Utjecaj onečišćenja zraka na ventilacijske funkcije pluća

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THE EFFECTS OF AIR POLLUTION ON VENTILATORY LUNG FUNCTIONS

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The prevalence of chronic bronchitis was studied among female subjects aged 18–63 years from three areas with different ambient air quality: Bakar and Krasica with SO_2 concentrations above the WHO guideline and Viškovo where the SO_2 concentrations were below the guideline. The subjects were examined and administered a questionnaire. Differences in their ventilatory lung functions were tested and related to air quality. The subjects from the two regions with a higher pollution level had lower FVC and FEV_1 values than those from the Viškovo region. However, no statistically significant differences in the prevalence of chronic bronchitis between the subjects from regions with different ambient air quality were found. The same applies to the occurrence of pathological restrictive ventilation disturbances. In the Krasica region the occurrence of pathological obstructive ventilatory disturbances was significantly higher than in the Viškovo and Bakar regions; a correlation between the duration of residence and ventilatory lung function was also observed.

Key terms:
ambient air pollution, chronic bronchitis, housing conditions, human exposure, sulphur(IV)oxide

Several factors can be interrelated in the occurrence of chronic bronchitis (1). In many studies, the effects of smoking (2–5), as well as of polluted working and/or living environments (6), have been pointed out. These factors are often considered responsible for the development of chronic bronchitis.

Numerous epidemiological studies point out adverse health effects of polluted ambient air on persons living in cities and industrial regions, particularly on their respiratory system (7–9).

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The incidence of chronic bronchitis is higher among persons with a history of repeated respiratory infection episodes during the childbearing age and among those living in poor social and financial circumstances. The latter usually imply poor living conditions in overcrowded and cold residences.

Continuous monitoring of ambient air sulphur(IV)oxide concentration in the Bakar region dates from 1974. In a nearby Krasica region, located higher up, the monitoring started in 1983. Finally, in 1986, an ambient air monitoring station was set up at Viškovo, settlement in the western part of the Rijeka region (Figure 1). Although the measurements in Viškovo started after the epidemiological studies were completed there is no doubt that the SO_2 concentrations levels could not have been higher in the previous years and that this region can serve as a control area.

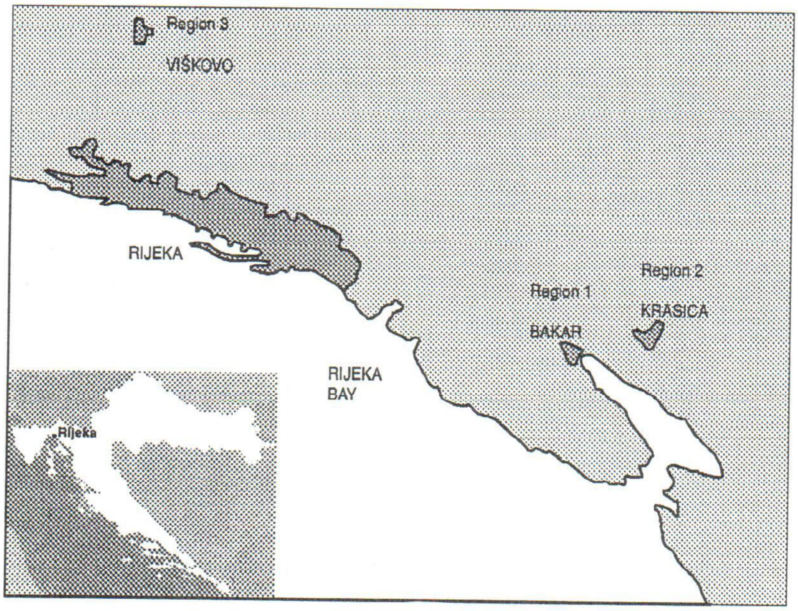

Figure 1 *Geographic location of the investigated areas*

Figure 2 shows the average annual SO_2 concentrations at the monitoring stations Bakar (1975–89), Krasica (1983–89) and Viškovo (1987–89) (12). At the end of the seventies the average annual SO_2 concentration increased significantly in the Bakar region. This could be attributed to the fact that several new industries, the coke plant Bakar, a thermo-electric power plant and a new oil refinery at Urinj started to operate in the area. Ever since, the average annual SO_2 concentration has permanently exceeded 50 $\mu g/m^3$, the guideline recommended by the World Health Organization (WHO) (13). The average annual SO_2 concentrations at Krasica were also above 50 $\mu g/m^3$, while the ambient air quality of the control region Viškovo complied with the WHO guideline.

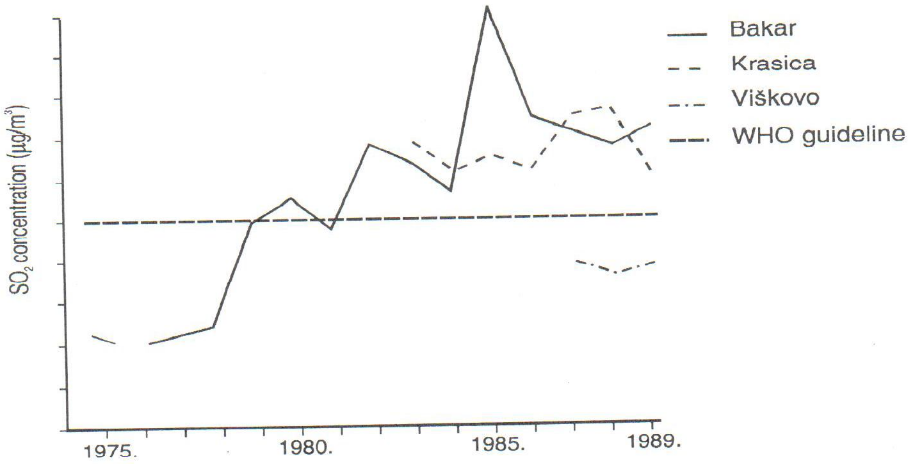

Figure 2 *The trend of the average annual concentrations of sulphur(IV)oxide (SO_2) measured in the period from 1975 to 1989*

This study aimed at examining the prevalence of chronic bronchitis in two groups of subjects and to establish possible differences. One group comprised two subgroups of women living in areas close to industrial facilities, and the other consisted of women residing in an area having satisfactory air quality according to the WHO guideline.

METHODS

The subjects in the study were 891 women from Bakar (region 1), Krasica (region 2) and Viškovo (region 3), between the ages of 18 and 63, housewives and employees. The study was carried out in April 1986. Ventilatory lung functions were tested and a questionnaire on chronic respiratory diseases including also questions on housing conditions was answered.

According to the standard questionnaire on respiratory symptoms of the *British Medical Research Council's Committee* (14), the diagnosis of chronic bronchitis can be established on the ground of confirmed history of persistent cough with sputum, lasting for longer than three months running in one calendar year and occurring in two consecutive years. Satisfactory housing conditions were assumed to pertain to a dry and clean accommodation, with enough room for all family members. Crowded and poor accommodation with most household members living in one room, subtenancy, accommodation in barracks and other temporary lodgings was not considered to be satisfactory.

Working conditions of all employed women were also analysed. The vast majority were clerks, and only a smaller group worked as cleaners. None reported working in a polluted working environment. In that respect, both the employed and unemployed were taken as a single group of subjects.

For ventilatory lung function testing a Mijnhardt Vicatest-2 dry spirometer was used. The relative values of the following parameters were measured: forced vital capacity (FVC), forced respiratory volume in the first second (FEV_1) and FEV_1/FVC ratio known as Tiffeneau index, expressed as absolute and relative values in relation to normal population. CECA standards were used (15). In addition, forced medium flow, between 25 and 75% of the exhaled vital capacity ($FMF_{25-75\%}$) in relation to normal healthy adult population standard, according to Morris and authors, was also determined (16).

The tests were performed on each subject three times in succession. Only the highest results were considered.

According to the *American Thoracic Society* (ATS) (17), the women with FVC values 20% lower than the normal population standard were classified as having a certain form of pathological restrictive ventilation disturbance. On the other hand the existence of pathological obstructive ventilation disturbance has been established in the subjects with the FEV_1/FVC ratio 25% lower than the normal population standard, again according to the ATS recommendations.

The prevalence of ventilatory disturbances as previously defined was related to the ambient air quality in a particular region, to individual housing conditions and to the subject's age.

The χ^2-test was used to compare:

- age distribution and housing conditions of the subjects from the regions of Bakar and Krasica (groups 1 and 2) and Viškovo (group 3)
- the prevalence of chronic bronchitis among subjects according to region, housing conditions and age group
- prevalence of restrictive and obstructive type of ventilation disturbances among subjects living in different regions and belonging to different age groups.

The probability level of $P<0.05$ was considered to be significant.

Student's t-test for large independent samples was used for the following comparisons:

- average ventilation lung function values of non-smoking subjects from different groups (1, 2 and 3)
- average age distribution of non-smoking subjects from the three groups
- average number of years non-smoking subjects lived in a particular region.

Finally, Pearson's correlation coefficient was calculated to test:

- the relationship between lung function values and the length of residence in a particular region, and
- the relationship of lung ventilation parameters and age distribution in the same group of subjects.

RESULTS

According to the 1981 census, the total number of women, between the ages of 18 and 63, living in the three regions was 1536. A total of 58% women filled in the questionnaire, and 28.5% had ventilatory lung functions tested.

In regions 1 and 2 the proportion of women who filled in the questionnaire and passed spirometric testing was greater than in Viškovo. In regions 1 and 3 more women were younger than forty, whereas in region 2, the women's ages were equally distributed (Table 1).

Table 1 *Age distribution of subjects by regions*

Housing conditions	Region 1 Bakar		Region 2 Krasica		Region 3 Viškovo		Total	
	n	%	n	%	n	%	n	%
< 30	95	31.3	60	24.0	114	33.8	269	30.2
30 – 39	105	34.5	69	27.6	119	35.3	293	32.9
40 – 49	54	17.8	71	28.4	47	14.0	172	19.3
> 49	50	16.4	50	20.0	57	16.9	157	17.6
Total	304	100.0	250	100.0	337	100.0	891	100.0

$\chi^2 = 25.0$; df = 6; $P < 0.001$

Most subjects (75.4%) claimed to be living in good housing conditions. The majority of those claiming inadequate housing, happened to live in region 1 (Table 2).

No statistically significant differences in the prevalence of chronic bronchitis, in relation to age distribution, were found, in any of the three regions (Table 3). The difference in the prevalence of chronic bronchitis between subjects from the two investigated regions with a higher pollution level and the Viškovo region was not statistically significant either (χ^2=1.27).

Table 2 *Distribution of subjects according to housing conditions by regions*

Housing conditions	Region 1 Bakar		Region 2 Krasica		Region 3 Viškovo		Total	
	n	%	n	%	n	%	n	%
Satisfactory	198	65.1	213	85.2	261	77.4	672	75.4
Unsatisfactory	106	34.9	37	14.8	76	22.6	219	24.6
Total	304	100.0	250	100.0	337	100.0	891	100.0

$\chi^2 = 31.0$; df = 2; $P < 0.001$

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Again, there was no statistically significant difference in the chronic bronchitis prevalence between the groups of subjects who were satisfied and dissatisfied with their housing conditions in any of the examined regions (Table 3).

Table 3 *The prevalence of chronic bronchitis in subjects according to housing conditions and the place of residence*

Housing conditions	Region 1 Bakar		Region 2 Krasica		Region 3 Viškovo		Total	
	n	%	n	%	n	%	n	%
Satisfactory	22/198	11.1	34/213	16.0	31/261	11.2	87/672	13.0
Unsatisfactory	18/106	17.0	5/37	13.5	11/76	14.5	34/219	15.5
	χ^2 = 2.08 df = 1 P>0.05		χ^2 = 0.14 df = 1 P>0.05		χ^2 = 0.70 df = 1 P>0.05		χ^2 = 0.73 df = 1 P>0.05	
Total	40/304	13.6	39/250	15.6	42/337	12.5	121/891	13.6

n = total number of subjects in a group; n_1 = the number of subjects with chronic bronchitis in a group

Table 4 *The prevalence of the restrictive (1) and the obstructive (2) type of ventilation disturbances in subjects according to housing conditions and the place of residence*

Place	Housing conditions: Satisfactory		Housing conditions: Unsatisfactory		χ^2	df	P	Total	
	n_1/n	%	n_1/n	%				n_1/n	%
1 Bakar	17/135	12.5	1/39	2.6	2.29	1	> 0.05	18/174	10.3
Krasica	8/113	7.1	0/16	0.0	0.30	1	> 0.05	8/129	6.2
Viškovo	3/78	3.2	0/14	0.0	0.01	1	> 0.05	3/92	3.3
Total	28/326	8.6	1/69	1.4	3.28	1	> 0.05	29/395	7.3
	χ^2 = 5.3 df = 2 P_1 > 0.05		χ^2 = 0.78 df = 2 P_1 > 0.05					c^2 = 4.81 df = 2 P_2 > 0.05	
2 Bakar	3/135	2.2	1/39	2.6	3.28	1	> 0.05	48/174	2.3
Krasica	9/113	8.0	3/16	18.8	0.23	1	> 0.05	12/129	9.3
Viškovo	1/78	1.3	0/14	0.0	0.87	1	> 0.05	1/92	1.1
Total	13/326	4.0	4/69	5.8	0.95	1	> 0.05	17/395	4.3
	χ^2 = 7.3 df = 2 P_1 < 0.05		χ^2 = 6.5 df = 2 P_1 < 0.05					χ^2 = 11.81 df = 2 P_2 < 0.05	

n = the total number of subjects in a group; n_1 = the number of subjects with pronounced restrictive or obstructive ventilation disturbances; P = the significance level of χ^2-test for the prevalence of restrictive or obstructive ventilation disturbances in subjects with different housing conditions in the same place of residence; P_1 = in subjects from different places of residence and comparable housing conditions; P_2 = in the subjects from different places of residence regardless of housing conditions.

The restrictive ventilatory disturbances were equally present in all the three regions irrespective of the housing conditions (Table 4).

The prevalence of obstructive ventilatory disturbances among subjects from region 2 was significantly greater than among those from regions 1 and 3 regardless of their housing conditions (Table 4). The difference in the prevalence of obstructive ventilatory disturbances between the subjects satisfied and those dissatisfied with their housing conditions was not statistically significant in any of the examined regions.

Table 5 shows the subjects' ventilatory lung functions in relation to air pollution levels in the three investigated regions.

Table 5 *Comparison of the ventilatory lung functions, age and duration of stay at the place of residence between non-smoking subjects from Bakar and Viškovo, from Krasica and Viškovo and from Bakar and Krasica*

Parameter	Regions			
	Bakar (n = 93) $\bar{X} \pm SD$	Viškovo (n = 63) $\bar{X} \pm SD$	t-value	P
FVC (%)	99.8 ± 21.2	113.6 ± 20.0	4.09	< 0.001
FEV_1 (%)	96.7 ± 27.7	130.8 ± 27.3	7.58	< 0.001
$FEV_1/FVC\%$	80.1 ± 13.7	82.8 ± 10.2	1.31	—
$FMF_{25-75\%}$(L/s)	2.7 ± 0.9	3.2 ± 1.4	2.20	< 0.05
Age (years)	41.9 ± 10.7	39.9 ± 10.8	1.16	—
HP (years)	24.2 ± 15.5	21.0 ± 16.5	1.22	—
	Krasica (n = 84) $\bar{X} \pm SD$	Viškovo (n = 63) $\bar{X} \pm SD$	t-value	P
FVC (%)	107.0 ± 16.9	113.6 ± 20.0	2.18	< 0.05
FEV_1 (%)	113.6 ± 26.7	130.8 ± 27.3	3.83	< 0.001
$FEV_1/FVC\%$	77.1 ± 18.1	82.8 ± 10.2	2.22	< 0.05
$FMF_{25-75\%}$(L/s)	2.9 ± 1.0	3.2 ± 1.4	1.48	—
Age (years)	43.4 ± 9.7	39.9 ± 10.8	2.07	—
HP (years)	25.0 ± 16.4	21.0 ± 16.5	1.43	—
	Bakar (n = 93) $\bar{X} \pm SD$	Krasica (n = 84) $\bar{X} \pm SD$	t-value	P
FVC (%)	99.8 ± 21.2	107.0 ± 16.9	2.47	< 0.02
FEV_1 (%)	96.7 ± 27.7	113.6 ± 26.7	4.12	< 0.001
$FEV_1/FVC\%$	80.1 ± 13.7	77.1 ± 18.1	1.25	—
$FMF_{25-75\%}$(L/s)	2.7 ± 0.9	2.9 ± 1.0	0.82	—
Age (years)	41.9 ± 10.7	43.4 ± 9.7	0.96	—
HP (years)	24.2 ± 15.5	25.0 ± 16.4	0.32	—

P = the significance level – only significant values are selected; $\bar{X}$ = the arithmetic mean; SD = standard deviation; FVC = forced vital capacity expressed in percentages in relation to the normal values according to the CECA i.e. VICATEST-2-spirometer standards; FEV_1 = forced expiratory volume in the first second expressed in the same way as FVC; $FEV_1/FVC\%$ = percent ratio of observed absolute values of FEV_1 and FVC (Tiffeneau-index); $FMF_{25-75\%}$ = forced medium flow between 25 and 75% forced expired vital capacity; HP = years of residence

The region 1 subjects showed significantly lower values of all analysed ventilatory functions than the region 3 subjects, except for the $FEV_1/FVC\%$ ratio. The region 2 subjects showed significantly lower values of all analysed functions compared to region 3, with the exception of $FMF_{25-75\%}$. Considering the subjects' age distribution and residence duration there were no statistically significant differences between regions 1 and 3. However, the region 2 subjects were in average older than the region 3 subjects. In respect to duration of residence there were no significant differences between regions 2 and 3.

The region 1 subjects showed significantly lower FVC and FEV_1 values than the region 2 subjects. The two regions, however, showed no significant differences in $FEV_1/FVC\%$, $FMF_{25-75\%}$, average age distribution or residence duration.

The region 1 subjects showed a significant negative correlation of FVC and FEV_1 to age distribution (Table 6). No significant correlation of $FEV_1/FVC\%$ and $FMF_{25-75\%}$ to age distribution, or any of pulmonary ventilatory functions to residence duration was found.

Table 6 *The correlation between ventilatory lung functions, age and the duration of stay at the place of residence for non-smoking subjects from Bakar, Krasica and Viškovo*

Regions	Ventilatory lung functions	Age of subjects r_d	P	Years of residence r_{HP}	P
Bakar n=93	FVC (%)	–0.27	< 0.001	0.02	—
	FEV_1 (%)	–0.20	< 0.01	0.01	—
	$FEV_1/FVC\%$	–0.14	—	–0.14	—
	$FMF_{25-75\%}$	–0.16	—	–0.17	—
Krasica n=84	FVC (%)	–0.20	—	–0.05	—
	FEV_1 (%)	–0.30	< 0.001	–0.20	< 0.01
	$FEV_1/FVC\%$	–0.20	—	–0.15	—
	$FMF_{25-75\%}$	–0.52	< 0.001	–0.31	< 0.001
Viškovo n=63	FVC (%)	–0.31	< 0.01	–0.08	—
	FEV_1 (%)	–0.22	—	–0.01	—
	$FEV_1/FVC\%$	–0.25	< 0.01	–0.09	—
	$FMF_{25-75\%}$	–0.47	< 0.01	–0.13	—

r_d = Pearson's correlation coefficient of the ventilatory lung functions and the subjects' age; r_{HP} = Pearson's correlation coefficient of the ventilatory lung functions with the duration of subjects' stay at the place of residence; P = the significance level of the Pearson's correlation coefficient – only significant levels were selected; FVC = forced vital capacity expressed in percentages in relation to the normal values according to the CECA i.e. VICATEST2-spirometer standards; FEV_1 = forced expiratory volume in the first second. expressed in the same way as FVC; $FEV_1/FVC\%$ = percent ratio of observed absolute values of FEV_1 and FVC (Tiffeneau-index); $FMF_{25-75\%}$ = forced medium flow between 25 and 75% forced expiratory vital capacity

A significant negative correlation between FEV_1 and $FMF_{25-75\%}$ on the one hand and age distribution and residence duration on the other was established for the subjects from region 2. This did not apply to FVC and $FEV_1/FVC\%$.

The region 3 subjects showed a significant negative correlation of FVC, $FEV_1/FVC\%$ and $FMF_{25-75\%}$ to age distribution. No significant correlation of FEV_1 and age distribution of any ventilatory lung function to the residence duration was found.

DISCUSSION

According to numerous epidemiological investigations (17–19) increased concentration of air pollutants in ambient air, especially that of SO_2, may promote the prevalence of chronic bronchitis. Many authors link the influence of poor housing conditions to the aetiology of this chronic disease (3, 4).

However, this study has not been able to prove a higher prevalence of chronic bronchitis among the subjects from Bakar and Krasica compared to that at Viškovo, although air pollution level in the Bakar bay area has been elevated during the last decade (12, 21) and at Krasica it is higher than at Viškovo where SO_2 levels are well below the WHO guideline.

No difference in chronic bronchitis prevalence was found among the groups of subjects with different age distribution or housing conditions in spite of a significantly higher number of subjects dissatisfied with their housing conditions at Bakar than at Krasica and Viškovo.

A higher prevalence of restrictive ventilation disturbances was not found in the polluted areas; the prevalence of obstructive ventilatory disturbances was significantly higher at Krasica than at Viškovo and Bakar. However, the fact that generally a small number of subjects had distinct ventilatory disturbances must be taken into account.

A significantly higher number of obstructive ventilatory disturbances at Krasica compared to Viškovo can partly be explained by the fact that the average age of the Krasica subjects was higher than of those at Viškovo. Such a conclusion can be backed up by the fact that the Krasica subjects showed a significant negative correlation of their age distribution and ventilatory functions; the FEV_1 and $FMF_{25-75\%}$. values pointed to the obstructive ventilatory disturbances. Comparison of the Bakar and Krasica subjects by age shows that generally the latter were not older, although, considering the age distribution of the entire sample of 891 interviewed women, women under 40 predominated at Bakar and all age groups were uniformly represented at Krasica. Furthermore, at Bakar the FVC and FEV_1 values showed a significant negative correlation to the subjects' age distribution.

Although the established ambient air pollution levels at Krasica are not much above the WHO guideline values, the described phenomena might be partially indirectly related to air pollution. The fact that only the same pulmonary ventilatory function of Krasica subjects, pointing to the obstructive ventilatory disturbances, i.e., FEV_1 and $FMF_{25-75\%}$, showed a significant negative correlation to the residence duration, further strengthens this conclusion.

The connection between the increased air pollution and ventilatory lung functions stems, to some extent, from the fact that both at Bakar and Krasica the ventilatory lung function values of both types were lower than at Viškovo. At Bakar, this was true of the FVC, FEV_1 and $FMF_{25-75\%}$ values and at Krasica of FEV_1 and $FEV_1/FVC\%$. It must be pointed out that at Bakar these values were even lower than at Krasica, and the difference was statistically significant for the FVC and FEV_1 values.

A small number of subjects from these regions had pathologically low values of the ventilatory lung functions. The manifested differences in lung functions were within normal range of spirometric standards. This can be explained by the fact that deviating pollution level during the residence and exposure of the subjects, might have caused a considerable difference in ventilatory functions within the normal values range, but was not sufficient for inducing differences in chronic bronchitis prevalence. To exclude the effect of smoking on ventilatory lung functions analysis was done only for non-smokers. The influence of working environment was also excluded as no major pollution effects were reported.

To verify the relationship between a chronic non-specific respiratory disease, chronic bronchitis, and ambient air pollution in the examined regions, it is planned to repeat the study after a longer period among the same subjects that have remained resident in the area.

CONCLUSION

The women living in the polluted regions of Bakar and Krasica, (defined by annual means of the measured SO_2 ($\mu g/m^3$) concentration levels exceeding the recommended WHO guidelines) had significantly lower values of ventilatory lung functions than those in the control region of Viškovo. This indirectly points to a possible influence of ambient air pollution on the respiratory system of the local population. The FVC and FEV_1 values followed the SO_2 pollution levels at Bakar, Krasica and Viškovo most consistently.

The level of ambient pollution and duration of exposure in the living environment were not sufficient to cause pathological manifestations.

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Sažetak

UTJECAJ ONEČIŠĆENJA ZRAKA NA VENTILACIJSKE FUNKCIJE PLUĆA

Anketnim upitnikom i funkcionalnim ispitivanjem dišnog sustava pokušala se utvrditi razlika u ventilacijskim funkcijama pluća u žena životne dobi od 18 do 63 godine, koje su se odazvale pregledu, na područjima s onečišćenjem zraka sa SO_2 većim od smjernica Svjetske zdravstvene organizacije (Bakar i Krasica) i na području gdje kakvoća zraka zadovoljava (Viškovo). Vrijednosti ispitanih ventilacijskih funkcija pluća u ispitanica s područja s onečišćenim zrakom bile su mnogo niže nego u ispitanica s područja s koncentracijom SO_2 nižom od vrijednosti iz smjernica SZO. Nisu utvrđene statistički značajne razlike u raširenosti kroničnog bronhitisa između ispitanica iz mjesta s različitim stupnjem onečišćenja, a niti u zastupljenosti patoloških smetnji ventilacije restriktivnog tipa. Jedino je u Krasici utvrđena statistički značajno veća raširenost patološkog stupnja smetnji ventilacije opstruktivnog tipa nego u Viškovu i Bakru, te povezanost dužine boravka u mjestu stanovanja s ventilacijskim funkcijama pluća.

Ključne riječi:
kronični bronhitis, izloženost ljudi, onečišćenje zraka, sumpor(IV)oksid, uvjeti stanovanja

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