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## **EVALUATION OF THE IMPACT OF BLACK CARBON ON THE WORSENING OF ALLERGIC RHINITIS AND ASTHMA IN THE REGION OF UZICE SERBIA**

**Summary:** Many epidemiological studies have shown a positive association between black carbon (BC) concentrations and exacerbation of allergic rhinitis and asthma. The aim of this study was to examine, for the first time in Serbia, the connection between visits to emergency services due to worsening of allergic rhinitis and allergic asthma and the concentration of BC in the air. **Materials and methods:** A time-stratified case crossover design was applied for emergency room visits due to allergic rhinitis and worsening asthma that occurred in the Užice region between 2012-2014. Data on visits were routinely collected at the Užice Health Center. **Results:** A statistically significant association was observed between the worsening of allergic rhinitis and BC concentration two days before the visit to the emergency department (UO = 359, UO = 3.20 and UO = 3.24, depending on whether the analysis is not adjusted or adju-

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sted for appropriate weather conditions). There was also a statistically significant association between worsening of allergic asthma and BC concentration two days before the emergency service visit (UO = 3.15, GP = 0.98–10.14) and three days before the emergency service visit (UO = 2.98; UO = 3.23 ; UO = 2.98). Conclusion: Exposure to soot, especially during the heating season, increases the risk of emergency services due to worsening of allergic rhinitis and asthma.

**Key words:** allergic rhinitis, asthma, soot

## *Introduction*

Previous studies conducted in major European and world cities have proven the impact of air quality on the flow and prognosis of acute and chronic diseases (1,2,3). Global urbanization, industrial development and increased use of various energy sources have contributed to human exposure to increasing air pollution.

Air pollution is a significant factor in the development of a large number of diseases of the respiratory organs, cardiovascular organs, and diseases of the central nervous system. All this disrupts the quality of life, the working ability of the population, increases the number of emergency services and the use of drugs in the treatment of an increasing number of comorbidities. Individual patient responses to individual air pollutants depend on the pollutants, exposure levels, health status, and genetics of individuals (4).

Air monitoring in Serbia is under the jurisdiction of the Environmental Protection Agency. Permitted mean daily, limit and tolerance values are regulated by the legal „Službeni glasnik Srbije“ No. 11/2010, 75/2010, 63/2013 (5). Based on the average daily values of pollutants, the Air Quality Index (AQI) is calculated. The index is determined by the mean daily concentration of the pollutant that is highest on that day. Based on the AQI, guidelines are given to the population on the potential risk to health and the length of stay in the external environment. Air monitoring in Serbia is under the jurisdiction of the Environmental Protection Agency. Data from all measuring points in Serbia are available to the public on the website [www.sepa.gov.rs](http://www.sepa.gov.rs).

In Uzice and its surroundings, the heating season lasts for six months, from November 15. until April 15, and in that period, for the most part, the average daily values of all pollutants were exceeded, about which data can be obtained on the website [sepa.gov.rs](http://sepa.gov.rs). During that period, the number of patients reporting to the emergency services due to all diseases, and, among other things, due to allergic diseases of the respiratory tract, which occur together. The most common allergic diseases are rhinitis and asthma.

Asthma is a heterogeneous disease characterized by chronic inflammation of the airways and is clinically manifested by attacks of wheezing, shortness of breath, dry, irritating cough of varying intensity and duration with reversible airway obstruction.

Allergic rhinitis is a chronic inflammatory disease characterized by hypersensitivity to one or more allergens and constant or seasonal nasal congestion, nasal secretions, discharge down the throat and which is based on inflammation predominantly eosinophils.

The prevalence of allergic rhinitis in Europe is 22.7% and in Serbia 20.5%. One in seven Europeans has allergic rhinitis. 50% have not been diagnosed and 83% require treatment. The prevalence of asthma in Europe is 0.08% to 12% and in Serbia 9% (7.32).

### ***Material and methods***

A descriptive, environmental study, in a two-year period, from July 1, 2012 to July 31, 2014, took data from the protocol of patients diagnosed with allergic rhinitis and / or asthma who turned to emergency services (emergency care and home care) in Užice, Kosjerić and Sevojno or were hospitalized in the hospital of the regional health center of Užice, where patients of the Zlatibor district gravitate. The study included adults with a confirmed diagnosis of allergic rhinitis and / or allergic asthma over the age of 18.

### ***Statistical analysis of data***

To assess the association between emergency visits to health services due to acute exacerbation of allergic rhinitis / asthma and exposure to various air pollutants, a time series with a “case-crossover” design was performed, which involves studying transient short-term effects of air pollution on acute risk in this case acute exacerbations of the disease. Daily concentrations of soot recorded at the measuring points were used and their relationship with the daily number of patients who reported to the emergency service or were hospitalized due to allergic rhinitis or asthma was analyzed.

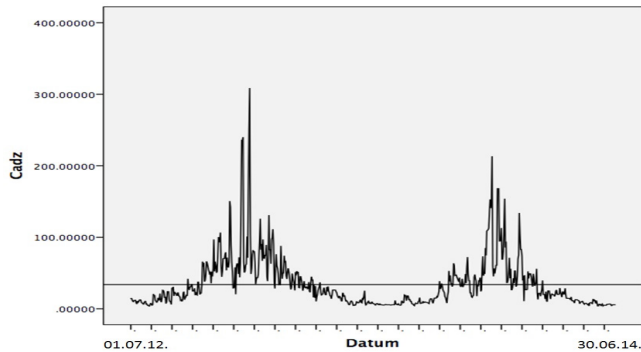
As in the literature, when examining the relationship between patient reporting to the emergency department / hospitalization due to disease exacerbation and air pollution, time lags are usually used from 2 to 7 days, the optimal delay time in our study was selected using t-values of regression coefficients (lag 0 to lag -3). Then, a factor analysis was performed on the connection between air pollutants and emergency services hospitalization due to worsening of allergic rhinitis or asthma. This analysis assessed the linear correlation of the examined variables, and enabled the reduction of the number of variables by grouping them into categories. Univariate conditional (logistic) logistic regression analysis was used to calculate cross ratios (OR) and 95% confidence intervals (CI), relative risks of patients reporting to the emergency services due to acute exacerbation of allergic asthma and rhinitis. The seventh day before and after each patient reported to the health service was a control for that patient. Temperature and humidity of the day before reporting to the emergency services were used as adjusters (potential confounding factors).

Statistical significance of  $P < 0.05$  and for conditional logistic regression analysis of  $P < 0.1$ .

Statistical analysis was performed using SPSS statistical software (SPSS for Windows, release 21.0, SPSS. Chicago, IL).

## Results

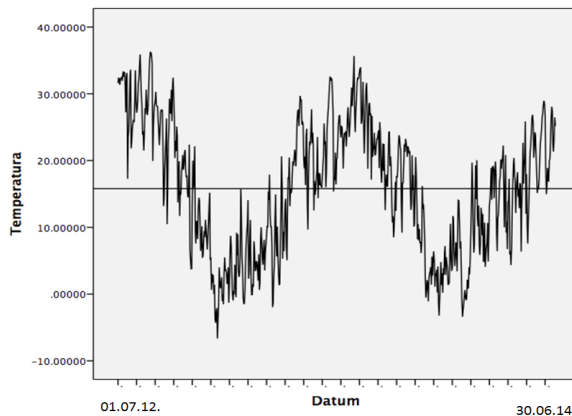
The soot pollutant concentration monitored in this study in the observed period (2012–2014) is shown in Figure 1.



**Figure 1.** Trends in soot concentration in the Užice region (2012–2014)

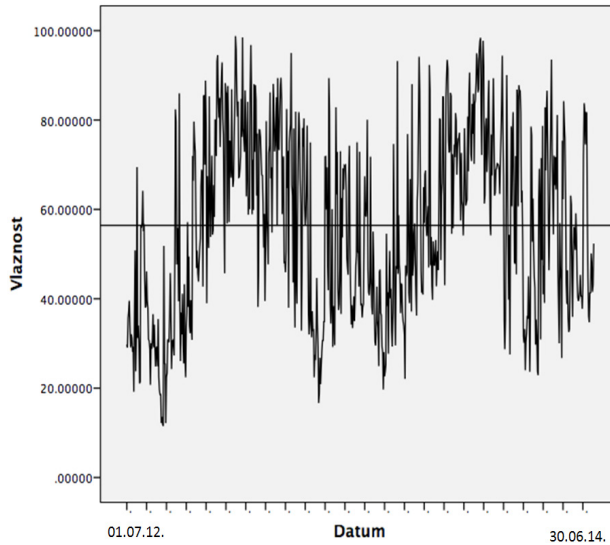
In the examined period, the concentration of soot in the winter months, during the heating season, exceeded the allowed daily average values several times, and they are 50 micrograms per cubic meter.

Variations in temperature, relative humidity and air pressure in the observed period (2012-2014) Figure 2-4.



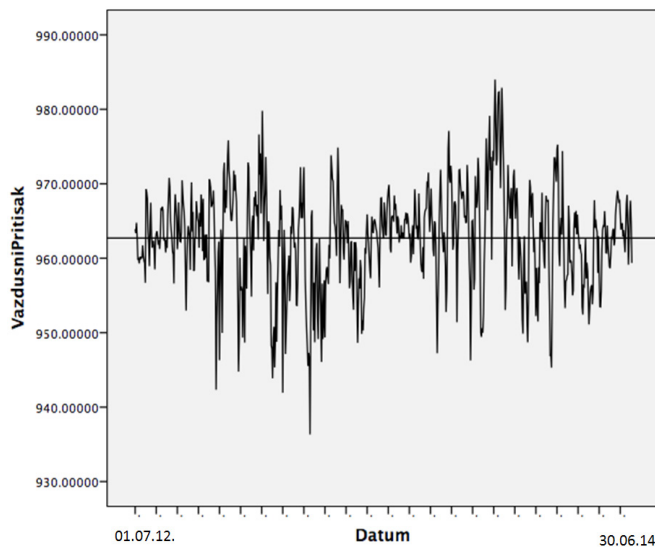
**Figure 2.** Air temperature trends in the Užice region (2012–2014)

In the observed period, the air temperature ranged from  $-8^{\circ}\text{C}$  in the winter months to  $38^{\circ}\text{C}$  in the summer months.



**Figure 3.** *Movement of relative humidity in the Užice region (2012–2014)*

In the observed period, daily variations in air humidity were observed, while in the winter months the relative air humidity was significantly higher.



**Figure 4.** *Air pressure trends in the Užice region (2012–2014)*

During the study period, there were large, daily fluctuations in air pressure, especially in winter.

The correlation between soot and weather conditions is shown in Table 1.

**Table 1.** Daily concentrations of soot and weather variables in the Užice region (2012–2014).

Varijabla	AS	IQO	Min	Percentili				Max
				20%	40%	60%	80%	
BC, 24h $\mu\text{g}/\text{m}^3$	21,66	38,67	80,78	8,33	16,33	29,00	54,67	308,67
Temperature, $^{\circ}\text{C}$	16,20	15,27	-6,67	5,80	13,02	18,79	24,23	36,23
Relative humidity %	58,30	34,43	11,53	38,23	48,53	64,83	78,13	98,80
Air pressure	962,90	8,47	936,33	956,87	961,53	964,40	967,57	982,33

IQO: Interquartile range; BC: soot.

During the monitoring period, soot concentrations exceeded the permitted values ( $50 \mu\text{g} / \text{m}^3$ ) prescribed by the national regulations for monitoring weather conditions and air quality (Table 1). The BC concentration was higher during the heating season (median = 23.67; Min - Max 4.00–2.52.00) compared to the non-heating season (Median = 13.33; Min - Max 4.00–308, 67), and this difference was statistically significant ( $p < 0.001$ ).

**Table 2.** Correlation coefficients between soot air pollutants and weather conditions in the Užice region (2012–2014)

Variable	BC	T	Humidity
BC	1,00		
Temperature	-0,67	1,00	
Humidity	0,41	-0,77	1,00
Air pressure	<b>0,01</b>	0,06	-0,14

\* Spearman correlation coefficients. All values are statistically significant.

**Table 3.** Relationship between exposure to soot concentration (BC) \* and visits to emergency services due to acute exacerbation of allergic rhinitis and asthma in the region of Užice, Serbia (2012–2014)

	Days	UO (95% GP) P	UO <sup>a</sup> (95% GP) P	UO <sup>b</sup> (95% GP) P
AR (N = 99)	Lag 0	0.82 (0.30-2.22) 0.696	0.81 (0.29-2.27) 0.684	0.70 (0.25-1.96) 0.495
	Lag (-1)	1.92 (0.69-5.37) 0.213	1.81 (0.63-5.21) 0.272	1.66 (0.57-4.81) 0.351
	Lag (-2)	<b>3.59 (1.18-10.89) 0.024</b>	<b>3.20 (1.00-10.18) 0.049</b>	<b>3.24 (1.03-10.22) 0.045</b>
	Lag (-3)	2.18 (0.78-6.04)	1.89 (0.64-5.58) 0.247	2.18 (0.78-6.04) 0.135
Asthma (N = 179)	Lag 0	1.22 (0.40-3.67) 0.726	1.35 (0.44-4.18) 0.602	1.30 (0.42-4.04) 0.652
	Lag (-1)	1.10 (0.39-3.10) 0.858	1.19 (0.41-3.44) 0.754	1.00 (0.34-2.88) 0.993
	Lag (-2)	2.52 (0.83-7.65) 0.103	2.47 (0.78-7.75) 0.123	<b>3.15 (0.98-10.14) 0.055</b>
	Lag (-3)	<b>2.98 (1.01-8.82) 0.048</b>	<b>3.23 (1.05-9.95) 0.041</b>	<b>2.98 (1.01-8.82) 0.048</b>

AR, Allergic rhinitis

\* third quintile when the first quintile is reference

adjusted for temperature, humidity, and air pressure on the day of the visit.

adjusted for temperature, temperature<sup>2</sup> humidity, and air pressure the day before the visit.

Bold values are statistically significant.

A statistically significant association was observed between the worsening of allergic rhinitis and BC concentration two days before the emergency visit (UO = 3.59, UO = 3.20 and UO = 3.24, depending on whether the analysis is not adjusted or adjusted for appropriate weather conditions). There was also a statistically significant association between worsening of allergic asthma and BC concentration two days before the emergency visit (UO = 3.15, GP = 0.98–10.14) and three days before the emergency visit, UO = 2.98; UO = 3.23 ; UO = 2.98).

## Discussion

This is the first study that investigated the connection between visits to emergency services and increased hospitalization due to worsening respiratory diseases, asthma and allergic rhinitis, and the concentration of soot pollutants in the air in Serbia. We performed a time-layered cross-sectional case study to assess the effects of daily BC concentrations on emergency room visits to the Užice region from 2012 to 2014 due to allergic rhinitis and allergic asthma. In the study, weather conditions,

temperature, relative humidity and pressure were monitored all the time together with the BC concentration. The results indicate a positive association between BC exposure and emergency visits due to allergic rhinitis and asthma. The results indicate a significantly higher frequency of acute exacerbations of these diseases with increasing soot concentration. A statistically significant correlation was observed between the visit to the emergency department due to acute worsening of asthma and exposure to BC concentration three days before the visit (ORs = 2.98–3.23; CI = 1.01–9.95;  $p = 0.041$ – $0.048$ ). A statistically significant association was observed between the visit to the emergency department due to acute exacerbation of allergic rhinitis and exposure to BC concentration two days before the visit (ORs = 2.98–3.23; CI = 1.01–9.95;  $p = 0.041$ – $0.048$ ).

The results of this study are in line with numerous published previous studies on the association between emergency room visits or hospital admissions due to worsening asthma due to increased soot concentrations.

There is ample evidence of an association between short-term variations in BC carbon black concentrations and an increased risk of hospital admission due to cardiovascular and respiratory complications. Studies also provide significant evidence of an association between cause, cardiovascular, and respiratory mortality with long-term average BC exposure (6,7,8).

A case-based cross-over study by Spanish authors found a positive correlation between acute exacerbations of asthma after soot exposure in Spain, in people over 14 but not younger on the day of exposure and three days after exposure to increased soot concentrations (38).

Our study has several significant advantages. Time-stratified cross-over design, in which each individual is self-controlled, as in this study, has proven to be a suitable method for assessing the relationship between air pollution factors and worsening allergic respiratory diseases. Also, the exclusion of the influence of weather factors such as pressure, temperature and humidity, as a controller, contribute to a more reliable assessment of the impact of air pollutants on the worsening of asthma and rhinitis.

The study excluded patients who had acute exacerbations due to acute respiratory infections because the data were taken from protocols that included other diagnoses that the patient has, not just asthma and rhinitis.

However, the design of the study does not exclude the influence of air quality parameters in the rooms where patients stay. It is necessary to perform additional analyzes of the relationship between the influence of gender and age and comorbidity on acute exacerbations of asthma and rhinitis, and under the circumstances of exposure to air quality parameters used in this study. Although we had data on gender, comorbidities and age in the database, we did not correlate this because we examined the impact of six air pollutants, two groups of adjusters, four LAGs



(pollutant exposure days) and three ways of measuring variables. , comorbidities) we would get 1440 regressions ( $6 \times 2 \times 4 \times 3 \times 10$ ) but this remains as a recommendation for further research.

In our study, significantly higher concentrations of soot were registered in the winter months. And during the heating season, which is from September 15 to April 14. We also received significant OR for exacerbations of asthma and asthma and rhinitis. The explanation for this can be found in the following: the wire is located in the valley of the river Cetinje and above it rise the slopes of Jelova Gora, Kapetanovina, Tatinac and Pora, whose altitude is 500 m above sea level (the bottom of the Uzice valley lies at 411 m above sea level). beaches, or 403 m above sea level in Cetinje near Ada in Krugovo). In winter, conditions are created for temperature inversions, where cold air falls to the bottom of the valley, and above it is a front of warmer air. Such temperature inversion prevents vertical air circulation, so all emitted pollutants accumulate in the lower layer. Suspended particles, soot and sulfur dioxide create smog in winter, which, even when it is sunny, reflects light, which prevents the lower layers of air from heating up and rising from the valley. At night, the air is additionally cooled, so that the cold trapped air remains in the valley. Then there are episodes of high pollution, which are characteristic of the heating season in Uzice. Most days with temperature inversion are recorded in December and January. Due to climate change, which is expressed all over the world, the number of days with temperature inversion has significantly increased, which is especially evident in the last two years. By analyzing the results, we come to the conclusion that despite the application of a number of measures to reduce pollution, temperature inversion in a large percentage overrides the implemented measures.

## ***Conclusion***

Exposure to soot, especially during the heating season, increases the risk of emergency services due to worsening of allergic rhinitis and asthma.

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