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FINAL REPORT

EARLY DETECTION OF HEALTH HAZARDS DUE TO
ASBESTOS EXPOSURE

Project No. 02-009-3

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OBJECTIVES

The main objectives of the investigation were to study the prevalence of non-specific respiratory symptoms in workers engaged in asbestos mining and processing, to assess lung function and radiological changes in these workers, and, particularly, to study the relationship between concentration of airborne dust, length of exposure and total exposure on one, and pulmonary impairment on the other side.

STUDY SITES AND POPULATION

Two asbestos (chrysotile) mines, two factories producing asbestos - cement products and one factory manufacturing asbestos - textiles and friction materials were studied.

A total of 1242 asbestos workers were examined as well as a control group of 1950 workers (801 men and 1149 women) with no known exposure to asbestos and matching the study group in age and sex distribution and socioeconomic status. The ages of the asbestos workers were in the range 16-59 years, and their duration of exposure to asbestos 1-27 years.

The following typical operations were identified for the purpose of asbestos fibre and total dust sampling and assessment of total exposures of workers:

Minesmining

drilling

sorting

transportation

separation

crushing

milling, drying, screening

packing

Asbestos - cement productionpipes

storing

mixing

pipe forming

pipe finishing

plates

storing

mixing

plate forming

plate finishing

millboard

mixing

finishing

packing

Asbestos textile and friction material productiontextile

fibre preparation

spinning

twisting

weaving

finishing

friction productsmixing, coating,
extrudingforming, pressing, cutting
baking

cutting, drilling

asbestos tapes

pressing

cutting

M E T H O D S

Evaluation of exposure

Airborne particles were collected on millipore AA filters (37 mm, 0.8 um pore size) by means of personal samplers (Casella, London) with millipore field monitors as sampling heads, at the flow rate 1.2. - 2.0 l/min.

Personal samplers were fixed on the working clothes at the breathing zone whenever they did not interfere with the regular activities of the worker. These workers were randomly selected at each typical working operation. Where the personal sampler could interfere with the work or it was considered likely that the sample could be damaged, the technicians - surveyors followed the worker holding the sampling head of the personal sampler as close as possible to his breathing zone.

The number of samples collected at a typical operation depended on the variations of the concentrations during work shift and duration of collection of individual samples which, in turn, was dependent on the dust level. Depending on the dust level, the samples were collected through periods from 1 minute to 3 hours. Sampling was performed in the course of all the work shifts in the seasons winter/early spring and summer/early fall. It was planned to carry out sampling in all the four seasons of the year, but testing the difference between variances of concentrations obtained in various seasons did not give more significant dispersions of results between than within seasons. It was therefore decided to carry out the

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airborne dust sampling through two seasons of the year at the site of each typical operation.

A total of 2116 samples were collected.

In order to collect samples of optimal dust density, the sample was checked in the course of sampling with a magnifying glass, under a simultaneous horizontal illumination with a strong pocket torch. In such a way samples with dust density suitable for counting were obtained in the majority of cases.

Fibres were sized and counted at 400 magnification, using phase contrast illumination, with sample mounted in high viscosity solution of membrane filter material. Dimethyl phthalate and diethyl oxalate (1:1) were used as mounting chemicals. Clean filter material was added to reach the described viscosity. Fibres greater than 5 μm in length, with maximum diameter 3 μm , were counted using a calibrated Porton reticle. Only fibres with an aspect ratio greater than or equal to 3:1 were counted.

Total particles and fibres were counted simultaneously on the same sample.

Count concentrations were calculated in the usual standard way on the basis of the number of particles or fibres within the Porton reticle, the area surface of the reticle, the surface area of the dust sample, and the

volume of air from which the sample was separated. A calculation sheet is presented as Annex I.

The daily weighted exposures to total particles and, separately, fibres were calculated in the usual way on the basis of mean concentrations measured during typical work cycles and the corresponding duration of exposures to these concentrations. All work shifts in both seasons of the year were treated in the same way, and the final characteristic exposure at a typical operation was described by the mean of all the weighted daily exposures.

A complete work history was obtained for each worker, including his/her length of stay at each work place since the beginning of his/her employment. On the basis of these elements and the weighted daily exposures assessed for each typical operation, the total exposure of each worker was calculated as the sum of the products of the time spent at an operation and the corresponding weighted exposure.

Respiratory Symptoms

Information on chronic respiratory symptoms and smoking habits was recorded by a modified form of the British Medical Research Council questionnaire. Data were obtained by the interview method, in a standardized way, without suggestive additional questions. In addition to questions on respiratory symptoms (cough, expectoration,

dispnoea, wheezing and nasal catarrh), the questionnaire contained questions on detailed occupational history, past illness and some clinical findings (clubbed fingers, bronchial ronchi, warts on the skin). Special attention was paid to chest illness in the last three years preceding the survey. The questionnaire is presented in Annex II.

Definitions

Chronic cough and/or phlegm: cough and/or phlegm production on most days for at least three months per year.

Chronic bronchitis: cough and phlegm on most days for a minimum of three months in the year and for not less than two successive years;

Dyspnoea grades: 3 - shortness of breath when walking with other people at an ordinary pace on the level; grade 4 - shortness of breath when walking at own pace on the level.

Lung Function Testing

Pulmonary function testing included measurement of ventilatory capacity.

From the forced expiratory spirogram recorded with a spirometer (Pulmonor, Jones Medical Instrument Company), the forced vital capacity (FVC) and the one-second forced

expiratory volume (FEV_1) were obtained and the ratio $FEV_1/FVC\%$ was calculated.

Maximum expiratory flow-volume (MEFV) curves were recorded with a portable flow-volume spirometer (Peters, Mead and Van Ganse, 1969). The maximum flow rates at 50% and the last 25% of the control vital capacity (MEF50%, MEF25%) and peak expiratory flow (PEF) were read from these curves. Three forced expiratory spiograms and three MEFV curves were recorded for each subject, and the mean of the two highest values was used as the result of the test.

Normal values

FVC and FEV_1 were compared with predicted normal values of Morris, Koski and Johnson (1971). PEF, MEF50% and MEF25% were compared with the normal values of Cherniack and Raber (1972).

X-ray survey

Radiological evaluation of the respiratory tract was made on the basis of one x-ray of the thorax in the posterior anterior projection, using the standard technique. As the x-rays were taken in the field, employing x-ray equipment available on the spot, the equipment was not of exactly the same type or model. However, the same batch of films and chemicals were used, and identical developing techniques applied. Sanix-5 films (35.6 x 35.6 cm) of the Fotokemika Co., Zagreb, were used. X-ray exposures

were made at 80-85 kilovolts and 15-20 milliamperseconds. Developing was performed at 20°C through 7 minutes.

As equipment available in the field was not of high quality at some sites, the focus-film distance of at least 180 cm could not always be achieved. As a consequence, magnifying of all anatomical structures and pathological details resulted in some x-ray films.

The films were read by three independent readers (one from the country, two from England) using the full ILO/UC classification of radiographs of pneumoconioses (ILO, 1971).

Asbestos bodies

Asbestos bodies were identified in smears prepared from workers' sputa on standard microscope slides. Slides were dried, dehydrated in alcohol and put in DPX. Three hundred fields were scanned at 80 magnification, whereupon every body suspected to be an asbestos body was checked at 320 and 800 magnifications.

Phase contrast illumination was used by means of a microscope "Carl Zeiss-Opton".

Statistical analysis

Regression and correlation analyses were mainly used. Graded radiological changes and changes in lung function tests were treated as continuous variables and regressed on the exposure indices (years of exposure, weighted

total exposure in fibre-years and total particle-years) and age.

All the statistical analyses have been done using the MINITAB statistical package (except the Shapiro-Wilks tests for normality of distribution of residual variations) at the Clinical Research Center, Harrow, U.K. (Dr. Charles E. Rossiter). The histograms, analyses etc. are presented in four Annexes as produced by MINITAB, with annotations added.

R E S U L T S

RESPIRATORY SYMPTOMS AND SIGNS

Symptoms and signs of a total of 1146 asbestos workers (897 males and 245 females) have been analysed. The results are presented in the Annex III, pp. 2-33.

Distribution of basic data, exposure indices and symptoms

Distribution histograms of age and smoking habit are presented on page 2 of the Annex III. Distributions of workers among the five plants studied and the distribution histograms of durations of exposure to asbestos, years when first employed in plant, fibre-years and total particle-years of exposure are shown on pages 3 and 4.

The distributions of the presence or absence of chronic cough, chronic phlegm, chronic bronchitis, asbestos bodies in the sputum and dyspnoea of various

grades are presented on page 5.

Average exposure indices for groups without and with symptoms or signs

The tables on pages 6-8 illustrate the relationships between absence or presence of chronic cough, chronic phlegm, chronic bronchitis, asbestos bodies and dyspnoea of various grades, and mean age, duration of exposure to asbestos, fibre-years and total particle years, for each symptom or sign, separately for males and females and combined.

Both male and female asbestos workers with cough, phlegm or bronchitis were older compared to those without the symptoms, and they had all the mean exposure indices higher (duration of exposure, asbestos fibre-years and total particle-years). Increasing dyspnoea grades were related to increasing mean age, but not to exposure indices except for particle-years.

Prevalence of symptoms and signs by age and exposure groups

In order to calculate the prevalences of symptoms and signs in different age groups and exposure groups, the indices of age, duration of exposure, and total exposure, expressed in asbestos fibre-years and total particle-years, have been re-grouped as shown on page 9.

Prevalences of cough, phlegm, bronchitis, asbestos bodies and dyspnoea (3+) by age (5 age groups: 15-64 years), years of exposure (6 groups: 1 to 20 years), fibre-years (7 groups: 5 to 160 fibre-years), total particle-years (7 groups: 500 to 16000 particle-years), separately for

male non-smokers and smokers, and female non-smokers and smokers, and combined, are presented on pages 10-13. Prevalences are expressed as proportions of positive findings.

The prevalences of all the respiratory symptoms increase steadily with age both in non-smokers and smokers (page 10). The prevalences are higher in smokers than in non-smokers. The pattern of dependence of the prevalence on age is similar in non-smoking men and women; the number of female smokers was small. The prevalence of asbestos bodies is not related to age.

The patterns of prevalences related to years of exposure to asbestos (page 11) are similar to those related to age except for phlegm and bronchitis in non-smoking men which are hardly related to duration of exposure. The prevalences of dyspnoea in both men and women smokers are related to duration of exposure while those in non-smokers are much less.

The relationships between the prevalences of respiratory symptoms and indices of exposure level (fibre-years and total particle-years) are less well pronounced, particularly for separate groups of men and women, smokers and non-smokers (pages 12 and 13).

Relation between symptoms and age, exposure duration and exposure indices by sex and smoking habit

The exposure indices have been transformed into logarithms (to base 10). Distribution histograms of the transformed indices (duration of exposure, fibre-years

and total particle-years) are presented on page 14.

On pages 15-33, the presence or absence of chronic cough, chronic phlegm, chronic bronchitis, asbestos bodies, dyspnoea grade 3 and dyspnoea grades 4 or above is related to age, duration of exposure, fibre-years and total particle-years for male non-smokers, female non-smokers, male smokers and female smokers.

As expected, cough is most significantly related to smoking habit and age (page 15). It is related to duration of exposure in a similar way (page 16). Women had higher total exposure (fibre-years and total particle-years) than men although they were younger and had shorter average duration of exposure (pages 17 and 18).

Phlegm is also most significantly related to age and smoking habit (page 19). It is approximately well related to duration of exposure (page 20) and particle-years (page 22); the relation to fibre-years is less significant (page 21).

Chronic bronchitis is, of course, related to smoking habit and age (page 23). The relations to duration of exposure (page 24) and particle-years (page 26) are similar.

Asbestos bodies are not related to either age (page 27), or duration of exposure (page 21) and total particle-years (page 33) and, to a lesser degree, fibre-years (page 32).

Summary of main findings

1. Each symptom analysed was more common in males than in females and in smokers than in non-smokers.

2. Among non-smokers, the relations of chronic cough, chronic phlegm, chronic bronchitis and dyspnoea grade 3 or grades 4+ were similar for the two sexes.

3. Asbestos bodies were recorded in 41 of the 897 men.

4. Chronic cough was most significantly related to smoking habit and age, to a lesser degree to duration of exposure, and least to fibre-years and particle-years.

5. Chronic phlegm was most significantly related to smoking habit and age. The relations to duration of exposure and total particle-years were equal.

6. The pattern of the dependence of chronic bronchitis on smoking habit, age and exposure indices was similar to that of chronic phlegm. Chronic bronchitis was most significantly related to smoking habit and age, with duration of exposure and particle-years following an approximately equal level of significance.

7. Dyspnoea (grades 3 and 4 +, resp.) was most significantly related to smoking habits and age, followed by duration of exposure and total particle-years, and, to a lesser degree, fibre-years.

8. All the symptoms were found much less related to asbestos fibre-years than to total particle-years.

9. Asbestos bodies were not at all related to age, duration of exposure or either of the two indices of total exposure level.

10. Excluding those for asbestos bodies, the relations of respiratory symptoms to the indices of asbestos or total particle exposures accounted for additional variation in

their prevalence compared to that accounted for by sex or smoking.

LUNG FUNCTION TESTING

PREDICTION EQUATIONS

The control group consisted of 801 men and 1145 women with no known occupational exposure to asbestos or any other dust. Subjects with respiratory symptoms (cough, phlegm, bronchitis, dyspnoea) were excluded. Subjects in the age range 25-64 years were included in the analysis. Thus the analyses were performed on data collected in 518 men and 861 women.

The regression analyses were done, for each, sex, for FVC, FEV₁, Peakflow, MEF50% and MEF25% on

Age and Height

Age, Height and Cigarettes smoked per day

Age, Height, Cigarettes, and their 3 interactions

Age and Height for non-smokers and smokers separately

Age and Height (non-smokers) and Age, Height and

Cigarettes/day (smokers)

The extent to which each extra term in the equations added to the precision of the prediction was the basis for the selection of the regression equation to be used for the prediction of expected "normal" lung function for the asbestos workers.

The results are presented in the Annex IV.

For each lung function test the distribution of residuals is shown; the probabilities have been calculated from the Shapiro and Wilks test for the normality.

Forced vital capacity

A satisfactory fits were obtained by the regression on age and height alone. None of the other regression equations fitted significantly better. The results are shown on pages 3 and 4 of the Annex IV.

The prediction equations for men and women, respectively, are as follows (FVC in litres, age in years, height in metres):

$$\text{FVC (men)} = 4.626 - 0.0325 \text{ age} + 6.17 \text{ height}$$

$$\text{FVC (women)} = 2.832 - 0.0224 \text{ age} + 4.50 \text{ height}$$

Forced expiratory volume in one second

The forced expiratory volume was found to significantly depend on smoking in addition to age and height. A single relation to age and height was found acceptable for smokers and non-smokers. The results of statistical analyses are shown on pages 5 and 6 of the Annex IV.

The prediction equations are as follows (smoking in cigarettes/day):

$$\begin{aligned} \text{FEV}_1(\text{men}) &= -2.647 - 0.0351 \text{ age} + 4.51 \text{ height} \\ &\quad - 0.00307(\text{smoking}) \end{aligned}$$

$$\begin{aligned} \text{FEV}_1(\text{women}) &= -1.516 - 0.0275 \text{ age} + 3.40 \text{ height} \\ &\quad - 0.00244 (\text{smoking}) \end{aligned}$$

Peakflow

The regressions of peakflow values on independent variables were not satisfactory. This is best shown by the distribution of residuals after fitting the best regression lines and confirmed by the normal plots and the Shapiro-Wilks test for the normality of distributions of residuals (for men, page 7, for women page 8).

The data were reanalysed after transforming the original peakflow values to logarithms (pages 9 and 10). This removed much of the skewness but did not give a satisfactory distribution of residuals for women (distribution and Shapiro-Wilks test on page 10).

A combined regression equation for smokers and non-smokers fitted neither the male data nor female data satisfactorily, separate regressions were therefore fitted for smokers and non-smokers. The following are the best fit regression equations (peakflow in litres/min):

$$\begin{aligned} \text{men non-smokers } \log e (\text{peakflow}) &= 2.108 - 0.00311 \text{ age} + \\ &+ 0.022 \text{ height} \end{aligned}$$

$$\begin{aligned} \text{men smokers } \log e (\text{peakflow}) &= 0.321 - 0.00168 \text{ age} + \\ &+ 1.038 \text{ height} \end{aligned}$$

$$\begin{aligned} \text{women non-smokers } \log e (\text{peakflow}) &= 0.934 - 0.00409 \text{ age} + \\ &+ 0.631 \text{ height} \end{aligned}$$

$$\begin{aligned} \text{women smokers } \log e (\text{peakflow}) &= 0.848 - 0.00040 \text{ age} + \\ &+ 0.627 \text{ height} \end{aligned}$$

Maximum expiratory flow at 50% vital capacity

A single regression equation for smokers and non-smokers did not describe the results

satisfactorily; therefore, separate equations for smokers and non-smokers had to be developed. In addition, smoking (cigarettes/day) had to be included as a predictor variable for men smokers (pages 11 and 12).

The following are the best fit regression equations:

men non-smokers	MEF50% = 2.61 - 0.0307 age + 2.65 height
men smokers	MEF50% = -9.05 - 0.0508 age + 10.03 height - 0.03068 smoking
women non-smokers	MEF50% = 1.35 - 0.0282 age + 2.917 height
women smokers	MEF50% = 5.30 - 0.0542 age + 1.032 height

Maximum expiratory flow at 25% of vital capacity

The regressions of MEF25% values on the independent variables were not satisfactorily. This is shown by the distributions of residuals after fitting the best regression lines and confirmed by the normal plots and the Shapiro-Wilks test for normality of distributions of residuals (pages 13 and 14).

The data were reanalysed after transforming the MEF25% values into natural logarithms (pages 15 and 16). The residuals were satisfactorily normally distributed. Single regression equations for fitting the data on smokers and non-smokers did not prove satisfactory; separate equations were therefore developed for smokers and non-smokers. For men smokers, it was found necessary to include smoking (cigarettes/day) as an independent vari-

able.

The following are the best fit regression equations:

men non-smokers $\log e$ (MEF25%) = 0.486 - 0.01796 age +
+ 0.552 height

men smokers $\log e$ (MEF25%) = -0.02563 age + 1.642
height - 0.00453 smoking

women non-smokers $\log e$ (MEF25%) = 0.401 - 0.02269 age +
+ 0.720 height

women smokers $\log e$ (MEF25%) = 0.754 - 0.02652 age +
+ 0.540 height

BASIC DATA ON ASBESTOS WORKERS AND EXPOSURES

Out of 1233 subjects exposed to asbestos, 1126 (888 men and 238 women) underwent lung function testing. The results are presented in Annex V, pages 2-63.

Distribution histograms of age and smoking habits are shown on page 2 of the Annex V. Distributions of workers among the plants studied and the distribution histograms of duration of exposure, years first employed in plant, fibre-years and total particle-years of exposure are shown on pages 3 and 4.

PREDICTIONS OF NORMAL LUNG FUNCTION VALUES IN STUDY GROUP

Predicted values of forced vital capacity (FVC.P), forced expiratory volumen in one second (FEV₁.P), peakflow (log e peakflows : LPFLW.P), maximum expiratory flow at 50% vital capacity (MEF50%.P) and maximum expiratory flow at 25% vital capacity (log e MEF25% : LMEF25%.P) were calculated for each asbestos worker using the prediction equations developed from data on the control groups (pages 6-8 of this Annex).

In addition, predicted values of FVC and FEV₁

(FVC.PR, FEV₁.PR) were estimated from nomograms developed by Morris, Koski and Johnson (1971) and C.E.C.A. (1971). Prediction relations proposed by Cherniak and Raber (1972) were used to estimate the predicted normal values of peak-flow, MEF50% and MEF25% (PFLW.PR, MEF50%.PR, MEF25%.PR) for all the asbestos workers.

The relations between the predicted values calculated by means of the prediction equations developed from data on the control groups (indices of lung function P) and those derived on the basis of published information (indices of lung function PR), as well as the corresponding correlation coefficients, are presented on pages 5-11 of the Annex V. Practically all the correlations were satisfactory.

Comparing the results of the analyses based on the prediction equations developed on control data and those based on the published equations, the former yielded somewhat better relations of indices of lung function deficit expressed as differences (lung function test. $D = \text{lung function value measured} - \text{lung function value predicted}$) to (asbestos) dust exposure. For the statistically less satisfactory ratio indices (lung function test. $R = \text{lung function value measured} / \text{lung function value predicted}$) the fits were about equal. Only for peakflow the published relations proved to yield slightly better fits, but these results were not considered reliable enough because of the considerable number of subjects both in the control and study group who failed to do the peakflow test.

For all the above reasons, only the results based on the prediction equations developed from the data on the control groups are shown on pages 12-63 of Annex V.

CORRELATIONS BETWEEN LUNG FUNCTION DEFICIT AND INDEPENDENT VARIABLES

Correlations between the indices of lung function deficit and age, height, duration of exposure, fibre-years, total particle-years and smoking, respectively, are preceded in two tables on page 12, separately for male and female asbestos workers.

The highest correlation between an index of lung function deficit and an exposure index was found for the duration of exposure (of the order of 0.2), similar to correlation between the indices of lung function deficit and age. The correlations with asbestos fibre-years and total particle-years were much lower, rarely exceeding 0.1.

DISTRIBUTIONS OF INDICES OF LUNG FUNCTION DEFICIT

Histograms distributing distributions of the 12 indices of lung function deficit (FVC.D, FEV₁.D, LPFLW.D, MEF50.D, LMEF25.D, PFLW.D, MEF25.D; FVC.R, FEV₁.R, PFW.R, MEF50.R, MEF25.R), separately for male and female asbestos workers, are on pages 13-21 of the Annex V.

Taking into account that the expected normal values of the "difference" indices (D) is zero, and that negative values indicate lung function values poorer than normal, the distributions of all the indices, for both men and women without exception, show that asbestos workers had

lowered lung function..

The expected normal value of the "ratio" indices (.R) being 100% and lower values indicating poorer lung function than normal, the distributions of all the indices, for both men and women, also show that asbestos workers had lowered values of all the lung function indices measured.

REGRESSION ANALYSES

Regression analyses were performed of each index of lung function deficit on years of exposure (first regression) and on exposure years plus any other independent variable for which the partial regression coefficient was significantly different from zero (second regression).

The results of the regression analyses, together with histograms showing the distributions of residual variations about the regression lines, are shown on pages 23-63 of the Annex V.

Regression analysis for FVC.D

In addition to exposure years, only the partial regression coefficient for height in men (pages 23,24) and for age in women (pages 46,47) were significant. The first and second regression equations were as follows:

men FVC.D = -0.169 - 0.0135 exposure years
 FVC.D = 1.13 - 0.0145 exposure years -
 - 0.7430 height

Women FVC.D. = - 0.323 - 0.016 exposure years
 FVC.D = - 0.605 - 0.0292 exposure years +
 + 0.0116 age.

Distribution of residuals were satisfactory.

Regression analysis for FEV₁.D

In addition to exposure years, the partial regression coefficients for age, height and smoking in men (pages 25,26) and none for women (page 48) were significantly different from zero. The first and second regression equations, respectively, were as follows:

men FEV₁.D = -0.0664 - 0.0175.exposure years
 FEV₁.D = 1.88 - 0.0124 exposure years - 0.0061 age -
 - 0.991 height - 0.0039 smoking
women FEV₁.D = -0.373 - 0.0099 exposure years

The distributions of residuals were acceptable.

Regression analysis For LPFLW.D.

The residual variations about the regression line were not normally distributed. The linear regression analyses applied were not satisfactory (pages 27,28,49,50).

Regression analysis for MEF50.D

In addition to exposure years, the partial regression coefficients for age, height and smoking for men (pages 29, 30), while none for women (page 51) were significantly different from zero. The first and second regression equations, respectively, were as follows:

men MEF50.D = -1.30 - 0,04223 exposure years

MEF50.D = 10.6 - 0.0223 exposure years - 0.0204
age - 6.22 height - 0.0406 smoking

women MEF50.D = 1.50 + 0.0148 exposure years

Regression analysis for LMEF25.D

The partial regression coefficients for age, height and smoking for men (pages 31,32), while more for women (page 52), were significant. The following were the first and second regression equations, respectively:

men LMEF25.D = -0.266 - 0.0127 exposure years

LMEF25.D = 0.939 - 0.0056 exposure years - 0.0065
age - 0.534 height - 0.0081
smoking

women LMEF25.D = -0.535 - 0.0113 exposure years

The distributin of residual variations was good for the first regression for men; not so for the other equations.

Regression analysis for PFLW.D

In addition to those for exposure years, the partial regression coefficients for age, height and smoking for both men and women were significantly different from zero (pages 33,34 and 53,54 resp.). The first and second regression equations for men were the following:

PFLW.D = -2.44 - 0.0135 exposure years

PFLW.D = 3.44 - 0.0017 exposure years - 0.0138 age -
- 3.03 height - 0.0145 smoking

The distributions of residual variations about the regression lines for women were not normal.

Regression analysis for MEF25.D

The distributions of residuals about the regression lines were not normal.

Regression analysis for FVC.R

The partial regression coefficients for age for women was significantly different from zero. The distribution of residual variations about the regression lines were normal. The regression equations were as follows (pages 37 and 57, 58):

men $FVC.R = 97.0 - 0.326 \text{ exposure years}$

women $FVC.R = 92.4 - 0.560 \text{ exposure years}$

$FVC.R = 86.6 - 0.827 \text{ exposure years} + 0.239 \text{ age}$

Regression analysis for FEV₁.R

In addition to those for exposure years, the partial regression coefficients for age, height and smoking for men (pages 38, 39), while none for women (page 59), were significant. The following were the first and second regressions:

men $FEV_1.R = 98.7 - 0.520 \text{ exposure years}$

$FEV_1.R = 135 - 0.349 \text{ exposure years} - 0.182 \text{ age} -$
 $- 16.9 \text{ height} - 0.115 \text{ smoking}$

women $FEV_1.R = 84.4 - 0.501 \text{ exposure years}$

The distribution of residuals were satisfactory.

Regression analysis for PFLW.R

The partial regression coefficients for age and smoking were significantly different from zero for men (pages 40,41) and women (pages 60,61), but the residual variations about regression for women were not normally distributed. The first and second regressions for men were as follows:

$$\text{PFLW.R} = 69.2 - 0.266 \text{ exposure years}$$

$$\text{PFLW.R} = 77.8 - 0.0160 \text{ exposure years} - 0.228 \text{ age} - 0.146 \text{ smoking}$$

Regression analysis for MEF50.R

The coefficients for age, height and smoking for men were significantly different from zero. The distribution of residual variations about regression for women (page 62) were better than those for men (pages 42,43). The regression equations are the following:

men $\text{MEF50.R} = 81.7 - 0.873 \text{ exposure years}$

$$\text{MEF50.R} = 208.0 - 0.370 \text{ exposure years} - 0.479 \text{ age} - 60.7 \text{ height} - 0.584 \text{ smoking}$$

women $\text{MEF50.R} = 72.5 + 0.0963 \text{ exposure years}$

Regression analysis for MEF25.R

The residual variations about regression lines were not normally distributed indicating that the applied linear regression analyses were not satisfactory (pages 44,45 and 63).

Summary of main findings

1. The distribution of all the indices of lung function deficit (both the "difference" and the "ratio" indices), for both male and female asbestos workers, showed that asbestos workers had all the lung function values measured lower than predicted for population without exposure to dust.
2. The highest correlation between an index of lung function deficit and an index of exposure to asbestos was found for the duration of exposure (of the order 0.2).
3. The correlations between an index of lung function deficit and asbestos fibre-years or total particle-years were much lower, rarely exceeding 0.1.
4. In no case did asbestos fibre-years or total particle-years add significantly to the explanation of the lung function deficit after allowing for the duration of exposure to asbestos.
5. Smoking contributed significantly to the explanation of the reduction of all indices of lung function except FVC, even though the specific prediction equations used contained terms for the effect of smoking. This suggests a possible potentiating effect of smoking in the case of asbestos fibre (or specific total dust) exposure.

X-RAY SURVEY

Five hundred fifty one X-rays of male and 214 of female asbestos workers, for whom the evaluations of total asbestos exposure could be made, were analysed. The results are presented in the Annex VI, pages 2-50.

Comparison of readers

Histograms of each reader's readings of X-ray variables and tables of the X-ray variables inter-relating readings by the three readers are presented on pages 3-28. Results are presented of the assessment of film quality and visibility of parenchyma; the readings of profusion, predominant size and second size of small opacities; the readings of large opacities (no sizes B or C were found); pleural thickening: diffuse, plaques, width, face on, extent, diaphragm thickening, costophrenic angle; pleural calcification: diaphragm, wall, other, extent.

With few exceptions, the agreement among the three readers was acceptable.

Basic and exposure data

Histograms of age distribution, smoking habit and distribution among the five plants studied are shown on page 29. Distributions of duration of exposure to asbestos, years when first employed and total exposure in asbestos fibre-years and total particle years are presented on pages 30 and 31.

Representative X-ray scores

The medians of the readings of the three readers were taken as representative and included in all the subsequent analyses.

The distributions of the medians of radiographic scores are presented on pages 32 and 33. The distributions are shown for profusion and predominant size of small opacities, large opacities (only one positive case, size A!), pleural thickening - extent, diaphragm thickening (only one positive case!), costophrenic angle, and pleural calcification - extent (only three positive cases!).

Regression of X-ray indices on age and exposure indices

The results of stepwise regression analyses of radiographic indices on age and indices of exposure (duration of exposure, fibre-years and total particle-years), for male and female asbestos workers, are presented on pages 35-39.

For each radiographic index, the best fit regression equation has been calculated. The distributions of residual variations about the regression are presented. Regression coefficients are given for small opacities - profusion, pleural thickening-extent and costophrenic angle.

The residual variations about the best regression line are not normally distributed, indicating that the method of regression analysis applied could not adequately describe the relations between the radiographic

indices, and age and indices of exposure.

Average age and exposure indices for different X-ray scores

The relations between radiographic scores and the mean values of age and indices of exposure to asbestos (duration of exposure, asbestos fibre-years and total particle-years) are shown on pages 40-45. The relations are shown for eight classes of the profusion of small opacities, five classes of the extent of pleural thickening, diaphragm thickening, costophrenic angle and four classes of pleural thickening.

No significant conclusions can be derived from the results obtained.

Prevalence of radiographic findings by age and exposure

Age groups and groups by duration of exposure, fibre-years and total particle-years have been regrouped as shown on page 64.

On page 47, the prevalences in five different age groups are shown, for men, women and combined, of small opacities 0/1 plus and 1/1 plus, large opacities A plus, pleural thickening-extent right and left 1 plus, diaphragm thickening right and left, costophrenic angle right and left, and pleural calcification-extent right and left 1 plus. The prevalences of small opacities, pleural thickening, thickening of costophrenic angle and pleural calcification show tendencies of increase with age.

The prevalencies of the same radiographic indices

in six groups of exposure duration, for men, women and combined, are presented on page 48. Unlike in the case of age, the prevalences of the majority of radiographic indices do not seem to be related to duration of exposure, except for small opacities the prevalence of which shows a general tendency to increase with increasing duration of exposure.

The prevalences of radiographic indices in seven groups of fibre-years and seven groups of total particle-years, respectively are shown on pages 49 and 50, respectively. Only the prevalences of small opacities were related to the indices of exposure, particularly to total particle-years.

Summary of main findings

1. Prevalence of small opacities of category 1/0 or more was 10.5% (men: 13.6%) and that of small opacities 1/1 or more 4.7% (men 5.8%); prevalence of pleural thickening of category 1 or more was 6.8 (men 8.7%); prevalence of obliteration of costophrenic angle was 3.3% (men 4.8%).

Other radiological findings were much less frequent.

2. Linear regression analysis was not appropriate for relating the radiographic indices to dust exposure.

3. Prevalences of practically all the radiographic indices increased with age.

4. Only the prevalences of small opacities increased more or less consistently with duration of exposure to asbestos, asbestos fibre-years and total particle-years.

There was no consistent pattern of the relation of pleural thickening to indices of exposure.

FAMILY MEMBERS

It is stipulated in the plan of operation that attempts will be made to study lung function in a group of family members of asbestos workers who are not occupationally exposed to asbestos but who live in the vicinity of asbestos industry or mines. Hundred-sixteen adult family members were examined (62 men and 54 women). No increase in the prevalence of chronic bronchitis as compared with that found in other unexposed population samples in Yugoslavia was observed. Their mean measured and predicted values of FVC, FEV₁ and MEF 50% are presented in Table 1 along with the results of significance testing of differences between the mean predicted and measured values.

Table 1

Mean measured and predicted values of FVC, FEV₁
male and female inhabitants

	N	FVC			FEV ₁			MEP50%		
		Meas- ured	Pred- icted	P	Meas- ured	Pred- icted	P	Meas- ured	Pred- icted	P
Male smokers	40	4469 (103.8)	4601 (452.1)	>0.05	3454 (932.6)	3610 (487.8)	>0.05	5.0 (2.3)	5.7 (0.5)	>0.05
Male non smokers	22	4937 (106.1)	5082 (514.1)	>0.05	4050 (876.1)	4065 (475.6)	>0.05	5.6 (1.8)	6.0 (0.4)	>0.05
Female non smokers	54	3181 (732.6)	3492 (505.4)	<0.05	2543 (637.4)	2721 (461.9)	>0.05	3.8 (1.3)	4.5 (0.4)	<0.05

Numbers in parentheses are standard deviations.

No significant differences were found between the mean predicted and measured values in male examinees irrespective of their smoking habit. The difference observed in nonsmoking females is of doubtful significance because it was very difficult to obtain satisfactory collaboration in functional tests in this group and the difference is likely to be the consequence of technically unsatisfactory blows, and thus an artefact.

RETIRED WORKERS

Twenty-five retired workers were examined. Eighty per cent of them had spent more than 15 years in asbestos mining or processing. The results of their lung function testing are presented in Table 2 as the mean difference between their predicted and measured values, and the standard error of this difference. The results of the t-testing of the difference between the predicted and measured values are also presented in the Table (t-test for paired variables).

Table 2

The mean differences between predicted and measured FVC, FEV₁ and MEF50% values in retired workers (M = 25)

	FVC	FEV ₁	MEF50%
d	639.6	332.0	1.65
s	499.9	428.1	0.92
t	6.39	3.87	9.82
P	<0.01	<0.01	<0.01

As can be seen from Table 2, the mean values of all the three measured lung function tests in the group of retired workers were significantly lower than the normal values expected for their ages and heights ($P \ll 0.01$).

NEW WORKERS

The plan of operations called also for lung function measurements in a group of new workers at the very beginning of their asbestos exposure followed by periodic repeated measurements in the course of the study. A group of 32 women in the asbestos spinning and weaving sections in Ploče were followed through four years. The differences between their FVC and FEV₁ measured in their first and their fourth year of employment are presented in Table 3.

Table 3

The mean differences of FVC and FEV₁ measurements in the first and the fourth year of employment in a group of women newly employed in asbestos spinning and weaving

	FVC	FEV ₁
N	32	32
d	233.8	125.6
s	265.8	296.2
t	4.97	2.39
P	<0.01	<0.05

The mean annual decline in the group of new workers of both FVC and FEV₁ was greater than would be expected from the prediction equations.

DISCUSSION AND CONCLUSIONS

A total of 1242 asbestos workers were studied, employed in two chrysotile mines, two plants producing asbestos-cement products and one plant manufacturing asbestos textile and friction materials. In addition, a control group of a total of 1950 subjects without significant dust exposure were examined.

The results have been presented in the main body of the Report with details of statistical analyses in six Annexes.

Surprisingly enough, there was more evidence of relations to exposure, after allowing for smoking, for respiratory symptoms than for either the lung function or radiographic changes. The prevalence of all the respiratory symptoms were most significantly related to smoking habit and age, but there was also a strong relation to duration of exposure and total particle-years, particularly in the case of chronic cough and dyspnoea. As all the symptoms were much less related to asbestos fibre-years than to total particle-years, they are most likely the effect of the general exposure to particles rather than the specific exposure to asbestos fibres.

The distributions of all the indices used to express lung function deficit (7 "difference" and 5 "ratio" indices), for both male and female asbestos workers, without

exception showed that asbestos workers had lung function values lower than expected for a population of corresponding sex, age, and height distribution with no significant exposure to dust. However, the only index of exposure which contributed significantly to lung function reduction was duration of exposure and an index of lung function deficit was of the order of 0.2, while that between asbestos fibre-years or total particle-years and an index of lung function deficit exceeded 0.1 rarely. Highly significant lung function reduction was found in retired workers after allowing for their age. Greater average annual decline of lung function than expected on the basis of prediction equations was found in the course of the first four years of employment in 32 newly employed female workers. In contrast, no significant differences between measured and predicted lung function values were found in a group of 116 family members.

As to radiographic changes, prevalence of small opacities of category 1/0 or more was 10.5% and of category 1/1 or more 4.7%, prevalence of pleural thickening of category 1 or more 6.8 % and the prevalence of thickening of the costophrenic angle 3.3%. Other radiological findings were far less frequent. Prevalences of practically all the radiographic indices increased with age, but only the prevalences of small opacities showed significant relations to duration of exposure, total particle-years and asbestos fibre-years for smokers and

non-smokers. However, even though the regression analysis suggested that the significant relation to the exposure indices are largely due to their correlation with age. As to the pleural thickening, after allowing for smoking there remained a residual relation to age but not to the indices of exposure.

Table 4

Prevalence of some lung function deficits, radiographic indices and symptoms for smokers and non-smokers (males only)

Index	Prevalence %	
	Smokers	Non-smokers
FVC 70% pred.	2.5	3.9
FEV ₁ 70% pred.	6.9	5.8
Peakflow 70% pred.	63.3	48.2
MEF 50 70% pred.	52.7	31.9
MEF 25 70% pred.	55.4	35.8
Small opacities 1/0 +	17.0	8.8
Small opacities 1/1 +	6.5	4.8
Pleural thickening (Right)	11.1	5.7
Pleural thickening (Left)	9.9	6.6
Cough	49.0	19.2
Phlegm	37.5	16.4
Bronchitis	16.1	13.8
Dyspnoea (grade 3 +)	43.2	31.4

As has been found in many other studies of asbestos

workers, smoking was the most significant contribution to health impairment, however defined, in our study too. Table 4 shows, for males by smoking habit, the prevalences of some respiratory symptoms, the proportions of subjects with lung function tests less than 70% of predicted, and the prevalences of small opacities 1/o +, and the prevalence of pleural thickening on the right and left. Except for FVC, which is recognized as not being affected by smoking, all indices show worse values for smokers than non-smokers. However, the predicted values for lung function take into account the effect of smoking on lung function. Therefore, the increased prevalences of low values relative to the predicted among the smokers must reflect the additional interaction between smoking and exposure to (asbestos) dust. Nevertheless, the correlations between the reduction of lung function indices and the indices of exposure were all low and were not increased by considering compound smoking exposure indices. Obviously, the form of the interaction between smoking and exposure effects cannot be simply described.

Summarizing, respiratory symptoms showed most evidence of response to (asbestos) dust. Lung function and radiographic changes, while existing, were much less related to exposure. There was, however, some evidence of a harmful effect of simultaneous smoking and exposure.

A C K N O W L E D G E M E N T

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R E F E R E N C E S

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3. Commission des communautés européennes - CECA, Collection d'hygiène et de médecine du travail No 11, 2nd Ed., Luxembourg, 1971.
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- 2 -

How long have you had this cough and/or phlegm?

less than 2 years

two years or more

Have you ever coughed up blood? Yes No

BREATHLESSNESS

Are you ever troubled by shortness of breath, when hurrying on the level or walking up a slight hill? Yes No

Do you get short of breath walking with other people at an ordinary pace on the level? Yes No

Do you have to stop for breath when walking at your own pace on the level? Yes No

Are you short of breath on washing or dressing? Yes No

WHEEZING

Does your chest ever sound wheezy or whistling? Yes No

Does your chest sound wheezy occasionally apart from cold? Yes No

Does your chest sound wheezy regularly during the day or night? Yes No

Have you ever had attack of shortness of breath? Yes No

When did you have it the first time

before 30 yrs of age

at the age of 30 or later

do you still have it

NASAL CATARRH

Do you usually have a stuffy nose or catarrh in the winter? Yes No

Do you usually have this in the summer? Yes No

Do you have this for as much as 3 months a year? Yes No

CHEST ILLNESS

During the past 3 years have you had any chest illness that has kept you of work, indoors at home or in bed?

PAST ILLNESS

YWS

NO

Age

Have you had:

Bronchitis

Pneumonia

Pleurisy

Pulmonary tuberculosis

Bronchial asthma

Other chest diseases

SMOKING HISTORY

Do you smoke?

Yes

No

Have you ever smoked

Are you troubled by shortness of breath while working in dust?

Number of cigarettes smoked daily

Now

Previously

At what age did you start regular smoking _____

At what age did you stop regular smoking _____

OCCUPATIONAL HISTORY

Name of the industry _____

Number of years exposed to dust _____

Type of the industry _____

Type of the work _____

Asbest /asbest used for/:

textile _____

friction material _____

asbest-cement _____

isolation material _____

Have you ever been exposed to dust, gas
and/or fumes?

Exposure	duration of exposure	type of work
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CLINICAL FINDINGS

Yes No

Clubbed fingers

Bronchial ronchi

Warts on the skin

ANTHROPOMETRIC MEASUREMENTS

Standing height /cm/ _____

Circumference of the chest /cm/ _____

B249
10

10

10

