# 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 laggers and laggermates, 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 laggers, 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

CLINCIAL, 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 | [illegible]6 | 0.08 |



Pulmonary function tests; in each subject, one measurement of forced vital capacity (FVC), one of forced expiratory volume in 1 sec ($FEV_1$), 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 microscopy[5];

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 fibers[6];

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 co[illegible]ption was 26.5 pack-years; there were 17 light smokers (less than 20 pack-years) [illegible] 26 heavy smokers (20 pack-years or more). In the control group, the 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

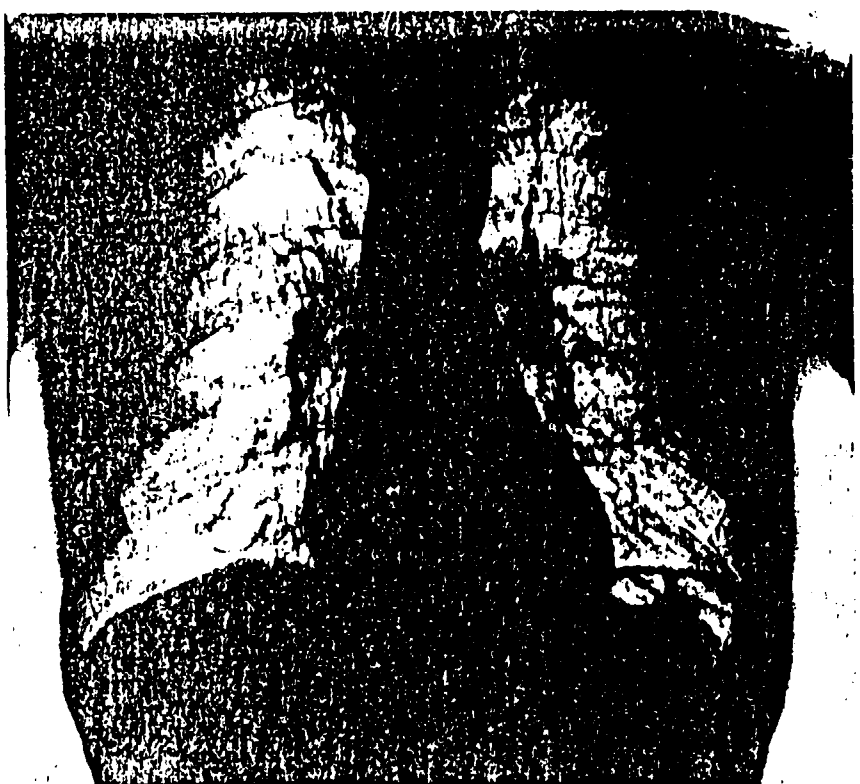

FIGURE 1. Rectitude of diaphragm (posteroanterior x-ray) in an asbestos-exposed worker.



FIGURE 2. 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.

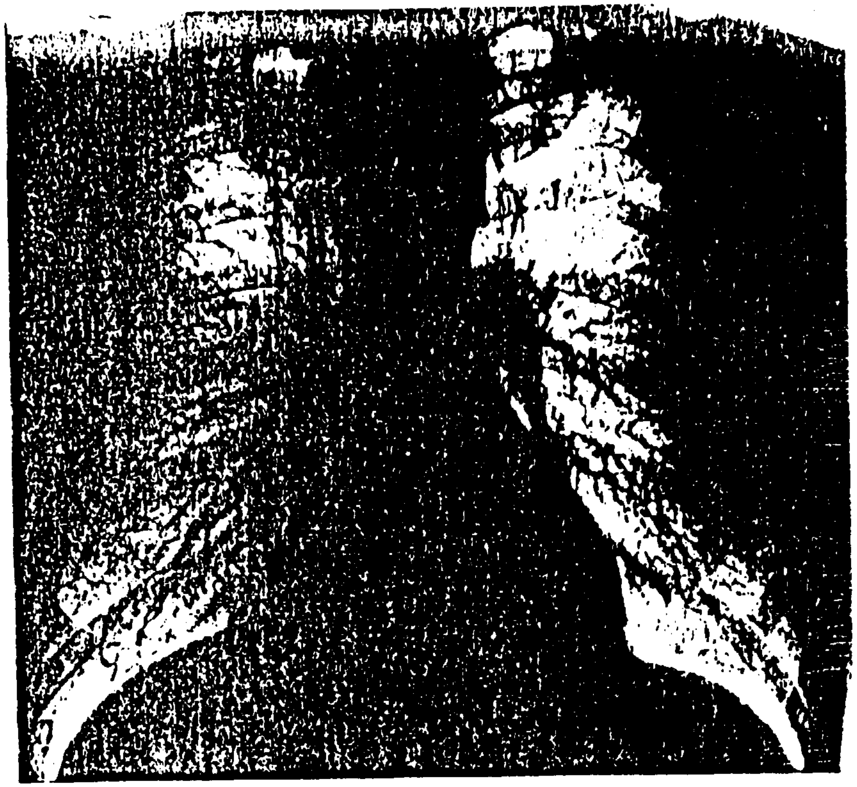

FIGURE 3. Pleural thickening in an asbestos-exposed worker.

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

| Abnormality | Number of Ferruginous Bodies per Sputum Sample: 0 ($n$ = 87) | 1–10 ($n$ = 14) | >10 ($n$ = 7) | p |
|---|---|---|---|---|
| Pleural calcification | 3.5 | 35.7 | 42.9 | 0.001 |
| Pleural thickening (>5mm) | 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 (>1/1 in lower two thirds of lung) | 62.5 | 78.6 | 57.1 | NS |



Analysis of the air in the power plant (TABLE 5) demonstrated the presence of airborne fibers in the range 0.1–6000 × $10^{-9}$ 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 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.

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 |
| New station | | indoor (0, 10, 45, 50 m level) | 0.1–0.5 | ND |
| | | outdoor | 0.4 | ND |
| | | | | ND |
| Old station | 24 hr after insulating operations | indoor, 2 to 10 m from lagging operations | 2–40 | 1–90 |
| | | outdoor | 0.4 | ND |
| Automobile factory (controls) | during usual work | indoor | 1 | ND |

ND = not detectable; m = meter.

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 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/cm$^3$ of fixed lung tissue, 5.10 TEM-sized fibers), mostly of the amphibole type (83%), with a mean diameter of 0.10 $\mu$m and a mean length of 4.7 $\mu$m (20% of the fibers were more than 8 $\mu$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.

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## 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 × $10^{-9}$ g/m$^3$ 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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