plants of the chemical industry - three vinyl chloride polymerization plants (Lilis et al., 1975, 1976), a styrene polymerization plant (Lorimer et al., 1976), a titanium dioxide manufacturing plant (Daum et al., 1977) and a dye manufacturing plant - undertaken by the Environmental Sciences Laboratory in the last few years, have called our attention to the occurrence of chest X-ray abnormalities (small irregular opacities and/or pleural changes) of the type known to be induced by dust exposure. Chest X-rays were read without knowledge of age, past medical history, occupational history or findings on physical examination. Yet when parenchymal changes (irregular or rounded opacities) and/or pleural changes (thickening or calcification) were found, exposure to asbestos, silica or coal dust had usually occurred.

When examining workers from chemical plants, special efforts were made to include maintenance personnel, since it is well known that their work implies a risk from significant overexposure to toxic substances, especially when repair becomes urgently necessary.

POPULATION AND METHODS

To obtain information concerning the potential dimensions of asbestos hazards among workers in the chemical industry, a cross-sectional investigation of maintenance workers of a large chemical plant in New Jersey was undertaken.

All were volunteers, and represented about half the men in maintenance categories in the plant (welders, carpenters, electricians, pipefitters, etc.). Efforts were made to include as many as possible of those with terms of employment of more than 10 years, and to examine only a sample of employees with shorter durations of exposure; 26% of those examined had less than 10 years, and 59% had more than 20 years from onset of exposure (Tables 1 & 2).

Table 1. Age distribution of 185 maintenance workers in a chemical plant

Age (yrs)									
20 - 29.9		30 - 39.9		40 - 49.9		50 - 59.9		60+	
No.	%	No.	%	No.	%	No.	%	No.	%
27	15	18	10	34	18	85	46	21	11

Table 2. Duration since onset of first asbestos exposure (yrs) for maintenance workers in a chemical plant

< 10		10 - 19.9		20 - 29.9		30+	
No.	%	No.	%	No.	%	No.	%
49	26	27	15	41	22	68	37

A similar study of 137 oil refinery workers was conducted. Employees with a duration of employment of more than 20 years were studied; almost half of those examined had more than 30 years of employment (Tables 3 & 4).

Table 3. Age distribution of 137 refinery workers

Age (yrs)							
40 - 49 ^a		50 - 59		60 - 69		70+	
No.	%	No.	%	No.	%	No.	%
37	27	79	57.7	18	13.1	3	2.2

^a No refinery workers under 40 years of age were examined.

Table 4. Duration since onset of work (yrs) in 137 refinery workers

15 - 19		20 - 29		30 - 39		40+	
No.	%	No.	%	No.	%	No.	%
1	0.7	74	54.0	50	36.5	12	8.8

The examination protocol included a lifetime occupational history, past medical history, smoking history, Medical Research Council respiratory questionnaire, complete physical examination, standard 14 x 17 inch posteroanterior chest X-ray films and pulmonary function tests (spirometry and maximal expiratory flow volume curves).

Chest X-ray films were read with no knowledge of past medical history, occupational history, respiratory symptoms or findings on physical examination, and categorized according to the ILO U/C International Classification of Radiographs of Pneumoconioses (International Labour Office, 1972). Results of pulmonary function tests - measurements of forced vital capacity (FVC), forced expiratory volume 1 second (FEV₁) and forced expiratory flow over the mid-FVC (FEF₂₅₋₇₅) - were compared with the values predicted by Morris et al. (1971), with no knowledge of occupational history, radiological findings, symptoms or findings on physical examination.

RESULTS

Radiological findings

1. Chemical plant maintenance workers

Small irregular opacities, mostly in the lower lung fields, sometimes extending to the middle lung fields, indicating parenchymal interstitial fibrosis, were present in 24% of those examined; in 10% this was the only abnormality (Table 5).

Pleural thickening and calcification (with or without thickening) in 10% and 4% of cases, respectively, were found in the absence of definite radiologically evident parenchymal abnormalities; 14% of all those examined had pleural abnormalities only; in another 14%, both parenchymal and pleural changes were seen. The overall prevalence of parenchymal and/or pleural abnormalities consistent with asbestos-induced changes was 38%.

As expected, the prevalence of all chest X-ray abnormalities was higher in workers with more than 20 years since onset of work (Table 6); pleural changes were a more frequent abnormality in the group than were parenchymal ones.

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Table 5. Chest X-ray abnormalities consistent with asbestos-induced changes (parenchymal and pleural) in 185 maintenance workers in a chemical plant

Radiological change (ILO U/C) ^a	Proportion of workers	
	No.	%
None		
0/0-0/1 *	115	62
Parenchymal changes, total	45	24
1/0-1/2	42	22.4
2/1-2/3	3	1.6
3/2-3/4	0	-
Parenchymal changes only	19	10
Pleural changes, total	51	28
Pleural thickening only	18	10
Pleural calcification (with or without thickening)	7	4

^a International Labour Office (1972)

Careful analyses of life-long occupational histories recorded for all 185 maintenance workers revealed that in 140 there had been no previous specific, defined occupational or nonoccupational dust exposure. In 45 workers, asbestos exposure, ranging from minimal to significant, had occurred in the past, preceding employment in the chemical plant.

Among those considered to have had significant previous exposure were workers who had been employed in an asbestos manufacturing plant, had been active as pipefitters or pipecoverers, had worked in brake maintenance and repair, or had participated in boiler repair work. Those considered to have had minor previous exposure included workers involved in spackling, shingle trimming, brake repair (minimal, intermittent), and in one case, residence in the neighbourhood (two blocks away) of an asbestos products manufacturing plant.

A separate analysis was made of workers with no (even minimal) known pre-existing asbestos exposure. When comparing the results with those obtained for the entire group of 185 workers, it was found that the prevalence of radiological abnormalities, both parenchymal and pleural, was almost identical (Table 7).

The relationship between radiological abnormalities and duration since onset of exposure (Table 8) was very similar in the group of 140 maintenance workers with no previous known asbestos exposure and in the

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Table 6. Duration since onset of asbestos exposure and chest X-ray changes in 185 maintenance workers

Radiological changes ^a	Proportion of workers			
	Less than 20 years (N = 77)		More than 20 years (N = 108)	
	No.	%	No.	%
Normal (0/0-0/1)	66	86	49	45
Parenchymal changes (total)	9	12	36	33
1/0-1/2	8	10	34	31
2/1-2/3	1	1	2	2
3/2-3/4	0	-	0	-
Parenchymal changes only	8	10	11	10
Pleural changes (total)	3	4	48	44
Pleural thickening only	1	1	17	16
Pleural calcification (with or without thickening, without parenchymal changes)	1	1	6	6

^a International Labour Office (1972)

total group of 185 examined workers (Tables 5 & 6); there was no statistically significant difference in prevalence of parenchymal or pleural changes.

2. Oil refinery workers

Small irregular opacities, indicating interstitial pulmonary fibrosis, were detected in 31 (23%) cases; in 20 (15%) this was the only radiological abnormality. Radiological abnormalities of the pleura (pleural fibrosis and/or calcification) were found in 34 (25%) cases; in 23 (17%), pleural abnormalities were found in the absence of radiologically detectable parenchymal changes (Table 9).

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Table 7. Chest X-ray abnormalities consistent with asbestos-induced changes (parenchymal and pleural) in 140 maintenance workers with no previous asbestos exposure

Radiological change (ILO U/C) ^a	Proportion of workers	
	No.	%
None (0/0-0/1)	90	64
Parenchymal changes, total	34	24
1/0-1/2	31	22
2/1-2/3	3	2
3/2-3/4	0	-
Parenchymal changes only	12	9
Pleural changes (total)	38	27
Pleural thickening only	14	10
Pleural calcification (with or without thickening)	2	1

^a International Labour Office (1972)

When the six insulation workers were removed from the analysis (Table 10), the prevalence of parenchymal abnormalities remained identical, while that of pleural abnormalities was found to be slightly lower: 22.5% of cases had pleural changes, and in 15% these were the only radiological abnormalities.

Clinical findings - symptoms and signs

The only symptom reported with a higher frequency in workers with radiological abnormalities was dyspnoea on exertion. Cough and sputum production consistent with a diagnosis of chronic bronchitis (Table 11) were found in 20% of the chemical plant maintenance workers examined. The difference in prevalence between current smokers and individuals who had never smoked regularly was not significant (22% versus 14%) in this group.

In the oil refinery workers, chronic bronchitis was found with a prevalence of 23.5% and was significantly higher in current smokers (Table 12).

Abnormalities on physical examination were infrequent; rales were present mostly in persons with pleural changes.

Table 8. Duration since onset of asbestos exposure and chest X-ray changes in 140 maintenance workers with no previous asbestos exposure

Radiological changes ^a	Proportion of workers			
	Less than 20 years (N = 61)		More than 20 years (N = 79)	
	No.	%	No.	%
Normal (0/0-0/1)	54	89	36	46
Parenchymal changes (total)	6	10	28	35
1/0-1/2	5	8	26	33
2/1-2/3	1	2	2	3
3/2-3/4	0	-	0	-
Parenchymal changes only	4 ^b	7	8	10
Pleural changes (total)	3	5	35	44
Pleural thickening only	1	2	13	16
Pleural calcification (with or without thickening, without parenchymal changes)	0	-	2	3

^a International Labour Office (1972)

^b 'Parenchymal changes only' was the only radiological abnormality with significantly higher prevalence in workers with previous asbestos exposure ($\chi^2 = 4.63$; $P < 0.05$).

Results of pulmonary function tests

In chemical plant maintenance workers, pulmonary function tests (Table 13) indicated a relatively low prevalence of restrictive dysfunction (5% of cases), probably related to the small number of cases with advanced parenchymal fibrosis. An obstructive pattern was found more often and was, as expected, more prevalent in current and ex-smokers. The finding of a lower than normal FEV₁:FVC ratio in 17% of maintenance workers with a negative smoking history suggests that dust, irritant fumes and gases in an industrial environment may have an adverse effect on respiratory function.

Table 9. Chest X-ray abnormalities consistent with asbestos-induced changes (parenchymal and pleural) in 135 refinery workers^a

Radiological change (ILO U/C) ^b	Proportion of workers	
	No.	%
None (0/0-0/1)	81	60
Parenchymal changes (total)	31	23
1/0-1/2	28	20.7
2/1-2/3	3	2.2
3/2-3/4	0	-
Parenchymal changes only	20	14.8
Pleural changes (total)	34	25.2
Pleural thickening only	20	14.8
Pleural calcification (with or without pleural thickening, without paren- chymal changes)	3	2.2

^a Two of the workers' chest X-ray films were unreadable.^b International Labour Office (1972)Table 10. Chest X-ray abnormalities consistent with asbestos-induced changes (parenchymal and pleural) in 129 refinery workers with no direct asbestos exposure^a

Radiological change (ILO U/C) ^b	Proportion of workers	
	No.	%
None (0/0-0/1)	80	62.0
Parenchymal changes (total)	30	23.3
1/0-1/2	27	20.9
2/1-2/3	3	2.3
3/2-3/4	0	-
Parenchymal changes only	20	15.5
Pleural changes (total)	29	22.5
Pleural thickening only	16	12.4
Pleural calcification (with or without pleural thickening, without paren- chymal changes)	3	2.3

^a Excluding six insulation workers^b International Labour Office (1972)

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Table 11. Prevalence of chronic bronchitis in maintenance workers in a chemical plant

Smoking habits	Total no. examined	Proportion with chronic bronchitis ^a	
		No.	%
Present smoker	67	15	22
Ex-smoker	75	15	20
Never smoked	42	6	14
Total ^b	184	36	20

^a Medical Research Council respiratory questionnaire^b Excluding one subject for whom no smoking history was recorded

Table 12. Prevalence of chronic bronchitis in oil refinery workers

Smoking habits	Total no. examined	Proportion with chronic bronchitis ^a	
		No.	%
Present smoker	42	16	38
Ex-smoker	55	11	20
Never smoked	39	5	12.8
Total ^b	136	32	23.5

^a Medical Research Council respiratory questionnaire^b Excluding one subject for whom no smoking history was recorded

In the oil refinery workers, restrictive ventilatory dysfunction (FVC < 80% of predicted) was found in 14% of cases, while an obstructive pattern was detected in 10.3% of cases (Table 14).

The prevalence of restrictive ventilatory dysfunction in oil refinery workers was higher than in the chemical plant maintenance workers. An obstructive pattern of respiratory dysfunction was not found in oil refinery workers with a negative smoking history. This confirms that irritant fumes and gases in the chemical industry significantly contribute to the obstructive ventilatory dysfunction found, even in nonsmokers.

Table 13. Pulmonary function abnormalities^a - restrictive and obstructive pattern - in maintenance workers in a chemical plant

	Current smoker (N = 67)		Ex-smoker (N = 75)		Never smoked (N = 42)		Total (N = 184)	
	No.	%	No.	%	No.	%	No.	%
Restrictive dysfunction FVC $\leq$ 79% of predicted	2 (1) ^b	3	6 (3) ^b	8	2	5	10	5.4
Obstructive dysfunction FEV ₁ :FVC $\leq$ 74% (only)	6 ^c	9	10	13	7	17	23	12.5
FEF ₂₅₋₇₅ $\leq$ 67% of predicted (only)	0	-	1	1	0	-	1	0.5
Both abnormalities	12	18	17	23	0	-	29	15.7
Total obstructive dysfunction	18	27	28	37	7 ^d	17	53	28.7

^a FEV₁ - forced expiratory volume (1 sec); FVC - forced vital capacity; FEF₂₅₋₇₅ - forced expiratory flow over the mid-FVC

^b Figures in parentheses - mixed ventilatory dysfunction, predominantly restrictive

^c Tests incomplete in two subjects (FEF₂₅₋₇₅ not available)

^d Difference in prevalence of obstructive dysfunction between current smokers and nonsmokers statistically nonsignificant ($\chi^2 = 1.52$; $P = 0.25$)

Table 14. Pulmonary function abnormalities^a - restrictive and obstructive pattern - in refinery workers

	Current smoker (N = 42)		Ex-smoker (N = 55)		Never smoked (N = 39)		Total (N = 136) ^b	
	No.	%	No.	%	No.	%	No.	%
Restrictive dysfunction FVC $\leq$ 79% of predicted	9	21.4	6	10.9	4	10.3	19	14
Obstructive dysfunction FEV ₁ :FVC $\leq$ 74%	7	16.7	7	12.7	0	-	14	10.3

^a FVC - forced vital capacity; FEV₁ - forced expiratory volume (1 sec)

^b No smoking history was obtained for one worker.

DISCUSSION

While in these groups of chemical plant maintenance workers and oil refinery workers chest X-ray abnormalities were relatively frequent, pleural changes being more prevalent than parenchymal fibrosis, subjective symptoms and pulmonary function abnormalities were much less prominent. This constellation has been found to be rather characteristic for relatively less intense asbestos exposure. While progression to severe disabling parenchymal asbestosis is less probable under such circumstances, the risk for lung cancer and mesothelioma remains.

The chemical plant maintenance workers examined had had various degrees of asbestos exposure; more than half of the examined had never been directly engaged in work with asbestos; as they had been present in areas where such work was performed. A list of some of the job designations in this last Table 15.

Table 15. Maintenance workers' occupations with asbestos

Labourer
Stock man
Area mechanic
Sheet-metal
Mechanic's
Maintenance
Millwright
Repair man
Pipefitter
Product

*welders
carpenters
electricians
pipe fitters*



In the group of oil refinery workers, only six were insulators. A list of job designations of oil refinery workers is given in Table 16.

Table 16. Refinery workers' occupations with no direct handling of asbestos

Boilermaker
Carpenter
Crane operator
Distillation worker
Electrician
Filter plant operator
Forklift operator
Inspection worker
Labourer
Painter
Shipping checker
Still operator
Welder

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Comparative analysis of the entire group of maintenance workers, and of the 140 subjects with exposure, yielded interesting results: prevalent abnormalities (both parenchymal and pleural) were

The relationship between prevalence of radiological abnormalities and duration since onset of exposure was also very similar. Also, in the group of oil refinery workers, exclusion from the analysis of six employees who had been insulators did not influence the prevalence of radiological abnormalities. These findings strongly suggest that asbestos exposure characteristic of maintenance work in chemical plants and in oil refineries, including indirect ('bystander') exposure, results in risks comparable, although not identical, to those documented for other types of asbestos exposure in other industries and occupations.

The higher prevalence of radiological pleural abnormalities (pleural fibrosis and/or calcification) than of parenchymal small irregular opacities (interstitial pulmonary fibrosis), the fact that parenchymal abnormalities were not very advanced (in only a small proportion of cases exceeding 2/1) and the paucity of clinical abnormalities all indicate that the risk for disabling asbestosis is less with this type of asbestos exposure.

In 1971, reports by Bittersohl (1971) and by Bittersohl & Ose (1971) had called attention to asbestos hazards in the chemical industry. Twenty-six cases of mesothelioma had been observed over a period of four years (1967-1971); this was in sharp contrast with the extreme rarity of this type of malignancy in the preceding period. Twenty-two patients had worked in a large chemical industry (Leuna), two in another chemical plant (Buna) and one in a foundry. The only female patient had had no occupational exposure to asbestos, but was the wife of a worker at the Leuna plant. Only 16 patients had had direct occupational exposure to asbestos, while nine had had indirect exposure (working in areas where asbestos was occasionally handled by other workers); in one case there was only a history of household exposure. Chest X-ray films taken before the development of mesothelioma were available in 23 cases; in 17, pleural thickening and pleural plaques were present.

It was known that extensive insulation work had taken place in several departments of the Leuna chemical plant in the early 1950s. Large amounts of asbestos had been used, and evidence was available that there had been high concentrations of airborne fibres in the past. Maintenance work was thought to carry a special risk.

The risk of lung cancer and mesothelioma is of concern for maintenance workers in the chemical industry and for oil refinery workers, since accumulated experience indicates that low-level asbestos exposure (indirect occupational, neighbourhood or household exposure) is sufficient to result in a significant risk of developing mesothelioma (Harries et al., 1972; Newhouse & Thompson, 1965; Selikoff, 1977; Wagner et al., 1960). It is possible that an increasing number of such cases may occur, since spectacular growth of these industries has taken place over the last 25-35 years, which is, on the average, the critical latent period (Selikoff, 1977).

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SUMMARY

Adverse health effects associated with asbestos exposure are well known and documented for occupational groups directly exposed to asbestos - asbestos miners, asbestos textile workers, insulation workers. However, the health hazards due to asbestos have not been completely ascertained for those workers who are indirectly exposed in industries where asbestos insulation was used extensively.

In order to evaluate the potential asbestos hazards in maintenance workers in the chemical industry and in oil refinery workers, two cross-sectional clinical field examinations were conducted: 185 maintenance workers in a large chemical plant and 137 oil refinery workers were studied. Long-term employment (more than 20 years) was characteristic for both groups.

In the chemical plant maintenance workers, radiological evidence of parenchymal interstitial fibrosis was found in 24% of the group; in 10% this was the only abnormality. Pleural fibrosis and/or calcification was found in the absence of parenchymal fibrosis in 14% of cases; in another 14%, both parenchymal and pleural abnormalities were detected. The prevalence was significantly higher in those employed for 20 or more years.

In the oil refinery workers, small irregular opacities, indicating interstitial pulmonary fibrosis, were detected in 31 (23%) cases; in 20 (15%), this was the only radiological abnormality. Radiological abnormalities of the pleura (pleural fibrosis and/or calcification) were found in 34 (25%) cases; in 23 (17%), pleural abnormalities were found in the absence of radiologically detectable parenchymal changes.

In both groups, pleural abnormalities were more prevalent than parenchymal changes. These findings indicate that radiological evidence of asbestosis is to be found with significant prevalence in chemical plant maintenance workers and in oil refinery workers. The risk of developing severe disabling pulmonary fibrosis seems to be unlikely, since few of the cases had small irregular opacities graded 2/1 or higher. The risk of lung cancer and/or mesothelioma in these workers has yet to be assessed.

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RESUME

Les effets adverses sur la santé associés à l'exposition à l'amiante sont bien connus et bien étudiés dans les groupes professionnels directement exposés à cette substance - mineurs d'amiante, travailleurs de l'industrie textile exposés à l'amiante, travailleurs de l'industrie des isolants. Mais on n'a pas complètement déterminé les dangers de l'amiante pour les travailleurs qui sont indirectement exposés dans les industries ayant fait un large emploi de l'amiante comme isolant.

Afin d'évaluer les dangers potentiels de l'amiante pour le personnel d'entretien de l'industrie chimique et pour celui des raffineries de pétrole, les auteurs ont effectué deux enquêtes cliniques transversales: 185 membres du personnel d'entretien d'une grande entreprise chimique et 137 membres du personnel d'une raffinerie de pétrole ont été étudiés. Les deux groupes se caractérisaient par un emploi de longue durée (plus de 20 ans).

Parmi le personnel d'entretien de l'usine chimique, on a observé des signes radiologiques de fibrose interstitielle parenchymateuse chez 24% des sujets; chez 10% ils constituaient la seule anomalie. Une fibrose et/ou une calcification pleurales ont été constatées en l'absence de fibrose parenchymateuse dans 14% des cas; dans une autre proportion de 14%, on a détecté des anomalies à la fois parenchymateuses et pleurales. La prévalence s'avérait sensiblement plus forte chez les personnes employées pendant 20 ans ou plus.

Parmi les employés de la raffinerie de pétrole, de petites opacités irrégulières, révélatrices d'une fibrose pulmonaire interstitielle, ont été décelées dans 31 (23%) cas; chez 20 sujets (15%) elles constituaient la seule anomalie radiologique. Des anomalies radiologiques de la plèvre (fibrose et/ou calcification pleurales) ont été observées dans 34 (25%) cas; chez 23 sujets (17%), les anomalies pleurales s'observaient en l'absence de lésions parenchymateuses radiologiquement détectables.

Dans les deux groupes, la prévalence des anomalies pleurales l'emportait sur celle des lésions parenchymateuses. Ces observations indiquent que les signes radiologiques d'asbestose se rencontrent assez fréquemment chez le personnel d'entretien des usines chimiques et chez les travailleurs des raffineries de pétrole. Le risque d'apparition d'une fibrose pulmonaire grave et invalidante semble peu probable, car rares étaient les sujets présentant des petites opacités irrégulières

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classées 2/1 ou plus. Le risque de cancer du poumon et/ou de mésothéliome chez ces travailleurs reste à déterminer.

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