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ASBESTOSIS IN THE BARCELONA AREA
A DOSE-RESPONSE RELATIONSHIP

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ABSTRACT

In an epidemiological study of 1 262 workers employed in four factories (two manufactures of fibrocement, one of textile and one of autobrakes) in the Barcelona area a dose-response relationship was established between the radiological images of asbestosis and the individual cumulative doses of exposure to risk (dose-year/cm^3). The accumulated exposure doses were calculated on the basis of hygienic – evaluations carried out with personal samples collected on membrane filters and counted by means of light microscopy with phase contrast.

The examined population (89.8% males and 10.2% females) had a mean age of 39.8 years (S.D. ± 12.4) and a mean exposure to risk of 12.6 years (S.D. ± 7.6). The number of radiologically diagnosed asbestoses was 255, i.e. 20.2% (11.2% pleural asbestosis only, and 9.0% pulmonary and pleuro-pulmonary asbestosis). The dose-response relationship was determined with the help of a logarithmic equation by means of which the corresponding exponential curves were obtained.

For pleural asbestosis only a quick response saturation at very low individual cumulative doses (5 fibres-year/cm^3) was recorded.

Theoretically, for pulmonary asbestosis (pulmonary only and pleuro-pulmonary) the T.L.V. calculated for 50 years of a working life should be, according to our data, 0.07–0.10 fibres/cm^3 (taking into account protection levels of 99% and 95% respectively). There is no doubt that the risk has been overestimated because the study was carried out retrospectively and included only active workers.

Nevertheless, we think that it is pertinent to conclude that the dose-response relationship of pleural radiological asbestosis is different from that of pulmonary radiological asbestosis, and that the present worldwide trend to establish more exigent hygienic criteria for exposure to asbestos is justified.

For the last two years the Regional Institute in Barcelona (Social Service for Hygiene and Safety at Work) has been carrying out a continuous epidemiological study of asbestosis in the industrial area of Barcelona. The first clinical results of this study have already been published[13].

The seriousness of the problem requires the total eradication of asbestosis by means of technical measures which enable the control of air pollution based on appropriate hygienic standards.

The hygienic standards for asbestos are being continuously discussed and reviewed and they are established according to criteria which tend to be more and more exigent. In the Western World the proof for it are the criteria of the British Occupational Hygiene Society (B.O.H.S.) and the last proposals of the Chemical Contaminants T.L.V. Committee of the A.C.G.I.H.[1,2,3,4,5,6,9]. The possible dose-response relationship derived from our epidemiological research in the Barcelona area is discussed in this paper.

In Barcelona which is one of the most important industrial areas in Spain there are about 3 500 workers exposed to asbestos who are employed in 18 factories (six manufactures of autobrakes; four of insulation materials, four of textiles, two of fibrocement and two other). There are no shipbuilding or asbestos mining industries. All asbestos used in Spain is imported. According to the data for the last known quinquennium[7] the Spanish import of asbestos tends to grow considerably: 65 287 tons of asbestos were imported in 1971, 82 608 tons in 1972, 109045 tons in 1973, 125971 tons in 1974 and 94114 tons in 1975.

SUBJECTS AND METHODS

The starting point for the study were the epidemiological data and the hygienic evaluations in four factories (two fibrocement, one textile and one autobrakes manufacturers) that employ 1920 exposed workers.

Factories

Both fibrocement factories use predominantly mixtures of chrysotile and, to a smaller extent, amosite and crocidolite. One factory has been in operation for 70 years and the other for 50 years. Their technology is obsolete and it has remained the same for the last 20 years.

The textile factory uses only chrysotile; the technology is relatively new, about twenty years, and it was renewed five years ago.

The autobrakes factory was installed 15 years ago and its technology has remained the same. Only chrysotile is used.

Hygienic evaluations

The hygienic evaluations of the air pollution in the referred factories were undertaken from 1974 to 1978. We carried out 173 evaluations based on air samples collected by the membrane filter method (Millipore AAWPO 3700 of 0.8 μm/pore diameter). The counting was performed by light microscopy with phase contrast at 400 magnifications. Only fibres longer than 5 μm length were counted[11,12].

The 173 hygienic evaluations enabled us to analyse 56 different jobs.

Examined population

We examined 1 262 workers who represented 65.7% of the entire staff of the four factories (Table 1). Six workers were excluded from the study because they

TABLE 1
Workers examined.

Industries	All workers	Workers examined	
		N	%
Fibrocement (A)	840	723	86.1
Fibrocement (B)	752	274	36.4
Textile	158	110	69.6
Autobrakes	170	155	91.2
Total	1 920	1 262	65.7

suffered from silicosis due to exposure to free silica in the mining industry where they had worked before.

The examined population consisted of 1 133 (89.8%) male and 129 (10.2%) female workers, the ages varying from 16 to 69 years, the mean being 39.8 years (S.D. ± 12.4). The time of exposure to asbestos in the examined factories varied from 15 days to 55 years, the mean being 12.6 years (S.D. ± 7.5).

The population was examined from October 1976 till May 1977.

Epidemiological data

The exposure time from the occupational history and the radiological diagnosis were the only data used in this epidemiological study[13].

For the radiological diagnosis of asbestosis we followed the criteria of the ILO-U/C International Classification of Radiographies of Pneumoconiosis, 1971[10].

Thorax radiographies were taken from all examined workers in standard size at three projections (P-A and two obliques) according to the high kilovoltage technique recommended by Jacobson[8]. The radiographies were interpreted by three independent readers.

The radiological diagnoses were classified into three groups: no asbestosis, pleural asbestosis only and pulmonary and pleuro-pulmonary asbestosis.

No asbestosis – absence of suspect radiological images of asbestosis in the pleura as well as in the lungs. The suspect cases with degree 0/1 according to the International Classification, were considered as no asbestosis.

Pleural asbestosis only – suspect pleural images of asbestosis, without parenchymal appearances. The most frequent images refer to a pleural thickening.

Pulmonary and pleuro-pulmonary asbestosis – these were the cases with parenchymal changes from degree 1/0 onward, according to the International Classification, both in the case of parenchymal images only or if accompanied by pleural images.

Method

For each examined worker we calculated the total cumulative dose multiplying the time of exposure at each job by its dust concentration (cumulative dose years-fibres/cm³). If a worker occupied several workplaces we summed up the partial cumulative doses of each job in order to obtain the individual accumulated total dose.

The individual accumulated total dose was taken as a basis to study the statistical distribution according to the radiological diagnosis and the statistical significance of the so found mean differences was analysed. In the end we tried to calculate the dose-response curve between the individual cumulative doses and the percentages of radiological asbestosis. The analysis of the differences between the found means was carried out according to the tests of Student and Darmois. The dose-response curve was fitted to our data by means of the least squares method and plotted in semilog coordinate axes.

RESULTS

The hygienic evaluation revealed that there was a great dispersion of asbestos fibres concentrations in the air of different workplaces (Table 2). They varied from 49 to 0 fibres/cm³, the arithmetic mean was 6.55 fibres/cm³, and the standard deviation ±10.01[11,12]. The median for all measurements was 2.10 fibres/cm³. The poorest hygienic conditions and the highest concentrations of asbestos dust were detected in the textile factory. The two fibrocement factories showed the lowest asbestos pollution.

TABLE 2
Hygienic evaluations.

Industries	N	Fibres/cm³			
		Maximum	Minimum	Mean ± S.D.	Median
Fibrocement (A)	48	33.0	0.0	2.7 ± 6.9	0.2
Fibrocement (B)	23	9.0	0.0	2.0 ± 2.5	1.0
Textile	50	49.0	0.6	12.8 ± 13.4	8.0
Autobrakes	52	44.4	0.7	6.1 ± 7.6	3.2
Total	173	49.0	0.0	6.6 ± 10.0	2.1

The diagnosis and radiographic results for the 1 262 examined workers show an incidence of radiological asbestosis of 20.2% (11.2% pleural only and 9.0% pulmonary only and pleuro-pulmonary). In absolute figures the number of radiographically diagnosed asbestosis is 255 (Table 3).

The individual cumulative doses for the 1 262 workers are shown in Table 4.

For the workers with no radiological asbestosis the arithmetic mean of the individual cumulative doses was inferior to those of the workers with

TABLE 3
Prevalence (%) of radiological asbestosis.

Industries	No asbestosis		Radiological asbestosis: Only pleural		Radiological asbestosis: Only pulmonary and pleuro--pulmonary		Radiological asbestosis: Total asbestosis		Total examined (100%)
	N	%	N	%	N	%	N	%	
Fibrocement (A)	517	71.5	117	16.2	89	12.3	206	28.5	723
Fibrocement (B)	241	88.0	18	6.6	15	5.5	33	12.0	274
Textile	105	95.5	–	–	5	4.6	5	4.6	110
Autobrakes	144	92.9	6	3.9	5	3.2	11	7.1	155
Total	1 007	79.8	141	11.2	114	9.0	255	20.2	1 262

TABLE 4
Cumulative doses and radiological findings.

Radiological findings	N	Cumulative doses (fibres/cm³ – years): Minimum	Maximum	Median	Mean ± S.D.
Only pleural asbestosis	141	0.2	254.8	15.1	33 ± 46.2
Only pulmonary and pleuro-pulmonary	114	0.6	627.7	22.6	53 ± 99.3
Total radiological asbestosis	225	0.2	627.7	17.3	48 ± 77.5
No asbestosis	1007	0.0	285.6	3.0	14.3 ± 30.6*
Total examined	1262	0.0	627.7	4.6	20 ± 46.5

* Statistically significant ($P < 0.05$)

radiological asbestosis, both with pleural asbestosis only, and with pulmonary asbestosis only and pleuro-pulmonary asbestosis. These differences are statistically significant according to the test of Darmois ($P < 0.05$).

Although the workers with pleural asbestosis only present an individual cumulative dose mean which is inferior to those with pulmonary asbestosis only and pleuro-pulmonary asbestosis (33.19 compared with 53.55 fibres-year/cm³) the difference is not statistically significant. The regression equations for dose--response are as follows:

Radiological asbestosis, pleural only: % Incidence (Y) = 1.50 ln cumulative dose (x) – 9.36 (regression coefficient 0.33);

Radiological asbestosis, pulmonary only and pleuro-pulmonary: % Incidence (Y) = 10.63 ln cumulative doses (x) – 11.66 (regression coefficient 0.78);

Total radiological asbestosis (pleural, pulmonary and pleuro-pulmonary): % Incidence (Y) = 12.13 ln cumulative dose (x) – 2.30 (regression coefficient 0.88).

DISCUSSION

The percentages of radiological asbestosis according to the cumulative exposures appear in the dose-response relationship of the three exponential curves shown in Figure 1.

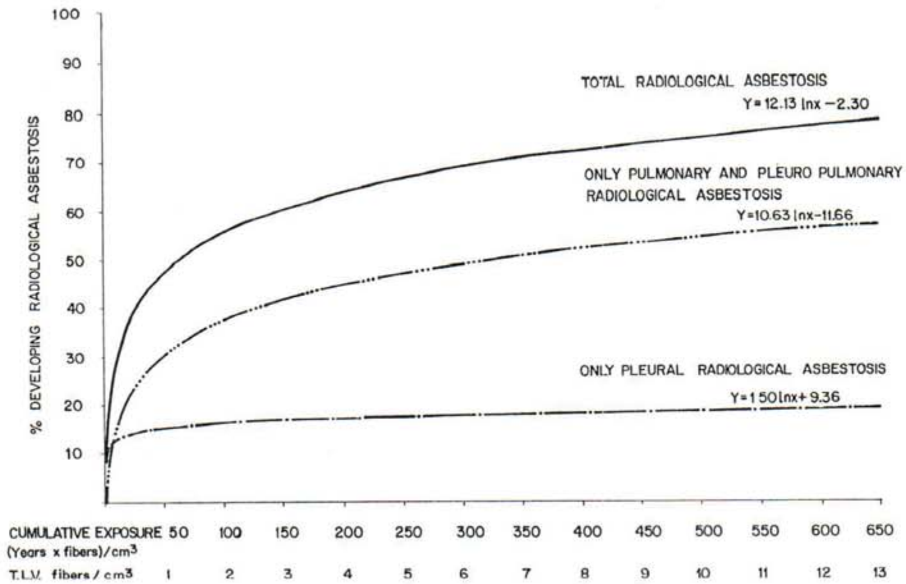

Fig. 1 – Doses (cumulative exposure) – response (% radiological asbestosis).

Considering the individual cumulative doses during 50 years of a working life, different T.L.V. will be obtained with the probable incidence of radiological asbestosis shown in Table 5.

TABLE 5

Incidence projected of radiological asbestosis according to the T.L.V. and cumulative doses (fibres/cm^3 × 50 years exposure).

T.L.V. (fibres/cm^3)	Cumulative doses 50 years exposure (fibres/cm^3)	Incidence projected of radiological asbestosis (%)		
		Pleural only	Only pulmonary and pleuro-pulmonary	Total radiological asbestosis
0.1	5	11.8	5.5	17.2
0.2	10	12.8	12.8	25.6
1	50	15.2	29.9	45.2
2	100	16.3	37.3	53.6
5	250	17.6	47.0	64.7
12	600	19.0	56.3	75.3

Although the average individual cumulative doses of the workers with pleural asbestosis only do not differ from those of the workers with pulmonary asbestosis only and pleuro-pulmonary asbestosis in a statistically significant way, there is a considerable difference between them in the dose-response relationship.

Both the regression equation and the shape of the fitting curve as well as the regression coefficients seem to lead to the conclusion that there exists a dose--response relationship completely different for the two types of radiological changes.

The radiological changes of only pleural asbestosis show an immediate response at a very low level of cumulative doses. At cumulative doses of 5 fibres year/cm^3 it is already possible to obtain a high incidence of only pleural asbestosis which remains stable at a level of 15% regardless of the dose.

We therefore suppose that the pleural response is independent and different from the parenchymal response. It occurs earlier and is more quickly saturable with the cumulative doses.

If we refer only to the dose-response relationship for pulmonary only and pleuro-pulmonary asbestosis at different hygienic levels, the theoretical T.L.V. are shown in Table 6 according to the probable percentage of incidence at 50 years of exposure. The theoretical T.L.V. of 0.07 fibres/cm^3 and of 0.10 fibres/cm^3 for protection levels of 99% and 95%, respectively, are much lower than those which the B.O.H.A. and the A.C.G.I.H. propose at present (from 2 to 0.2 fibres/cm^3[2,3,4,5]. According to our dose-response fitting, the percentages of pulmonary radiological asbestosis (pulmonary only and pleuro-pulmonary) for the mentioned T.L.V. would be 12.8% and 37.3% after 50 years of exposure to risk (25.6% and 53.6% if the pleural only radiological asbestosis is also taken into account).

TABLE 6
Incidence of radiological asbestosis based on the T.L.V. according to dose-response relationship.

Incidence of asbestosis (%)	T.L.V. (fibres/cm^3)	
	Only pulmonary and pleuro-pulmonary	Total asbestosis (pulmonary and pleural)
0	0.06	0.02
1	0.07	0.03
5	0.10	0.04
10	0.15	0.06
25	0.63	0.19
50	6.61	1.49
75	69.43	11.71
90	284.71	40.33
95	455.70	60.91
100	729.39	91.98

We are conscious that the foregoing theoretical figures are excessively strict for multiple reasons:

1) Errors in sampling and in hygienic evaluations;
2) Miscalculation in computing individual cumulative doses;
3) Underestimation of individual cumulative doses since the hygienic evaluations of the past were undoubtedly much less reliable than the present ones;
4) Finally, this has been a crossectional epidemiological study and therefore it lacks the necessary follow-up of the cohorts, i.e. there has been no morbidity-mortality control of those workers who left work before our study.

The only possible conclusion is that in the cases we analysed in Barcelona the dose-response relationship denotes a trend to better hygienic standards and that there is an important difference between the pleural only radiological responses and the pulmonary as well as pleuro-pulmonary responses.

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