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ASBESTOS RISK AMONG FULL-TIME WORKERS IN AN ELECTRICITY-GENERATING POWER STATION*

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The significant association of pleural fibrosis and/or mesothelioma with slight and/or transient exposure to asbestos^{1,2} has led to investigations undertaken to determine, whether persons working full-time in electricity-generating power stations might be at risk.³ In such stations, there are many areas with elevated temperatures, which in the past have been insulated with asbestos-containing materials. The asbestos fibers could be inhaled by the workers during lagging operations, particularly during the dismantling and stripping of old lagging material.

In early 1965, medical officers in an electricity-generating power station in London warned of the serious potential problem of asbestos exposure for workers of that company. It was not until 1975, however, that a report of the medical findings was given by Bonnel *et al.*,⁴ at the XIIIth International Congress on Occupational Health. They showed that of 77 ladders and laddermates, whose exposures ranged from 8 to 18 years, there had been 45 cases of asbestosis, including three workers with bronchogenic carcinoma, eight cases of mesothelioma, and 13 workers with pleural plaques. Although these findings were made only in ladders; it is clear that other workers involved in maintenance work at power stations are also at risk, although at a lower level.

For this reason, a survey has been conducted among volunteers from the full-time staff of a French electricity-generating power station.

MATERIALS AND METHODS

Two groups of subjects were studied simultaneously: 55 male workers from the full-time staff of the electricity-generating power station (EDF, Vitry), with an average period of employment of 24.2 years and a minimum of 3 years, and 53 males working in an automobile factory in the same area (Renault, Choisy le Roi), who had no previous asbestos exposure and served as the control group.

The 108 workers, from both groups, were examined during the period June 6 to November 7, 1977 according to the following procedure:

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TABLE 1
CHARACTERISTICS OF EXPOSED AND CONTROL WORKERS

Characteristic	Exposed (n = 55)	Control (n = 53)	p
Mean age (years)	49.6	49.9	NS
Range (years)			
<45	7	6	NS
45-49	15	17	NS
50-54	28	26	NS
>55	5	5	NS
Females	1	1	NS
Smoking habits			
Nonsmokers	12	11	NS
Ex-smokers	13	17	NS
Smokers	30	26	NS

A standardized questionnaire on past history of pulmonary disease, on current symptoms relating to the upper and lower respiratory system and to the gastrointestinal tract, and on occupational, domestic, and environmental histories for detection of past exposure to asbestos;

Posteroanterior (PA) and left lateral (L) chest x-rays, read blindly by two experienced physicians according to the ILO/UC 1971 classification;

TABLE 2
CLINICAL, FUNCTIONAL, AND CYTOLOGIC DATA
FOR EXPOSED AND CONTROL WORKERS

Data	Exposed (n = 55)		Control (n = 53)		p
	Number	Percent	Number	Percent	
Clinical					
Chronic bronchitis	11	20	10	18	NS
Shortness of breath at exercise	31	56	22	42	NS
Thoracic pain	19	34	9	17	0.03
Voice hoarsening	8	14.6	5	9.4	NS
Intestinal transit abnormalities	22	40	16	29.6	NS
Dyspepsia	1	1.8	2	3.8	NS
Gastralgia	15	27.3	21	38.9	NS
Abdominal pain	3	5.4	6	11.1	NS
Functional					
Normal	39	79	38	88	NS
Obstructive abnormalities (FEV ₁ /FVC < 80% predicted)	6	12	2	4	NS
Restrictive abnormalities (FVC < 80% predicted)	4	8	1	2	NS
Mixed	0		2	4	NS
Not reliable	6		11		NS
Cytologic					
Ferruginous bodies	18	32.7	3	5.6	0.001
Bronchoalveolar cells	39	74	30	57.6	0.08

Pulmonary function capacity (FVC), one curve (maximum expiratory FVC);

Three consecutive screening and two in bodies by light micro

Air was sampled Analysis of the asbestos (TEM) for identification of fibers⁶;

Statistical studies

X-RAY

X-Ray Data

Parenchymal opacities
Small opacities
Size

Profusion

Irregular Opacities
Size

Profusion

Pleural abnormalities
Diaphragm rectitude
Pleural thickening
(≥ 5mm)
Pleural calcification

*1971 ILO/UC Clas

Age and sex, as in and control Renault was a total of 43 cigarette consumption (pack-years) and 26 h

Pulmonary function tests; in each subject, one measurement of forced vital capacity (FVC), one of forced expiratory volume in 1 sec (FEV₁), and a flow-volume curve (maximum expiratory flow rate at 25% of forced vital capacity, MEFR 25% FVC);

Three consecutive sputum samples were collected, one in 60% alcohol for cytologic screening and two in 10% formaldehyde for detection and numeration of ferruginous bodies by light microscopy⁵;

Air was sampled both inside and outside the various workplaces of the two plants. Analysis of the asbestos fibers was performed by transmission electron microscopy (TEM) for identification and quantitation of TEM-sized chrysotile amphibole fibers⁶;

Statistical studies were performed by use of standard tests (chi-square).

TABLE 3
X-RAY FINDINGS* FOR EXPOSED AND CONTROL WORKERS

X-Ray Data		Exposed (n = 55)		Control (n = 53)		p	
		Number	Percent	Number	Percent		
Parenchymal opacities							
Small opacities							
Size	p	18	33.5	16	30.2	NS	
	q	3	5.6	6	11.3	NS	
	r	—	—	—	—	NS	
	Profusion	0/0-0/0	10	18.1	7	14.2	NS
		1/1	8	14.8	11	20.6	NS
		1/2	2	3.7	2	3.8	NS
		2/1	—	—	1	1.9	NS
	2/2	1	1.8	1	1.9	NS	
Irregular Opacities							
Size	s	31	57.4	37	69.8	NS	
	t	16	29.6	7	13.2	NS	
	u	2	3.7	1	1.9	NS	
	Profusion	0/0-0/0	14	25.4	14	26.4	NS
	1/1	19	35.2	19	35.8	NS	
	1/2	8	14.8	6	11.3	NS	
	2/1	5	9.3	4	7.6	NS	
	2/2	3	5.6	2	3.8	NS	
Pleural abnormalities							
Diaphragm rectitude		23	41.8	9	17.3	0.005	
Pleural thickening (≥ 5mm)		15	27.3	7	13	0.06	
Pleural calcification		9	16.7	2	3.9	0.03	

*1971 ILO/UC Classification.

RESULTS

Age and sex, as indicated in TABLE 1, were identical for both groups (exposed EDF and control Renault groups). Smoking habits were also identical in both groups: there was a total of 43 cigarette smokers in the two groups. In the exposed group, the mean cigarette consumption was 26.5 pack-years; there were 17 light smokers (less than 20 pack-years) and 26 heavy smokers (20 pack-years or more). In the control group, the

p	
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NS	

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Percent	p
NS	
NS	
17	0.03
9.4	NS
29.6	NS
3.8	NS
38.9	NS
11.1	NS
88	NS
4	NS
2	NS
4	NS
NS	
5.6	0.001
57.6	0.08

mean cigarette consumption was 28 pack-years; there were 15 light cigarette smokers and 28 heavy smokers.

Clinical data are given in TABLE 2. Respiratory symptoms (chronic bronchitis, dyspnea) were observed with the same frequency in the two groups, except chest pain, which was significantly more frequent in the exposed group than in the controls. Voice hoarsening and intestinal transit abnormality were more frequent in the exposed group; gastralgia, dyspepsia, and abdominal pain were more frequent in the control group. These differences were not significant, however.

Results of functional tests in the exposed group were: 39 patients with normal tests, six men with air flow obstruction (with an FEV_1/FVC ratio less than 80% of predicted values), and four workers with restrictive abnormalities (FVC less than 80% of predicted values). These findings were not significantly different between the two groups. However, the mean values of FVC (percent predicted) and MEFR 25%/FVC (percent predicted) were significantly lower in the exposed group (FVC 96%; MEFR 25%/FVC 87%) than in the control group (FVC 103%, MEFR 25%/FVC 106%; $p = 0.03$ and 0.05).

X-ray findings are given in TABLE 3. With regard to parenchymal opacities, there was no significant difference between the two groups. By contrast, three pleural abnormalities were significantly more frequently observed in the exposed group than

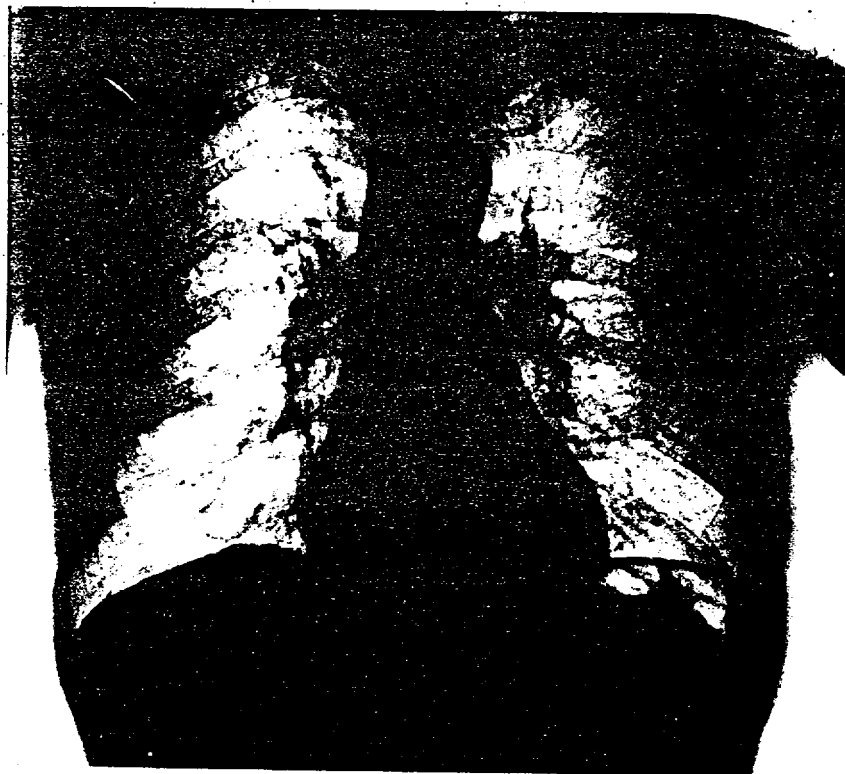


FIGURE 1. Rectitude of diaphragm (posteroanterior x-ray) in an asbestos-exposed worker.

FIGURE 2. Rect

in the controls: in (FIGURES 1 & 2), pleural calcification.

Cytologic examination have bronchoalveolar one exposed worker (TABLE 2).

Ferruginous bodies in the exposed group and the number of ferruginous bodies recalled previous, light bile factory. By contrast from 1 to 282 FB, with FB, one had 35 FB, the frequency of some number of FB for parenchymal opacities

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FIGURE 2. Rectitude of diaphragm (lateral x-ray) in an asbestos-exposed worker.

in the controls: in decreasing frequency, localized rectitude of the diaphragm (FIGURES 1 & 2), pleural thickening more than 5 mm thick (FIGURE 3), and pleural calcification.

Cytologic examination of sputa revealed that exposed subjects more frequently have bronchoalveolar cells; none had atypical cells suggestive of malignancy, although one exposed worker examined a few months later was found to have a lung carcinoma (TABLE 2).

Ferruginous bodies (FB) were found in the sputa of 18 workers (32.7%) in the exposed group and in only three workers (5.6%) in the control group; however, the number of ferruginous bodies in the latter subjects was very low (1-2 FB), and all recalled previous, light asbestos exposures before they started working in the automobile factory. By contrast, the number of FB in the exposed group was much higher: from 1 to 282 FB, with a mean of 24 FB for the positive cases: 16 subjects had 1-17 FB, one had 35 FB, and one had 282 FB (TABLE 2). A correlation was found between the frequency of some abnormalities possibly related to asbestos exposure and the number of FB for both groups (TABLE 4). However, there was no relation to parenchymal opacities.

sposed worker.



FIGURE 3. Pleural thickening in an asbestos-exposed worker.

TABLE 4
PERCENTAGE OF ABNORMALITIES RELATED TO NUMBER
OF FERRUGINOUS BODIES IN SPUTUM ($n = 108$)

Abnormality	Number of Ferruginous Bodies per Sputum Sample			P
	0 ($n = 87$)	1-10 ($n = 14$)	>10 ($n = 7$)	
Pleural calcification	3.5	35.7	42.9	0.001
Pleural thickening (≥ 5 mm)	14.8	35.7	54.1	0.01
Hoarsening of voice	8		28.6	0.06
Gastrointestinal symptoms	30.7		52.4	0.06
Small opacities, rounded and/or irregular ($\geq 1/1$ in lower two thirds of lung)	62.5	78.6	57.1	NS

Analysis of the
airborne fibers in
fibers in the air of

The finding of
that there is a risk
power plant. They
have been heavy in
was not restricted
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asbestos in air in

Building
Electricity-genera
power station
(exposed)
New station

Old station

Automobile factor
(controls)

ND = not detectable

indicated low levels
buildings. One of the
material; this pair
was used only in
longer periods in
asbestos dust, although
high concentrations
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There is more
diseases in the
as pleural calcification
demonstrated the
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Analysis of the air in the power plant (TABLE 5) demonstrated the presence of airborne fibers in the range $0.1\text{--}6000 \times 10^{-9} \text{ g/m}^3$; there were virtually no asbestos fibers in the air of the automobile factory.

DISCUSSION

The finding of asbestos bodies in the sputa of 33% of exposed workers confirms that there is a risk from asbestos for the full-time staff of an electricity-generating power plant. The intensity of asbestos exposure was moderate in most cases but must have been heavy in others, as indicated by the mean value of 24 FB.⁴ The asbestos risk was not restricted to workers involved in lagging operations, because FB and asbestos-related abnormalities were also found in other workers. Measurements of asbestos in air inside and outside the power station made at the time of this survey

TABLE 5
LEVELS OF ASBESTOS IN THE AIR OF BUILDINGS WHERE
EXPOSED AND CONTROL GROUPS WERE AT WORK

Building	Sampling Conditions	Sampling Site	Asbestos in Air (10^{-9} g/m^3)	
			Chrysotile	Amphibole
Electricity-generating power station (exposed)	during usual work	storeroom (asbestos materials)	6000	ND
		repair shop (asbestos sprayed)	8	ND
		indoor (0, 10, 45, 50 m level)	0.1–0.5	ND
		outdoor	0.4	ND
Old station	24 hr after insulating operations	indoor, 2 to 10 m from lagging operations	2–40	1–90
		outdoor	0.4	ND
		indoor	1	ND
Automobile factory (controls)	during usual work			

ND = not detectable; m = meter.

indicated low levels of fiber contamination. The power station is housed in two buildings. One building is old, in which many areas are insulated with asbestos material; this part of the station was in full-time use from 1928 to 1964 and thereafter was used only intermittently. All of the workers in the study worked for shorter or longer periods in the old power station. The new building appears to be less polluted by asbestos dust, although no sample has yet been taken during insulating operations, and high concentrations have been found in a storeroom where asbestos material is usually deposited and handled.

There is medical evidence of asbestos-related diseases or symptoms of such diseases in the exposed group. In addition to classic asbestos-related conditions, such as pleural calcification, pleural thickening, and decreased vital capacity, this study demonstrated the statistical significance of other abnormalities, such as localized rectitude of the diaphragm, recent hoarsening of the voice, thoracic pain, and various gastrointestinal tract symptoms. These abnormalities may also be related to asbestos

NUMBER
(38)

uginous
n Sample

)	>10 (n = 7)	p
	42.9	0.001
	54.1	0.01
28.6		0.06
52.4		0.06
	57.1	NS

exposure, as suggested by their relationship to the number of FB in sputum samples (TABLE 4), a factor known to be correlated with the intensity of asbestos exposure.⁵ These abnormalities may correspond to early symptoms that might be useful in detecting asbestos exposure in different occupations, although it is well known that the use of respiratory questionnaires is very difficult, and the interpretation of data must be cautious.⁷

By contrast, abnormal irregular parenchymal opacities, even more than 1/1, were not significantly different between exposed and control groups; moreover, their frequency was not greater in cases with more than 10 FB per sputum sample.

More severe diseases were also observed during this study: four cases of asbestosis were declared to the French Social Security system for compensation, and one case of bronchogenic carcinoma was diagnosed 6 months after the end of the study. There were no FB in the sputum of this patient, and, on operation, no pleural plaque was found in the left thorax; parenchymal samples from the lower lobe of the left lung showed no fibrosis and only a very small amount of asbestos fibers (63 FB/cm³ of fixed lung tissue, 5.10 TEM-sized fibers), mostly of the amphibole type (83%), with a mean diameter of 0.10 μ m and a mean length of 4.7 μ m (20% of the fibers were more than 8 μ m in length). Furthermore, during 1977, two laryngeal carcinomas were diagnosed among the 500 other workers of the power station; this finding should be compared with the significantly high frequency of voice changes observed among the workers investigated.⁸ The finding must, however, be interpreted with caution, in view of the selected nature of the population studied; this rate of laryngeal carcinoma should be compared with the incidence of this tumor in the general population or in a control group without asbestos exposure. Periodical medical surveillance by regular examinations, including chest radiography, will continue at the power station, not only for workers previously investigated but also for other workers, even after retirement.

These findings emphasize the following points:

An analogous asbestos risk must exist in other power stations in other plants where high temperatures demand the use of insulation materials. This aspect of occupational asbestos exposure, in workers not directly involved in lagging operations, requires further investigation.⁹ The present survey was an etiologic retrospective study, without measurement history in the different workplaces during the entire working period. A more precise study of the dose-response relationship at this kind of asbestos exposure would require more data on the concentration of airborne asbestos fibers in different areas of the power station during usual work hours and during the different operations of insulation and of removal of old lagging. The concentration of asbestos fibers in biologic specimens sampled from the workers should also be investigated more extensively.

New, asbestos-free, thermal insulating materials must be promoted for use in electricity-generating power stations and in other plants where asbestos materials have commonly been used in the past. In England, a decision was made as early as 1969 to abandon the use of asbestos-containing materials throughout the central electricity-generating system.⁴ For the replacement of old insulating asbestos-containing material, special protection is needed to avoid the contamination of the air in the whole building, which would otherwise pose the risk of asbestosis for the entire staff of the plant.

Sociale, Paris, France, by I chest x-rays.

A matched survey of electricity-generating power stations and an automobile plant has been confirmed by the presence of asbestos in the air sampled during the survey of the workers. The follow-up of the study group showed pleural thickening, pleural plaques, and, in some cases, gastrointestinal symptoms related to the number of years of exposure.

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in sputum samples
asbestos exposure.⁵
might be useful in
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data must

more than 1/1, were
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pleural plaque was
above of the left lung
fibers (63 FB/cm³ of
type (83%), with a
the fibers were more
al carcinomas were
this finding should be
observed among the
with caution, in view
of laryngeal carcinoma
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surveillance by regular
power station, not only
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In other plants where
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the entire staff of the

Sociale, Paris, France, by Dr. G. Bonnaud and Mr. P. Sebastien. Dr. R. Lilis read the chest x-rays.

SUMMARY

A matched survey of 55 full-time workers probably exposed to asbestos in an electricity-generating power station (exposed group) and of 53 unexposed workers in an automobile plant has been conducted. The asbestos risk in the power station was confirmed by the presence of airborne fibers in the range $0.1-6000 \times 10^{-9}$ g/m³ in the air sampled during the survey period and by the presence of FB in the sputa of 32.7% of the workers. The following parameters were significantly related to asbestos exposure in the study group: FB in the sputa, localized rectitude of the diaphragm, pleural thickening, pleural calcification, and chest pain. Moreover, for all persons studied, gastrointestinal symptoms and recent hoarsening of the voice were significantly related to the number of FB in the sputa.

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