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CANCER OF THE LUNG, PLEURA, LARYNX AND PHARYNX IN AN AREA WITH AN ASBESTOS-CEMENT PLANT

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Data on persons who died of cancer of the respiratory tract and pharynx in a Croatian coastal area with an asbestos-cement industry were collected and analysed for the period 1970–1990. Cancer mortality data were obtained from the Cancer Registry of Croatia. By the poll method, additional data on occupation, life style (smoking, alcohol drinking), length of residence in the area, educational level and cancer mortality among the relatives were obtained. The results of the investigation showed that the mortality rates for the lung, larynx and pharynx cancers, standardized according to age, were lower in the study area than expected (data for Croatia). Standardized mortality rates for mesothelioma were higher in the area under study for both sexes (except for women in the rural part of the area) than in Croatia. Within the study area the highest mortality rates for follow-up cancers were registered in the settlement where the asbestos-cement plant was located. Some settlements in two municipalities within the area also had higher mortality rates caused by these tumours in comparison with the rest of the study area or Croatia as a whole. In the evaluation of the obtained findings possible uneven distribution of emissions from the asbestos-cement plant caused by prevailing wind and air stream direction were considered.

Key terms:
alcohol consumption, coastal area, environmental exposure, epidemiological investigation, occupation, place of residence, smoking

Environmental exposure to asbestos has been studied to a much lesser extent than the occupational exposure. Epidemiological investigations show that risk of developing mesothelioma could be higher among people living in the vicinity of asbestos mines or asbestos processing plants (1–4). However, some studies do not confirm such findings (5). In similarly exposed populations there is much

less evidence for the risk of lung cancer to be higher than expected. A study on malignant tumours performed in a Croatian costal area with an asbestos processing plant (6, 7) showed that the average annual incidence rates (per 100,000 inhabitants) in the area under study compared with the expected rates for Croatia were lower for all followed-up tumours except for mesothelioma. The interesting finding in this particular study was that the distribution of the observed tumours among/within different villages/towns varied: in some of them the observed rate was higher than the expected rate. This pointed to a conclusion that air currents might be responsible for an uneven ambiental asbestos exposure and consequently for an uneven distribution of tumour incidence among separate settlements in the area.

The objective of the study presented in this paper is based on the assumption that emissions from an asbestos-cement plant which has been in operation for more than 70 years may have caused an increased risk of cancers of pleura, lung, larynx and pharynx in the area.

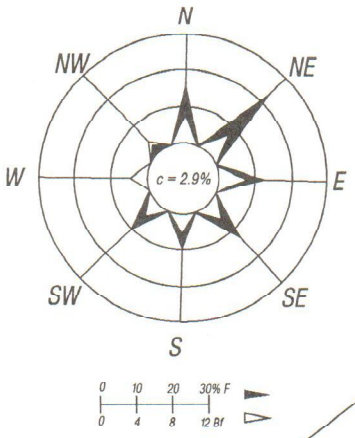
POPULATION AND METHODS

The investigation was carried out in the communities of Split, Solin and Kaštela located in the central part of the Croatian Adriatic coast. In addition to the asbestos cement industry located in Vranjic (Solin), there are also other industrial activities in the area: cement production, polyvinylchloride (PVC) production and processing, shipbuilding, construction industry, etc. Nineteen per cent of the area under study belongs to the coastal region with the town of Split and neighbouring settlements (8). In this particular part live 90% of the total number of inhabitants from the study area. Industry is also concentrated there. Mountains Kozjak (780 m) and Mosor (1340 m) separate the rural part from the rest of the area. In the rural subarea dominate small settlements (villages) with up to 500 inhabitants. The annual wind rose shows that prevailing winds in the area are those from the north-east (NE): 25%, north (N): 16%, south-east (SE): 14%, and south (S): 10% (9) (Figure).

When mild winds blow from the northern direction the contaminated air spreads towards the town of Split and the seven Kaštela villages. South winds accumulate polluted air towards the mountain barrier which protects the rural part of the area. During the calm period pollution stays within the narrow area in the vicinity of the emission source.

Based on the census data from 1981 the study area had 235,922 inhabitants: 115,255 men and 120,667 women. The town of Split counted 179,723 inhabitants, and the two neighbouring communities of Solin and Kaštela, where major industries are located, 38,318 inhabitants. At the same period the rural part, protected by the mountains, had 17,881 inhabitants. On the island of Šolta, also within the study area, there were 1470 inhabitants.

For the study a retrospective epidemiological approach was used, which covered a period of 21 years (1970–1990). The following malignant tumours, with the code numbers in parentheses, were followed: lung cancer (162), mesothelioma (163), laryngeal cancer (161) and pharyngeal cancer (146–148).



Calm (C) 2.9 F	N		NE		E		SE	
	F	Bf	F	Bf	F	Bf	F	Bf
	16.1	3.2	24.5	3.2	13.7	3.4	13.5	2.3
	S		SW		W		NW	
	F	Bf	F	Bf	F	Bf	F	Bf
	9.8	2.2	10.9	2.1	3.5	1.8	5.1	1.8

F = friquency of wind direction (%); Bf = wind force

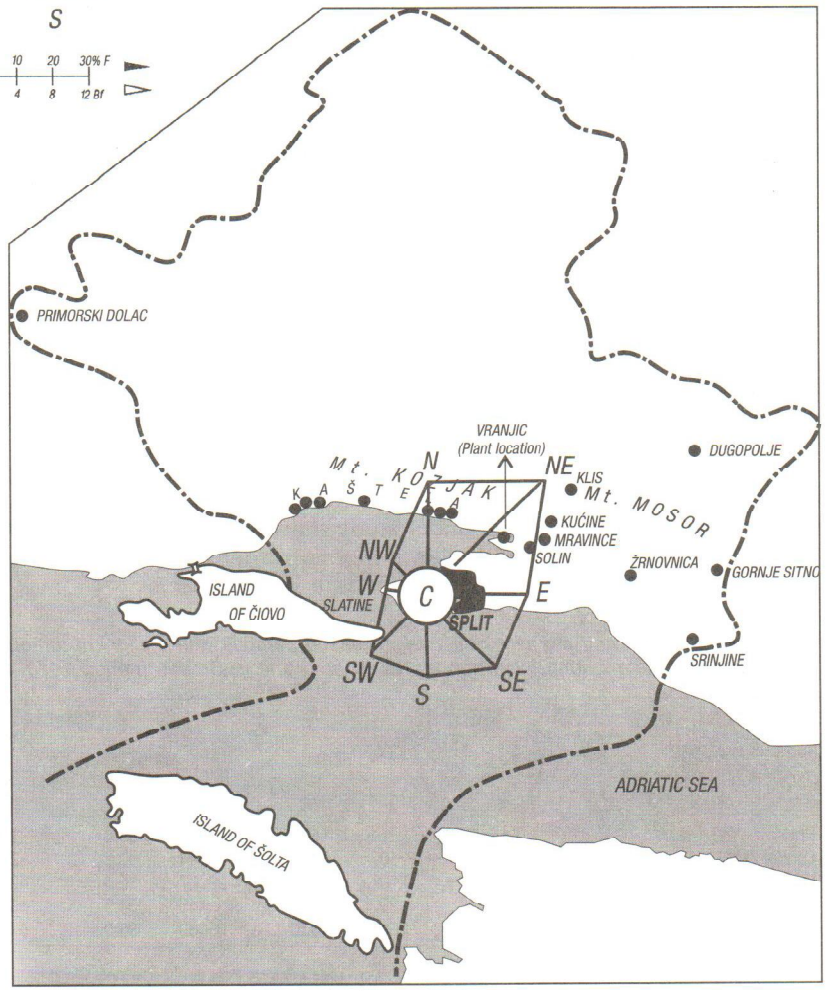


Figure *Study area and average annual wind rose*

The diagnoses verified as cause of death were based on the 1979 International Classification of Diseases, Injuries and Causes of Death. Data on cancer mortality were obtained from the Cancer Registry of Croatia. Analysis was made according to the cancer site and according to the person's age, sex and permanent residence. As there was no significant difference in the population structure during the 1970–1990 period, calculation of rates was based on the population census data from 1981, the middle year in the observation period.

The poll method was applied in families of persons who had died of cancer to gather additional data on their occupation, life style (smoking, alcohol consumption), educational level, length of residence in the study area, and cancer mortality among the person's relatives. A questionnaire was prepared to interview all the families of the deceased persons with mesothelioma, laryngeal and pharyngeal cancers. For those with lung cancer a selective approach was planned to include families of persons who had died of this type of tumour between 1975 and 1979, and between 1985 and 1989. For the evaluation of the ratio between the observed and expected cancer mortality rates, age standardisation was done (direct method was used) (10). Statistical differences between the variables were tested using the χ^2-test and comparison of Poisson rates (Statgraphics 3.0 1988, Statistical Graphics Corporation, U.S.A., 1988). $P<0.05$ was considered to be significant.

RESULTS

As shown in Table 1, in the study area and in Croatia in general the percentage of followed-up malignant tumours was much higher among men than among women. However, in the area under study the women to men ratio was different, with a lower percentage of studied tumours in men and a higher percentage in women compared to those for Croatia as a whole.

Table 1 *Number and sex distribution of deceased persons with malignant tumours of the pharynx, larynx, lung, pleura in the study area and in Croatia (period 1970–1990)*

Tumour site	Study area				Croatia			
	Men		Women		Men		Women	
	n	%	n	%	n	%	n	%
Pharynx (146-148)	62	84.9	11	15.1	1683	89.0	207	11.0
Larynx (161)	114	91.9	10	8.1	3844	93.2	281	6.8
Lung (162)	1025	83.0	210	17.0	29097	85.5	4919	14.5
Pleura (163)	38	65.5	20	34.5	445	58.9	310	41.1
Total	1239	83.2	251	16.8	35069	86.0	5717	14.0

Note: Numbers in parentheses in this and in the following tables are code numbers from the International Classification of Diseases, Injuries and Causes of Death (WHO, 1979)

In Table 2 age standardized (30 years and older) death rates per 100,000 studied malignant tumour cases are presented. As seen from this table, the rates of pharyngeal and laryngeal tumours in men, as well as the total rate of lung tumours were significantly lower in the study area than in Croatia. On the other hand the rates of mesothelioma in men (as well as the total rate) were significantly higher in the area under study than in Croatia. As far as the observed rates in the subareas (within the study area) are concerned, in Split the rates of pharyngeal, laryngeal and lung tumours in men were significantly lower compared with the expected rates, but the rate of mesothelioma was significantly higher compared with that for Croatia. In the Solin subarea the rates of lung tumours in women and of pleural tumours in men (as well as the total rate of mesothelioma) were significantly higher than expected. In the case of the rural part of the study area (Zagora) the rates of lung tumours were significantly lower compared with those for Croatia.

Table 2 *Age standardized (30 years and older) death rates/100,000 of malignant tumours of the pharynx, larynx, lung and pleura in the study area and in Croatia (period 1970–1990)*

Tumour site		Subareas in the study area					Croatia
		Split	Solin	Kaštela	Zagora	Total	
Pharynx (146-148)	Men	5.0**	11.4	6.9	6.6	5.6*	6.8
	Women	0.6	3.3	2.8	0.8	0.9	0.7
	Total	2.6*	7.2	4.8	3.4	3.1	3.5
Larynx (161)	Men	9.6***	26.2	15.2	8.9	10.9***	15.7
	Women	1.1	1.5	-	-	0.9	1.0
	Total	5.2***	13.4	7.5	4.0	5.5***	7.8
Lung (162)	Men	93.7***	174.7	129.7	74.5**	98.9***	118.4
	Women	17.2	34.7*	21.6	11.5	17.9	17.1
	Total	53.6***	104.2	75.2	39.7***	55.2***	63.9
Pleura (163)	Men	3.1	8.0*	5.0	3.7	3.6**	1.8
	Women	1.8	3.4	1.9	0.7	1.8	1.1
	Total	2.4*	5.6*	3.4	2.1	2.6***	1.4

For statistical analysis comparison of Poisson rates (Statgraphics 3.0, U.S.A., 1988) was used.
*P < 0.05, **P < 0.01, ***P < 0.001

To get information on the distribution of tumours in individual settlements within the study area average annual death rates per 100,000 persons were calculated according to the place of residence (Table 3).

The highest cancer mortality rates were registered in Vranjic, where the asbestos-cement factory is located. Particular settlements in the municipalities of Solin and Kaštela which are open to the winds blowing from the south and from the west (K. Sućurac, K. Gomilica, K. Lukšić) also had higher mortality rates caused by these tumours in comparison with the rest of the study area. Higher tumour rates were also registered in settlements where calm situations (periods without winds) may have often caused accumulation of pollutants in the vicinity of the emission source (town of Solin, Mravince, Kućine).

Table 3 *Cumulative number and average annual death rate (per 100,000 inhabitants) caused by malignant tumours by place of residence in selected settlements (period 1970–1990)*

Settlement	Inhabitants n	Distance from the asbestos-cement plant (km)	Geographic position from the emission source	Deceased persons n	Rate per 100,000 inhabitants
Vranjic	768	Plant location		17	105.4
Mravince	936	4.3	NE	13	66.1
Kućine	396	5.4	NE	5	60.1
Solin (town)	11880	2.3	E	96	38.5
Kaštel Lukšić	3588	8.3	NW	34	45.1
Kaštel Sućurac	5516	3.3	N	49	42.3
Kaštel Gomilica	2987	4.9	N	22	35.1
Klis	1826	5.8	NE	19	49.5
Žrnovnica	1155	8.4	E	13	53.6
Gornje sitno	1117	11.8	E	4	17.1
Zagora (total)	17881	6.8-27	NE	111	29.6
Split (town)	172137	3.1-5.9	S	1026	28.4

Interviews of the families of the cancer cases studied included 37 out of 73 persons with pharyngeal cancer, 71 out of 124 persons with laryngeal cancer, 35 out of 58 persons with mesothelioma, and 330 out of 660 persons with lung cancer. The rest of the families planned to be interviewed were not included for different reasons, such as change of address, longer absences, lack of cooperation. In the following tables (Tables 4–6) data obtained in the interviewed families are presented.

Table 4 *Cumulative number and average annual death rates (per 100,000 inhabitants) caused by malignant tumours by occupation of deceased persons (period 1970–1990)**

Type of industry	Average number of employees	Number of subjects with tumours of pharynx, larynx, lung and pleura	Average annual death rate caused by tumours studied
Asbestos-cement plant	850	11	61.6
Cement production	4100	42	48.8
Chemical (PVC) industry	2400	23	45.6
Construction industry	3800	28	35.1
Other	26000	140	25.6

* Data relate to 473 deceased persons (out of a total of 1490) obtained by interview from members of family

Table 4 shows the number of malignant tumours and death rates (per 100,000) by professional activities of the persons involved. The highest mortality rates were found in those who used to work in the asbestos-cement industry and cement production. Table 5 shows smoking habit (%) in persons who died from the studied tumours. As seen from the table the percentage of smokers was

much higher among the deceased men than among deceased women. The highest percentage of smokers in men and women pertained to those with cancer of the larynx and lung cancer. The highest percentage of deceased men was in the group of those who smoked between 20 and 30 cigarettes daily; 45.9% of those who had lung cancer used to smoke 40 or more cigarettes per day (Table 5). There was no difference either in smoking habit or in the intensity of smoking by subareas in the area under study.

Table 5 *Data on smoking habit for persons with malignant tumours obtained by family interview*

Tumour site	Men		Women	
	Total	Smokers n (%)	Total	Smokers n (%)
Pharynx (146-148)	33	29 (87.9)	4	1 (25.0)
Larynx (161)	64	64 (96.9)	7	4 (57.1)
Lung (162)	273	257 (94.1)	57	27 (47.4)
Pleura (163)	27	20 (74.1)	8	1 (12.5)
Total	397	368 (92.7)	76	33 (43.4)

The highest percentage of those who used to consume alcohol regularly (Table 6) was found among the subjects with laryngeal, pharyngeal and lung cancers. There was a statistically significant difference ($P<0.05$) in alcohol consumption between persons with studied tumours in subareas (Split: 80.8% men and 14% women; Solin: 87.9% men and 15.4% women; Kaštela 97.6% men and 33.3% women).

Table 6 *Data on alcohol consumption for persons with malignant tumours obtained by family interview*

Tumour site	Men		Women	
	Total	Regular alcohol consumers n (%)	Total	Regular alcohol consumers n (%)
Pharynx (146-148)	33	28 (84.8)	4	0
Larynx (161)	64	59 (92.2)	7	2 (28.6)
Lung (162)	273	231 (84.6)	57	8 (14.0)
Pleura (163)	27	21 (77.8)	8	2 (25.0)
Total	397	339 (85.4)	76	12 (15.8)

Analysis of the length of residence showed that 46.5% of the subjects with cancer in the Solin subarea and 67.8% in the Kaštela subarea lived there for

more than 50 years. The majority of those from Zagora used to live there practically all their life, while in the Split subarea for 40% of the deceased subjects with tumours the length of residence was between 30 and 40 years, and for 36% 50 years or longer.

In the same subareas the majority of persons with cancer had only elementary school education, while in the Split subarea most subjects had secondary school education. In general, comparison of the three subareas in terms of educational level shows their population structure to be comparable.

The relatives, parents, brothers and sisters, and grandparents of persons who died of the followed-up cancers died more frequently of the same site cancer than from another site cancer, as shown in Table 7.

Table 7 *Deaths caused by malignant tumours in close relatives of 473 persons who died of studied cancers (data obtained by family interview)*

Tumour site	Men		Women	
	n	%	n	%
Pharynx (146-148)	8		1	
Larynx (161)	13		1	
Lung (162)	53		9	
Pleura (163)	3		1	
Total	77	47.0	12	48
Gastrointestinal organs	46	28.0	8	32.0
Other	41	25.0	5	20.0
Total	164		25	

Note: Percentages were calculated from the total number of relatives with malignant tumours.

DISCUSSION

Results of the investigation showed that the mortality rates concerning cancer of the respiratory organs (larynx, lung) and pharynx (men), when standardized according to age, were lower in the area under study than expected. The standardized cancer mortality rates for pleural cancer were significantly higher in the area under study for both sexes taken together (except in the Kaštela and Zagora subareas) than in Croatia. As mentioned earlier, similar findings were reported in another coastal area of Croatia with an asbestos processing plant (6, 7).

Most men with the followed-up cancers were industrial workers. The highest cancer mortality rates were found among persons who used to be employed in the asbestos-cement and cement industries. Out of 38 men with mesothelioma 24 were industrial workers; 16 of them had jobs involving occupational exposure to asbestos. In a previous study, which dealt with lung and liver cancers in the

same area (11), a higher number of lung tumours was also recorded in the cement and the asbestos-cement industries than in other industries, as well as in the close proximity of the asbestos-cement plant than in the rest of the area.

For women living in the area under study occupational exposure as a factor in cancer incidence can be neglected. Only one woman with mesothelioma used to work in the asbestos-cement industry. The highest percentage, 59%, of the deceased were housewives: 58% in the Split subarea, 54% in the Solin subarea and 83% in the Kaštela and Zagora subareas. In addition to being housewives, in accordance with the local tradition and demands, most women used to be engaged in farming as well. This was very common in the Solin and Kaštela subareas. It may be assumed that working in the open air they were more exposed to asbestos emitted from the plant, which induced an accumulated adverse health effect.

The importance of working in the open air was also pointed out in the interpretation of the results of similar studies which were mentioned earlier (6, 7). There too, the rate of lung tumours in women compared with men was higher than in Croatia in general. When the working conditions of the other subjects with tumours were analysed in more detail, it was realized that a number of them had worked outdoors. So, out of the total number of persons with tumours in those studies, altogether 78% had a job that involved work in the open air.

The results of our present study showed that the distribution of the followed-up cancers in the settlements within the study area was uneven. The highest mortality rates, although not statistically significant for all cancer sites, were registered in the settlement where the asbestos-cement plant is located. A number of settlements in the municipalities of Solin and Kaštela (as shown in Table 3) also had higher tumour mortality rates in comparison with the rest of the study area. A possible influence of the prevailing wind direction (and the relief) on environmental contamination with asbestos from the emission source and consequently on an uneven distribution of the tumour incidence in the area under study has to be considered.

In the study area the percentage of smokers among those who developed cancer, as shown in Table 5, was, as expected, much higher in men than in women. Similar findings were reported by other authors as well (12). It should be noted that in persons with the studied tumours the percentage of smokers was higher compared with the average number of smokers in the area. Based on data obtained in a study on smoking habit in Croatia (13) about 52% of men and about 15% of women aged between 38 and 57 years were smokers. In the area under study the number of smokers was similar, about 55% of men and 23% of women. During the same period, from 1970 to 1990, in the study area the percentage of smokers among persons having malignant tumours of the gastrointestinal organs, who were also followed (14), was 44% (66% among men and 15% among women). There is a difference concerning the relationship between exposure to asbestos and smoking habit. In the case of lung and larynx cancers the correlation is positive (15, 16) as was found also in our study. In a study which included 200 persons who died of cancer of the respiratory organs and 800 control subjects tobacco consumption was twice higher among the deceased than among the controls (17). As far as mesothelioma is concerned no synergism

has been noticed between the effect of smoking and exposure to asbestos (18, 19). In our study 60% of the mesothelioma cases were smokers. In men the percentage of smokers was 74. This is in agreement with the observation from another study in which 75% of the subjects with mesothelioma were smokers (20).

The majority of persons with malignant tumours of respiratory organs and pharynx lived for more than 50 years at the some location. The correlation between the length of residence in the asbestos contaminated area and the incidence of malignant tumours which can be attributed to exposure to asbestos was noticed also in other studies (21).

The registered information that close relatives of persons with cancer of the respiratory organs died more frequently of the same site cancer than of other site cancer can indicate a genetic predisposition (22, 23). However, the role of factors which might have had an effect both on persons with cancer and on their relatives living in the same environment cannot be neglected. Almost all of these persons (relatives) used to live in the same area and even in the same settlements as the subjects in the study.

In discussing the results presented in this study it is necessary to comment on the problem of extrapolation of data obtained by family interviews. As mentioned earlier, only a part of families of deceased persons with the studied cancers were interviewed. The data obtained by this approach related to 56% of the subjects with mesothelioma, laryngeal and pharyngeal cancers, and to 50% of those with lung cancer who were selected for a family interview. Considering the distribution of those who were not included in the interview and the reasons for not participating, it seems appropriate to believe that no particular selection took place which could have biased the data used for qualitative (but not quantitative) comparisons made in the study.

CONCLUSION

Although mortality rates pertaining to cancer of the lung, larynx and pharynx seem to be positively correlated with smoking habit, and those of pharynx cancer with concurrent alcohol drinking habit, and in spite of an obvious relationship between occupation and pleural cancer (in men), the results for the study area indicate that environmental exposure to asbestos plays a role in cancer incidence. It can be assumed that an uneven distribution of cancer of the respiratory organs depended partly on an uneven distribution of pollution emitted from the asbestos-cement factory, as a consequence of prevailing wind and air stream direction. Therefore, it seems justified to think that certain narrower parts of the study area were more exposed to asbestos pollution and that this could have resulted in respective different tumour rates.

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Sažetak

RAK GRKLJANA, PLUĆA, POPLUĆNICE I ŽDRIJELA U PODRUČJU S TVORNICOM AZBESTNO-CEMENTNIH PROIZVODA

Prikazani su i analizirani podaci o osobama umrlim od raka dišnih organa i ždrijela u jednom priobalnom području Hrvatske, u razdoblju od 1970. do 1990. godine. U radu se polazi od pretpostavke da je zbog onečišćenja koja potječu iz tvornice azbestno-cementnih proizvoda, koja djeluje više od 70 godina, smrtnost od navedenih tumora na ovom području veća od očekivane. Podaci o smrtnosti od raka prikupljeni su iz Registra za rak Hrvatske. Izvršena je analiza stopa prema lokalizaciji raka, dobi i spolu, te mjestu stalnog boravka ispitanika. Anketom koja je provedena u uzorku od 437 obitelji umrlih osoba dobiveni su podaci o zanimanju, životnim navikama (pušenje, konzumacija alkoholnih pića), dužini boravka u ispitivanom području i podaci o smrtnosti od raka srodnika ispitanika. Rezultati istraživanja su pokazali da su pojedinačne dobno standardizirane stope smrtnosti od raka pluća, grkljana i ždrijela niže na području ispitivanja od očekivanih stopa (podaci za Republiku Hrvatsku). Standardizirane stope smrtnosti od raka poplućnice u oba spola (osim u žena u ruralnom dijelu ispitivanog područja) bile su veće na području istraživanja nego u Hrvatskoj. Raspodjela smrtnosti od raka dišnih organa i ždrijela u naseljima unutar područja nije jednolična. Najveće stope smrtnosti zabilježene su u naselju gdje se nalazi tvornica azbestno-cementnih proizvoda. Pojedina naselja u dvije općine imala su također veće stope smrtnosti od praćenih tumora u usporedbi s preostalim dijelom u području ispitivanja kao i u odnosu na stope u Hrvatskoj. Stope smrtnosti od raka pluća, grkljana i ždrijela bile su značajno povezane s navikom pušenja, a u slučaju raka ždrijela i s navikom konzumiranja alkohola. Postojala je povezanost između učestalosti raka poplućnice a u manjoj mjeri i raka pluća s profesijom (rad u azbestno-cementnoj industriji, proizvodnji cementa). Međutim, rezultati upućuju i na ulogu izloženosti azbestu iz okoliša u incidenciji raka u području ispitivanja. Može se pretpostaviti da je neravnomjerna raspodjela pojedinih oblika raka ovisila o neravnomjernom raznošenju onečišćenja emitiranih iz tvornice azbestno-cementnih proizvoda s obzirom na ružu vjetrova i prevalentne smjerove zračnih struja.

Ključne riječi:
epidemiološko istraživanje, izloženost u okolišu, konzumacija alkohola, mjesto stanovanja, obalno područje, pušenje, zanimanje

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