Arh hig rada toksikol 1988;39:489–498

Congress Communication
UDC 613.65:611.24:549.6:616-036.22

ENVIRONMENTAL EXPOSURE TO CHRYSOTILE ASBESTOS AND CANCER EPIDEMIOLOGY

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A total of 1931 persons from the general population living around a chrysotile asbestos mine and mill were selected for the study as an exposed group. The control group consisted of 1250 persons from a village without asbestos fibre content in the ambient air. The exposed population decreased by 22% from the 1961 to the 1981 census and liveborn children were three times fewer. X-ray data show a high percentage of pleural involvement, suspect findings of the »Z« and »PL« categories with the prevalence of chronic bronchitis among the exposed, reaching a level of $P<0.01$. The incidence of malignant tumours was statistically significantly greater in the exposed than in the control group ($K=1$, $P<0.01$, $\chi^2=8.538$).

Since its establishment in 1954 the »Kolubara-azbest« plant at Stragari has been manufacturing a wide assortment of final products with chrysotile asbestos as basic raw material.

A sample of the Stragari asbestos was analysed in the National Bureau for Occupational Health and Safety at Work in Stockholm by X-ray diffraction and X-ray fluorescence spectroscopy. In the predominating crystal phase dominated chrysotile asbestos, which could also be optically established. A very low concentration of quartz (under 1%) was found. The presence of talc was not confirmed. Magnesium, silica and iron were dominant in the examined sample. A major element contained by chrysotile was ferrous oxide. Large quantities of chromium, nickel and manganese were also determined.

METAL AND BENZO(A)PYRENE CONTENTS IN STRAGARI CHRYSOTILE

A sample of chrysotile asbestos was analysed in the Toxicological Laboratory of the Institute of Public Health of Serbia in Belgrade. The sample was treated with 10% hydrochloric acid. The following values were obtained: nickel 424.0, chromium 2720.0, lead 2.0, copper 6.2, cadmium 0.1, manganese 530.0, and iron 29523.8 mg/kg. In addition, the presence of benzopyrene in asbestos was established.

Within the project »The Effect of Asbestos Dust on the Health of the Population Living in the Vicinity of the Mine and Asbestos Separation Plant at Stragari«, a detailed study was undertaken of the asbestos dust around the separation plant and in the immediate and wider atmosphere of the mine. The investigation of the presence of asbestos dust in the atmosphere of villages was carried out by the Hygiene Department of the Serbian Institute for Occupational Health (1).

The measurements took place in August 1975 and in November 1976, under normal working conditions of the separation plant. The first measurement was carried out during a rainy period, in order to exclude the dust originating in the ground, that present in the village under normal conditions of life, and in particular the dust caused by traffic.

The area of Stragari

The separation plant at Stragari is situated at an elevation of 300 m dominating the area. The village is located on a 260 m hill, in the valley of the small Jasenica river. The difference in altitude between the village, the separation plant and the neighbouring villages greatly influences the direction and diffusion of asbestos dust. At the same time the valley of the Jasenica river shows the direction of the air flow – from the east to the west, and thus the direction of dust circulation. The dust reaches the villages mainly by directed air circulation. In the areas with a less marked relief, the possibility of dust conveyance is greater, because of lower natural obstacles. The dust is partly transported by gravitation. It reaches more distant regions particularly the higher areas only with the wind. During the measurement procedure, the separation plant was in normal operation and the humid-wet ground prevented the appearance of any other dust in the atmosphere, except the one produced by the asbestos separation plant.

The dust in the atmosphere of villages was measured at sites with a dominant circulation, in order to obtain a clear picture of the harmful exposure of villages. Particles up to 7 μm in size were analysed by the granulometric method, and the total level of dustiness was determined by the gravimetric method, using large quantities of air (1 m^3). The particles – asbestos dust fibres were clearly visible in the microscopic field. The following values were obtained: Kotraža village 81–152 p/cm^3, 0.1–0.2 mg/m^3; Kotraža village, at 400 m distance from the separation plant: 92–233 p/cm^3, 0.1–0.6 mg/m^3; a site below the mine administration building, 350 m from the separation plant: 205–317 p/cm^3, 0.3–0.8 mg/m^3; a site 2 km from the separation plant: 60–107 p/cm^3, 0.0–0.1 mg/m^3; the separation grounds: 924 p/cm^3, 5 mg/m^3.

The measurements were carried out at 10 sites at different distances from the separation plant. The values obtained ranged from 57 to 117 p/cm^3, and from 0.0 to 0.1 mg/m^3. In a large number of places (more distant) gravimetric values were so small that they could not be recorded despite large quantities of air.

This study aimed at establishing the effect which asbestos dust may have produced on the health of the population living in the vicinity of the mine and the chrysotile asbestos separation plant so as to find out:

– whether vital parameters show or do not show significant differences between the villages that are exposed to asbestos and those that are not,

– whether the incidence of lesions established by X-rays which is high in the experimental and control groups is greater in the experimental than in the control group,

– whether the incidence of respiratory diseases is significantly greater among in the inhabitants living in the experimental area than in control subjects,

– whether the frequency of malignant diseases is higher in the population group exposed to asbestos dust in the environment.

METHODS

The demographic and vital parameter data were collected by the Institute of Statistics of Serbia, for the populations of Stragari, Vlakče and Maslaševo as the populations of the experimental area, and for the village of Rača Kragujevačka, which was taken as the control population. The data included the last three population censuses (1961, 1971, and 1981).

During 1986 fluoroscopy (10x10 cm) and two control examinations were undertaken of the population of Stragari (1023), Vlakče (485) and Maslaševo (423 inhabitants), and of the total of 1250 inhabitants from the control area (Rača Kragujevačka). From all inhabitants with suspect findings an X-ray with standard 35–40 cm films was taken. Those inhabitants received special instructions from the radiologist.

A total of 156 males and 232 inhabitants living in the close vicinity of the mine and the Stragari separation plant were radiographed and clinically examined.

For the sake of comparison with the 1980 results the radiographs were interpreted according to the 1971 international classification.

The questionnaire on chronic bronchitis of The British Medical Research Council (2) was used for the investigation of non-specific respiratory lesions. The findings are presented according to the instructions representing an integral part of the questionnaire.

The data on malignant diseases were first collected during the visits paid to all households. The data obtained in this way were then identified in the health service records.

RESULTS

Data about the population fluctuation (Table 1), according to the 1961 and 1981 censuses show that the number of inhabitants in the villages in the immediate vicinity of the separation plant and asbestos mine decreased by 22%. The indices of the entire population fluctuation in the control group amounted to 161 during the same period.

Table 1

Total number of inhabitants in the villages exposed to asbestos dust and in the control village (censuses 1961, 1971, 1981)

Census	Villages exposed to asbestos dust								Control village	
	Total		Vlakča		Maslaševo		Stragari		Rača	
	n	I	n	I	n	I	n	I	n	I
1961	3930	100	1236	100	908	100	1786	100	1417	100
1971	3560	96	1016	82	809	89	1735	97	1751	121
1981	3076	78	950	77	685	75	1441	81	2305	161

Table 2

Total number of newborns in the villages exposed to asbestos dust and in the control village by sex (censuses 1961, 1971, 1981)

Village	Number of newborns								
	1961			1971			1981		
	M	F	Total	M	F	Total	M	F	Total
Stragari	15	14	29	9	11	20	4	1	5
Vlakča	4	8	12	6	5	11	5	6	11
Maslaševo	10	5	15	3	3	6	–	2	2
Rača (control)	9	6	15	8	15	23	7	8	15

The number of liveborn children showed a declining trend (Table 2). From a total of 56 liveborn children, as per 1961 census, the number decreased to 37 liveborn children in 1971, and dropped to only 18 children in the 1981 census. The number of liveborn children in the control territory also decreased, if the population increase index is taken into consideration.

Table 3 shows death rates by villages, comparatively for the experimental and the control group.

From the latest population censuses a continuous decrease in birth rate may be noted, with an increase in the mortality rate in the area exposed to asbestos dust (Table 4). After an increase in the birth rate to 13.1 in 1971, a sudden fall to 6.5 was recorded in 1981 in the control group. However, the death rate significantly decreased from 11.3 in 1961 to 4.3 in 1981.

Table 3

Total number of the dead in the villages exposed to asbestos dust and in the control village (censuses 1961, 1971 and 1981)

Village	Number of dead								
	1961			1971			1981		
	M	F	Total	M	F	Total	M	F	Total
Stragari	7	9	16	16	13	29	5	6	11
Vlakča	4	6	10	3	12	15	6	8	14
Maslaševo	1	–	1	4	5	9	4	2	6
Rača (control)	11	5	16	8	12	20	6	4	10
District Rača	109	102		116	117		108	105	

Vital statistics data recorded in the villages from 1961.

Table 4

Trend in the birth rate and crude mortality rates in the areas exposed to asbestos dust and in the non-exposed area

Census	Experimental		Control group	
	Natality	Mortality	Natality	Mortality
1961	14.2	6.9	10.6	11.3
1971	10.4	14.9	13.1	11.4
1981	5.9	10.1	6.5	4.3

The radiography results for the inhabitants of Stragari and the surrounding area are presented in Tables 5 and 6, according to the 1980 and 1986 reports.

The data show a high percentage of pleural involvement and suspect findings of the »Z« type, with an increase in respect to the 1980 results. Pulmonary emphysema remained within the same levels, ranging from 9.8% to 16.0%.

Pleural lesions were established in nearly all cases suspect of pneumoconiosis, although the former could also be found outside the PL category, as shown by Table 6.

During the study of the incidence of chronic bronchitis two factors were paid special attention: smoking, and exposure to asbestos dust (Table 7). The prevalence of chronic bronchitis showed a higher statistical significance in the group of exposed men and women non-smokers, reaching a level of $P < 0.01$. The difference at the same level of significance ($p < 0.05$) was found for all examined women, and for men. However, no differences were established in the prevalence of chronic bronchitis among light and heavy smokers from either the experimental or control group.

Table 5

Radiographic data for the inhabitants of Stragari and vicinity (reports from 1980 and 1986)

Classification mark	1980				1986			
	Males (144)		Females (214)		Males (156)		Females (232)	
	N	%	N	%	N	%	N	%
O	120	83.3	62	75.7	123	78.8	167	72.0
Z	22	15.3	48	22.4	30	19.2	58	25.0
PL	44	30.6	55	25.7	55	35.3	70	30.2
EM	21	14.6	21	9.8	25	16.0	23	9.9
CO	31	21.5	49	22.9	35	22.4	53	22.8
OD	7	4.9	9	4.3	9	5.8	11	4.7
CN	3	2.0	15	7.0	4	2.6	12	5.2
DI	2	1.3	2	0.9	3	1.9	4	1.7
HO	2	1.3	–	–	2	1.3	1	0.4

Table 6

Pleural lesions in subjects suspect of having pneumoconiosis

Classification mark	1980				1986			
	Males		Females		Males		Females	
	N	%	N	%	N	%	N	%
Z	22	100	48	100	30	100	58	100
PL	18	81.8	31	64.6	25	83.3	38	65.5
EM	13	59.1	16	33.3	18	60.0	20	34.5
CO	10	45.5	23	47.9	14	46.7	27	50.0
OD	1	4.5	3	6.2	2	6.7	6	10.3
ON	1	4.5	5	10.4	1	3.3	3	5.2

Table 8 shows malignant diseases in the experimental and control population groups according to the type, location, sex and village. In addition to a four times higher incidence of malignant tumours in the vicinity of the mine and asbestos separation plant, there is a considerable difference in the type and location of tumours in control subjects.

In view of the differences in the number of inhabitants the testing was performed with χ^2 test. The incidence of malignant tumours was statistically significantly greater in the experimental than in the control population group (K=1, $P<0.01$, $\chi^2=8.538$).

Table 7

Prevalence of chronic bronchitis in the exposed and control groups by sex and smoking habits

Smoking category	Non-smokers				Light smokers*				Heavy smokers**				Total			
	Males		Females		Males		Females		Males		Females		Males		Females	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Experimental group																
– all	399	52.6	740	18.8	144	18.6	58	7.0	216	28.5	32	3.8	759	100	830	100
– with chronic bronchitis	75	18.8	128	17.3	32	22.2	12	20.7	68	31.5	10	31.3	175	23.1	150	181
Control group																
– all	325	46.4	552	86.3	139	19.9	53	8.3	236	33.7	35	5.5	700	100	640	100
– with chronic bronchitis	39	12.0	63	11.4	26	18.7	9	17.0	61	25.8	8	22.9	126	18.0	80	12.5

* fewer than 10 cigarettes per day; ** 10–20 cigarettes per day.

$\chi^2 = K = 1$
Non-smokers: $P<0.01$, 6.933 (M); $P<0.01$, 45.791 (F)
Total: $P<0.05$, 5.741(M); $P<0.01$, 8.388 (F)
Light smokers: $P<0.05$, 0.349 (M); $P<0.05$, 0.349 (F)
Heavy smokers: $P<0.05$, 1.568 (M); $P<0.05$, 1.307 (F)

Table 8

Sites of malignant tumours in the inhabitants who died between 1st July 1978 and 1st July 1987

Site of malignant tumours	Stragari		Kotraža		Vlakča		Maslaševo		Total		Rača (control)	
	M	F	M	F	M	F	M	F	M	F	M	F
lung	3	2	2	–	1	1	–	–	6	3	1	–
peritoneum	1	3	–	–	–	–	–	–	1	3	–	–
stomach	–	–	–	2	–	3	1	–	1	5	–	1
oesophagus and nasopharynx	3	–	–	–	–	–	–	1	3	1	–	–
haematopoetic system	–	1	1	–	1	–	–	1	2	2	–	–
rectum	1	–	–	–	–	1	–	1	1	2	1	2
liver and pancreas	–	2	–	–	–	–	–	–	–	2	–	–
breast	–	2	–	–	–	–	–	–	–	2	–	2
uterus	–	2	–	–	–	–	–	–	–	2	–	2
urogenital tract	2	1	–	–	–	–	–	1	2	2	–	–
others	3	1	–	–	(Hodgkin)			–	6	1	3	–
total	13	14	3	2	4	5	8	4	22	25	5	2

DISCUSSION

Concentrations of asbestos dust in the communal environment were determined by the thermoprecipitation method (1). Fully aware of all disadvantages of this method we used it in the absence of the standard equipment for the membrane filtration method. It undoubtedly proved that the population living in the vicinity of the mine and the separation plant was exposed to atmospheric asbestos.

During previous investigations (2) asbestos fibres were microscopically identified in the drinking water sediment (welled water), and in the sputum of inhabitants living in this area. The type and composition of the ore were determined by the methods of X-ray diffraction and fluorescence spectroscopy. Chrysotile asbestos was a predominant variety, with a high percent share of carcinogenic substances.

The significant differences in the demographic fluctuation, i.e. a great decrease in the number of inhabitants in the experimental area, as well as the disordered vital parameters, may be partly ascribed to the harmful effect of asbestos.

As established by previous studies (2), requests for health service were statistically significantly more numerous and use of health service was greater in the experimental than in the control area.

In order to assess the effects of exposure X-ray examination (Standard 35–40 cm radiographs) of the lungs was undertaken. In addition to the »Z« category, a slightly higher percentage of pleural lesions was found than during the previous examination (2). This fact points to the increase of positive X-ray findings with an extended exposure to asbestos dust in the living and working environment.

In consideration of the incidence of non-specific respiratory lesions, special attention was paid to the smoking habit and to the length of exposure to asbestos dust. The percentage of smokers was smaller (47.4%) in the exposed than in the control (53.6%) group, and considerably smaller among women (10.8 and 13.7%) than among men. There was also a considerably higher number of heavy smokers among men in both examined groups, and of light smokers among women.

The effects of air pollution with asbestos dust are best illustrated by a statistically significant difference in the occurrence and prevalence of chronic bronchitis among non-smokers of both sexes in the experimental and control group alike.

However, in the groups of smokers, despite percentual differences in the prevalence of chronic bronchitis, no statistically significant differences between the experimental and control group were established. Obviously, smoking habit in the majority of cases had a decisive role in the occurrence and prevalence of chronic bronchitis.

The finding of a large number of malignant tumours in the population living in the vicinity of the mine and the asbestos separation plant, agrees with the findings of many other authors (3–9). The finding of a large number of pulmonary and peritoneal cancers undoubtedly supports the attitudes that chrysotile asbestos has a carcinogenic effect. However, a large number of carcinogenic substances were identified by toxicological analysis of the sample of asbestos from that mine.

The industry to-day is more interested to find out whether certain types of asbestos have different effects, and whether all types can induce malignant diseases. It must be borne in mind that all types of asbestos may cause asbestosis, lung cancer and mesothelioma in humans and in experimental animals. However, from the follow-up of mortality rates and relative risks firm conclusions about the role of asbestos types could be drawn. The occurrence of asbestosis has little or no relevance to exposure to different types of asbestos. Any type of asbestos may cause pulmonary asbestosis (2, 4). It is different with mesothelioma. Here exposure to crocydolite matters more than to chrysotile (2, 9), although according to some authors mesothelioma does not occur only as a result of the effect of crocydolite, when the exposure to its mixture with chrysotile (10, 11) is in question.

It seems that despite uncertainties in the investigation of the harmful effect of asbestos in the living environment a great deal of attention is devoted to the methods for preventing lung cancer and mesothelioma. Smoking is one of the factors contributing to the faster occurrence of lung cancer. Contact with airborne fibres should be reduced as much as possible. There is a relationship between the concentration of fibres in the air and the occurrence of mesothelioma. Careful planning of asbestos use, and substituting asbestos with other less harmful materials remain principal recommendations (12).

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Sažetak

IZLOŽENOST KRIZOTIL AZBESTU U OKOLIŠU I EPIDEMIOLOGIJA RAKA

Studijom je obuhvaćena 1931 osoba opće populacije što živi u okolici azbestnih rudnika i mlinova. Kontrolna skupina sastojala se od 1250 osoba koje nisu izložene azbestu u okolišu. Izložena populacija smanjila se 22% u razdoblju od 1961. do 1981. godine budući da je bilo tri puta manje živorođene djece negoli u kontrolnoj skupini. Rendgenske snimke pokazuju visok postotak pleuralnih promjena, suspektnih nalaza »Z« i »PL« kategorije s prevalencijom kroničnog bronhitisa koji doseže razinu statističke značajnosti od $P<0,01$. Nađeno je da je incidencija malignih tumora statistički značajno veća u izoženih stanovnika negoli u kontrolnoj skupini ($K=1$, $P<0,01$, $\chi^2=8,538$).

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