A MORTALITY STUDY AMONG MALE WORKERS OCCUPATIONALLY EXPOSED TO ASBESTOS DUST IN POLAND

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Abstract. A cohort study of 2194 male workers employed at a chrysotile asbestos factory between 1945 and 1973 is described. Mortality analysis was based on a subcohort of 670 male workers employed at the factory between 1945 and 1955. The analysis was performed twice, on 31 December 1981 and on 31 December 1985. The risk of death was determined on the basis of the SMR calculated by the man-years method. The reference population was the general male population in Poland. The results for neoplastic diseases were compatible. The total SMR for neoplasms was 133.0; for lung cancer — 183.3; these values were statistically significant. No cases of pleural mesothelioma were reported.

INTRODUCTION

The objective of the study was the mortality analysis of the persons occupationally exposed to asbestos dust, and, especially, the estimation of risk of malignant neoplasms.

At present there exist a considerable number of proofs based on the data collected in both experimental and epidemiologic studies which make it possible to indicate the carcinogenic role of asbestos for man. A review of literature concerning epidemiologic studies of populations exposed to asbestos dust shows that each type of asbestos causes an increased risk of lung cancer. However, the rate of cancer risk depends on the type of asbestos fibre used, and consequently, on the content of the most carcinogenically aggressive fibres in a given raw material. The content of fibres which are most carcinogenic varies depending on the type

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of asbestos mined from different deposits. Considerable differences among the contents of fibres were also observed in samples of asbestos taken from various beds of the same deposit. The rate of lung cancer risk depends also on dust dose, i.e. on dust concentration in air and on the length of exposure. It is known from literature that the rate of cancer risk, and especially of lung cancer, is strictly connected with technology of asbestos processing which varies depending on the country.

These premises indicate that for a population in a given country assessment of cancer risk cannot be treated as reliable when based on the results of epidemiologic studies performed in other countries. The estimation of risk in the study population is based on mortality in the reference population, which, most frequently, is the general population. Mortality in the general population reflects the influence of ethiological agents, both endogenous and exogenous, including extraoccupational agents such as cigarettes, alcohol, drugs and diet specific to a given population. For different industrial cohorts the absolute values of cancer risk determined on the basis of the incidence calculations in the general population are incomparable.

The rate of cancer risk in a historically prospective cohort can be a reference point for the successive risk assessments in exposed populations in the years following the implementation of the routine control of asbestos dust concentrations.

MATERIAL AND METHOD

The study was performed in a historically prospective cohort of workers employed in Lodz, at one of asbestos factories producing packings, gaskets, needled cloth, yarn, cords, asbestos-rubber cardboards and friction products. Every worker who had worked for at least 3 months in this plant in the period 1946—1973 was included in the cohort.

In the post-war history of the study factory the period between 1945 and 1955 was most unfavourable. During those years there were no ventilation systems at the factory and very high concentrations of asbestos dust were then reported. Modernization of the factory took place in 1956. Having this in mind and using the reports on the relatively long period of latency of neoplasms caused by exposure to asbestos dust, a decision to study a subcohort of workers employed between 1945 and 1955 was taken. This group was homogeneous as far as the magnitude of exposure went and observed long enough to treat the results concerning cancer risk as reliable. In this paper only the results obtained from examination of this subcohort are presented. 824 male workers were included in the group (Table 1).

Between 1945 and 1955 no systematically checked registers of con-

ditions at the work-stand were kept. Also workers' individual documentations concerning exposure during the whole period of service at the factory are not complete. Thus, after referring to the available documents and information obtained through the worker responsible for safety and hygiene at the workplace, a maximum value of asbestos dust concentration of each person in the cohort was established. This value together with the information about period of service became a basis for an approximate evaluation of an asbestos dust dose. Because of the imprecise estimation of the dose, it was considered in only two categories during the successive stages of the analysis, i.e. in high exposure dose and low exposure dose categories.

TABLE 1. Follow-up and Vital Status of the Cohort

Subjects	I analysis Period of observation: from 1945 to 1981		II analysis Period of observation: from 1945 to 1985	
	Number	%	Number	%
Total in study	824	100.0	670	100.0
Traced	670	81.3	667	99.6
Alive	445	54.0	382	57.0
Dead	225	27.3	285	42.6
Lost to follow-up	154	18.7	3	0.4

The situation of the cohort was described twice: on 31 December 1981 and on 31 December 1985 (Table 1). Till the end of 1985 the situation of 667 men, i.e. of 81% of the observed population, was reported. Within the group 382 men were alive and 285 dead.

The source of information about the causes of death in the cohort were death certificates of deceased persons. In 28 cases (9.8% of all deaths) it was impossible to establish the cause of death either because the death certificate was lost, or because a notice "the cause of death unknown" was included in the certificate. These deaths were considered only in the general mortality assessment.

All the cases of malignant neoplasms specified as causes of deaths were checked in the register of neoplasms at the Oncological Centre in Lodz. This was one of the methods to verify the information about deaths. In some cases additional information about the histopathological form of a neoplasm was obtained.

In order to establish the complete lists of workers eligible for inclusion in the cohort, the names of persons suffering from asbestosis were checked in the register of occupational diseases at the Institute of Occupational Medicine in Lodz. Attention was also given to finding out whe-

ther the information coming from the two sources and concerning personal and occupational data as well as the data connected with exposure to asbestos dust were consistent.

The risk of death was assessed using the standardized mortality ratio (SMR). Expected deaths were calculated using the number of man-years in exposure and age-specific as well as cause-specific deaths rates of men in Poland between 1945 and 1985.

RESULTS

At the end of 1985, 285 male workers from the observed cohort had died. The most frequent causes of death were circulatory system diseases (114 deaths) including atherosclerosis (34 deaths) and ischaemic heart disease (31 deaths). The second group of cases were malignant neoplasms (61 deaths). Most often they were localized in respiratory and intrathoracic organs (28 cases) including lungs (24 cases), and in digestive organs and peritoneum (25 cases). 14 deaths from stomach cancer were recorded in the group. The next groups of causes of deaths comprised injuries and poisonings (20 deaths), respiratory system diseases (19 deaths), and digestive system diseases (12 deaths) with dominating chronic liver disease and cirrhosis (10 cases). In the death certificates of 15 men from the study cohort notices "the cause of death unknown" or "sudden and inexplicable death" were found. Deaths caused by reasons other than the ones mentioned above occurred in single cases. Results of the first mortality analysis in this cohort carried out at the end of 1981 were presented in detail in separate publications (11, 12, 13) (Table 1).

Proportions of malignant neoplasms and circulatory system diseases among the total number of causes of deaths in the cohort exceeded analogous proportions calculated based on the data concerning the number of deaths among men over 20 years of age in Poland between 1945 and 1985. The proportion of deaths from respiratory system diseases and digestive system diseases corresponded to that observed in the population. In the latter group of diseases a clear disproportion was observed in the percentage of deaths from chronic liver disease and cirrhosis (3.5% in the cohort, 1.1% in the population). Injuries and poisonings occurred less frequently in the cohort than in the population (Fig. 1).

In the cohort the most numerous group of causes of death — circulatory system diseases — was divided into 3 subgroups: ischaemic heart disease, cerebrovascular disease and atherosclerosis. The proportion of ischaemic heart disease and atherosclerosis among the general number of causes of deaths is remarkably larger in the cohort than in the population of adult males in Poland (Fig. 2).

Ratios of mortality caused by the above mentioned groups of malignant neoplasms exceeded analogous ratios for the male population. The greatest disproportion was to be noted in the case of malignant neoplasms of respiratory and intrathoracic organs and malignant neoplasms of the trachea, bronchus and lung. The proportion of each of these two groups of cancers among the number of deaths in the cohort is twice as large as in the general population (Fig. 3).

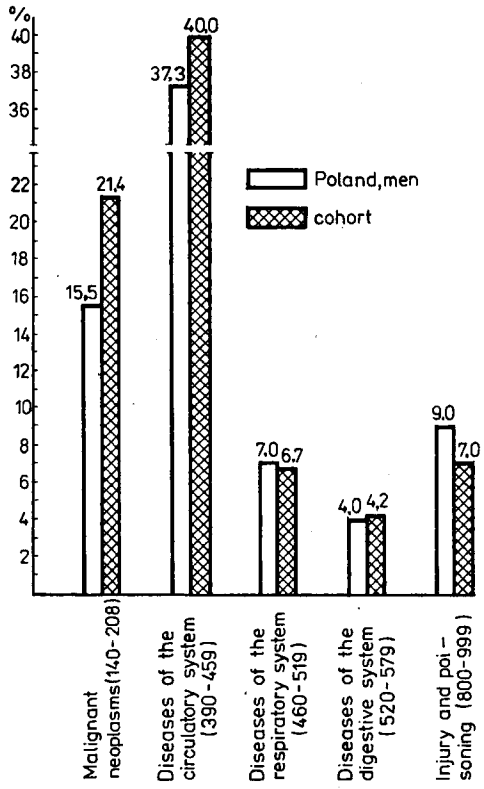

Fig. 1. Proportional mortality ratio from selected causes in Poland and in male cohort in period 1945—1985.

Mortality analysis based on the standardized mortality ratio has shown that the overall number of deaths in the cohort approximates the number of expected deaths which can be identified using the data for the reference population (SMR = 104.2); yet, while considering particular causes of death an excess mortality as compared to the expected number of deaths can be observed. The excess was recorded in the case of circulatory system diseases (SMR = 112.3) including ischaemic heart disease (SMR = 130.5) and, especially, in atherosclerosis (SMR = 184.5, $p < 0.05$). In the cohort an almost threefold excess of risk of deaths attributed to

chronic liver disease and cirrhosis was observed (SMR = 293.3, $p < 0.01$), the rate of the overall mortality from all digestive system diseases being the same as in the study population (SMR = 101.1) (Table 2).

In the group of causes of deaths which was most interesting from the viewpoint of the study, i.e. in the group of malignant neoplasms, a remarkable increase of risk (SMR = 133.0, $p < 0.05$) was noticed. The increase of risk was also observed in the case of malignant neoplasms of

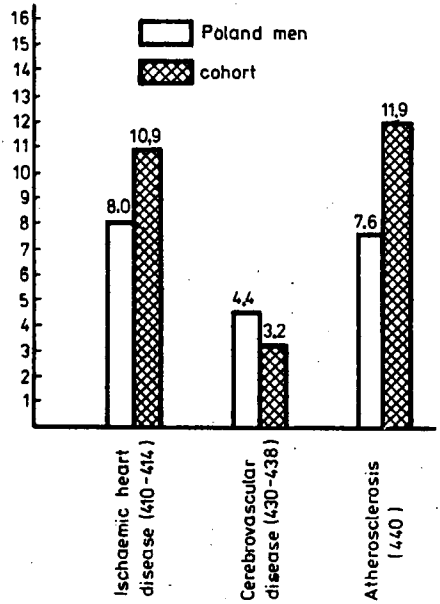

Fig. 2. Proportional mortality ratio from selected diseases of the circulatory system in Poland and in male cohort in period 1945—1985.

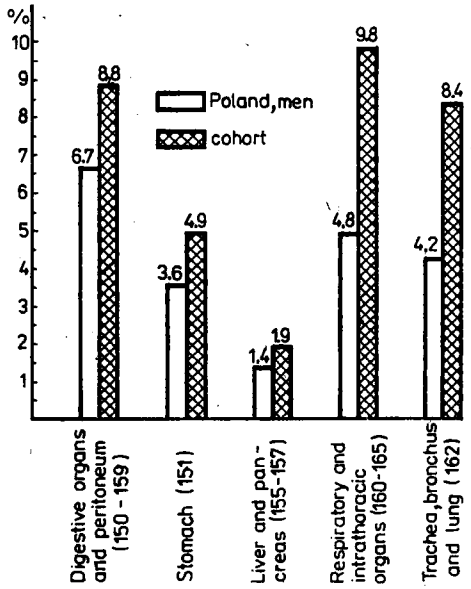

Fig. 3. Proportional mortality ratio from malignant neoplasms of selected sites in Poland and in male cohort in period 1945—1985.

respiratory and intrathoracic organs (SMR = 186.3, $p < 0.01$). The number of recorded deaths attributed to malignant neoplasms of the digestive system exceeded the expected number, similarly with the detailed determination of localization considered, but the excess was not statistically significant. Malignant neoplasms of different localization occurred less frequently than would have been expected on the basis of the data from the general population (Table 3). The obtained results, particularly for malignant neoplasms, confirm the results from the first study which was based on the observation of the cohort up to the end of 1981 (Table 2 and 3).

The analysis of the standardized mortality ratios in subgroups ac-

cording to age at the beginning of the work in exposure to asbestos dust (Table 4) showed an important excess of deaths only in those men who started work in exposure before they were 40 years old. The excess was recorded in the same groups of causes as the significant increase of mortality in the entire study cohort, i.e. in the general group of malignant

TABLE 2. Number of Deaths Observed and Expected by Cause

Cause of death	I analysis Period of observation: from 1945 to 1981			II analysis Period of observation: from 1945 to 1985		
	17964.75 person-years			19368.92 person-years		
	Deaths obs.	Deaths exp.	SMR	Deaths obs.	Deaths exp.	SMR
All causes (001—999)	225	247.95	90.7	285	273.62	104.2
Malignant neoplasms (140—208)	49	35.99	136.2 *	61	45.86	133.0 *
Diseases of the circulatory system (390—459)	85	89.30	95.2	114	101.54	112.3
— ischaemic heart disease (410—414)	25	19.38	129.0	31	23.76	130.5
— cerebrovascular disease (430—438)	4	11.39	35.1	9	12.20	73.8
— atherosclerosis (440)	22	14.99	146.8	34	18.43	184.5 **
Diseases of the respiratory system (460—519)	15	16.98	88.3	19	19.22	98.9
Diseases of the digestive system (520—579)	10	10.95	91.3	12	11.87	101.1
— chronic liver disease and cirrhosis (571)	8	2.96	270.0 *	10	3.41	293.3 **
Injury and poisoning	18	21.43	84.0	20	23.20	86.2

* $p < 0.05$
** $p < 0.01$
Figures in parentheses are ICD (9th Revision) code numbers

neoplasms (SMR = 159.1, $p < 0.05$), of malignant neoplasms of respiratory and intrathoracic organs (SMR = 225.0, $p < 0.01$) and of malignant neoplasms of the trachea, bronchus and lung (SMR = 216.5, $p < 0.05$). In this group of men a remarkable increase was observed in mortality from neoplasms of digestive organs and peritoneum (SMR = 143.9), and especially from stomach cancers (SMR = 152.1); but considering the small number of deaths observed, the above mentioned SMR-s are not of statistical significance. Among men who started work in exposure to asbestos dust at the age of 40 or later, the mortality rate increased by about 50% as compared to that among the general population. This mortality

TABLE 3. Observed and Expected Deaths from Malignant Neoplasms by Site

Cause of death	I analysis Period of observation: from 1945 to 1981			II analysis Period of observation: from 1945 to 1985		
	17964.75 person-years			19368.92 person-years		
	Deaths obs.	Deaths exp.	SMR	Deaths obs.	Deaths exp.	SMR
Malignant neoplasms (140—208)	49	35.99	136.2 *	61	45.86	133.0 *
digestive organs and peritoneum (150—159)	22	10.99	137.6	25	19.54	127.9
stomach (151)	12	8.89	135.0	14	10.48	133.6
liver and pancreas (155—157)	4	3.84	104.2	5	4.15	120.5
respiratory and intrathoracic organs (160—165)	21	10.99	191.1 **	28	14.75	189.8 **
trachea, bronchus and lung (162)	18	9.60	187.5 *	24	12.89	186.3 **
other sites (170—208)	6	8.00	75.0	8	10.29	77.8

* $p < 0.05$
** $p < 0.01$
Figures in parentheses are ICD (9th Revison) code numbers

TABLE 4. Observed and Expected Deaths from Malignant Neoplasms by Age at First Exposure and Site

Cause of death	— 39 years			40 and more years		
	15629.41 person-years			3739.50 person-years		
	Deaths obs.	Deaths exp.	SMR	Deaths obs.	Deaths exp.	SMR
Malignant neoplasms (140—208)	38	23.89	159.1 *	23	21.97	104.7
digestive organs and peritoneum (150—159)	14	9.79	143.0	11	9.75	112.8
stomach (151)	8	5.26	152.1	6	5.22	114.9
liver and pancreas (155—157)	2	2.09	95.8	3	2.06	145.6
respiratory and intrathoracic organs (160—165)	18	8.00	225.0 **	10	6.75	148.1
trachea, bronchus and lung (162)	15	6.93	216.5 *	9	5.96	151.1
other sites (170—208)	6	5.39	111.3	2	4.90	40.8

* $p < 0.05$
** $p < 0.01$
Figures in parentheses are ICD (9th Revision) code numbers

TABLE 5. Observed and Expected Deaths from Malignant Neoplasms by Dose of Asbestos Dust and Site

Cause of death	low			high		
	15091.51 person-years			4277.42 person-years		
	Deaths obs.	Deaths exp.	SMR	Deaths obs.	Deaths exp.	SMR
Malignant neoplasms (140—208)	41	36.91	111.1	20	8.95	223.5 **
digestive organs and peritoneum (150—159)	16	15.78	101.4	9	3.76	239.4 *
stomach (151)	10	8.46	118.2	4	2.02	197.9
liver and pancreas (155—157)	2	3.35	59.7	3	0.80	375.5
respiratory and intrathoracic organs (160—165)	19	11.80	161.0	9	2.95	304.8 **
trachea, bronchus and lung (162)	16	10.31	155.1	8	2.57	311.0 **
other sites (170—208)	6	8.30	72.3	2	1.98	100.9

* $p < 0.05$
** $p < 0.01$
Figures in parentheses are ICD (9th Revision) code numbers

was attributed to malignant neoplasms of the liver and pancreas (SMR = = 145.6), of respiratory and intrathoracic organs (SMR = 148.1), of the trachea, bronchus and lung (SMR = 151.1). These values are not statistically significant.

Within the cohort 2 subgroups were isolated as far as the level of exposure was concerned. To estimate the exposure, an asbestos dust dose to which a worker was exposed during his service was established. The group with low exposure comprised the workers for whom the dose was not greater than 50 mg/m³ x years of service; the group with severe exposure comprised persons exposed to a dose greater than that figure. A significant excess of mortality rate was observed only in the latter group of workers. Mortality among them was attributed to the same causes as in the case of the entire cohort, i.e. to malignant neoplasms of respiratory and intrathoracic organs (SMR = 304.8, $p < 0.01$), to malignant neoplasms of the trachea, bronchus and lung (SMR = 311.0, $p < 0.01$), and to malignant neoplasms of digestive organs and peritoneum (SMR = 239.4, $p < 0.05$) (Table 5).

DISCUSSION

The mortality analysis conducted twice (on 31 December 1981 and on 31 December 1985) in the cohort of male workers exposed to chrysotile asbestos between 1945 and 1955 confirmed the consensus results referring

to malignant neoplasms. Statistically significant excess mortality attributed to lung cancer, neoplasms of respiratory organs and malignant neoplasms in general was observed. The extension of the follow-up period of the cohort by more than 30 years in the second analysis resulted in obtaining slightly lower SMR-s due to malignant neoplasms and in an increase in the number of deaths from atherosclerosis. These facts support our assumptions concerning SMR-s and the length of follow-up period (2, 4, 15). A significant excess of deaths from chronic liver disease and cirrhosis (SMR = 293.3) can probably be explained by the overlapping of the effect of a high incidence of viral hepatitis in Poland and an increased number of persons abusing alcohol in the study group.

The obtained results cannot be directly compared with the results of the study of the cohort exposed to asbestos dust presented in the literature, because of the great variability of technological processes in the study cohort and consequent significant differences in dust concentrations at the work-stands. Through the study of heterogenous cohorts different, remarkably varying results were obtained (8, 14). A general rate of risk of lung cancer in the study cohort of men can be compared to that in the study cohort in the textile industry (5, 7, 9). Risk of death from lung cancer in the studied cohort was higher than that in the cohorts employed exclusively in the production of friction materials (1, 6).

The retrospective observation does not make it possible to obtain information about tobacco smoking in order to estimate the risk quota connected with the possible excess of the number of smokers in the study cohort. One indirect method for the control of the influence of the expected increased number of smokers in the cohort is the analysis of deaths from diseases resulting from smoking addiction and other than neoplasms (10). In the cohort SMR of circulatory system diseases in the first analysis was 95.2, and SMR of respiratory system diseases was 88.3; so, it was smaller than that in the general population.

The significant excess of deaths from cancer of the lung in the groups of workers exposed to the greatest asbestos dust doses indicates a causal relationship between the exposure and an increased risk of lung cancer.

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