

Correlation between atmospheric air pollution by nitrogen dioxide meteorological parameters and the number of patients admitted to the Emergency Department

Korelacija između atmosferskog zagađenja zraka dušikovim dioksidom, meteorološkim parametrima te brojem pacijenata primljenim u hitan odjel

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Summary

In recent years there has been more awareness about the impact of air pollution on the incidence of acute and chronic diseases. The aim of this study was to evaluate the correlation of certain meteorological factors, the concentration of nitrogen dioxide (NO₂) in the air and the number of patients who were admitted in the Emergency Department of Internal Medicine, Sestre milosrdnice University Hospital Center in Zagreb, over the period of two years. The total number of patients was 44,245. The study took into consideration the observed meteorological parameters (temperature, atmospheric pressure, atmospheric moisture) during the cooler and warmer periods of the year and the nitrogen dioxide concentrations during the study period. The results showed that the total number of patients coming to the Emergency Department was the largest in summer. The correlation of the number of patients admitted to the Emergency Department with meteorological conditions and air pollution parameters showed that the total number of patients in the Emergency Department was proportionally higher with higher temperature ($r = 0.164$, $p < 0.001$), higher concentration of nitrogen dioxide ($r = 0.219$, $p < 0.001$) and inversely proportional with the average daily moisture ($r = -0.116$, $p = 0.002$) and the average daily atmospheric pressure ($r = -0.096$, $p = 0.009$). Taking account of the time of the year, more patients were admitted in the Emergency Department in the summer months, especially during days when the value of nitrogen dioxide was high ($r = 0.569$, $p < 0.001$), as well as when the temperatures were high ($r = 0.195$, $p = 0.008$). According to these results, there is a need for further research into the importance of the photochemical processes and their impact on human health, especially on chronic patients.

Key words: NO₂, aeropollutants, meteorological conditions, patients in emergency department

Sažetak

Posljednjih godina sve je više saznanja o utjecaju zagađenosti zraka na pojavnost akutnih i kroničnih bolesti. Cilj ovog istraživanja je procjena ovisnosti pojedinih meteoroloških parametara, koncentracije dušikovog dioksida (NO₂) u zraku i broja bolesnika koji su se javili u Hitnu službu Interne klinike Kliničkoga bolničkog centra Sestre milosrdnice u Zagrebu u vremenskom razdoblju od dvije godine. Ukupno je pregledano 44.245 bolesnika. U obzir su uzeti promatrani meteorološki parametri (temperatura, tlak zraka i vlaga zraka) tijekom toplijeg i hladnijeg dijela godine, te koncentracije dušikovog dioksida tijekom razdoblja praćenja. Rezultati pokazuju kako je ukupan broj bolesnika koji se javljaju u Hitnu službu najveći ljeti. Ukupan broj bolesnika koji su se javili u Hitnu službu proporcionalno je veći s većom temperaturom zraka i većom koncentracijom dušikovog dioksida, a obrnuto proporcionalan s prosječnom dnevnom vlagom u zraku i atmosferskim tlakom. Uzimajući u obzir doba godine, veći je broj pacijenata primljen u Hitnu službu tijekom ljetnih mjeseci, osobito u danima kada je razina dušikovog dioksida bila

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visoka ($r = 0,569$, $p < 0,001$) i kada su temperature bile visoke ($r = 0,195$, $p = 0,008$). Navedeni rezultati ukazuju na potrebu za daljnjim istraživanjem važnosti fotokemijskih procesa i njihova učinka na ljudsko zdravlje, osobito u kroničnih bolesnika.

Ključne riječi: NO₂, zagađivači zraka, meteorološki uvjeti, pacijenti u Hitnoj službi

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Introduction

Recent studies and reviews have shown that the environmental and air pollution have important short-term and long-term effects on human health.^{1,2} The exposure to aeropollutants (particulate matter < 10 µm (PM₁₀), particulate matter < 2.5 µm (PM_{2.5}), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), carbon monoxide (CO), ozone (O₃)) is directly related with higher morbidity and mortality and with a higher number of patients examined in the Emergency Department (ED).^{3,4}

The exact pathophysiological mechanisms responsible for the acute and chronic effects of aeropollutants have not been cleared yet, however, some of the possible mechanisms could include inflammation, changes in the function of the autonomic nervous system and vascular dysfunction.^{5,6}

Nitrogen dioxide (NO₂) is an adverse aerosol widespread worldwide because it has a high number of natural and artificial origins. Because its mass is higher than air mass, NO₂ precipitates in the lower layers of the atmosphere. Due to that fact, it is an easily accessible inhalant toxin.^{7,8}

The aim of this study was to evaluate the correlation of certain meteorological parameters: temperature (°C), atmospheric pressure (hPa), relative atmospheric moisture (%) and the concentration of NO₂ (µg/m³) in the air, with the number of patients who were admitted in the Emergency Department (ED) over a period of two years.

Patients and methods

In the study period between July 2008 and June 2010 there were 44,245 patients in the Emergency Department of Internal Medicine, Sestre milosrdnice University Hospital Center. The number of patients was increased by 20% in July and August due to the summer migration of the population to the sea coast.

The total number of patients was compared with the meteorological conditions and the concentration of NO₂ in the air during the observed period and during all seasons. The seasons were determined by weather conditions and not by calendar division (winter = December to February, spring = March to May, summer = June to August, autumn = September to November).

The concentration of NO₂ was measured daily using the method of chemical luminescence at the

height of 3 meters and data were taken from the National Monitoring Station Zagreb – 1 (Environmental Protection Agency). The concentrations of other aeropollutants: sulfur dioxide (SO₂), particles of dimensions ~10 micrometers or less (PM₁₀) and ozone (O₃) were also measured by the National Monitoring Station Zagreb – 1. The statistical analysis of SO₂, PM₁₀ and O₃ was carried out in order to exclude the synergistic effect on the number of patients in the ED.

The average atmospheric temperature (°C), average values of atmospheric pressure (hPa) and relative atmospheric moisture (%) were based on the data collected by the Meteorological and Hydrological Service of Croatia.

Statistics

The mean values of individual variables were tested by nonparametric Mann-Whitney test which included two samples and a non-parametric analysis of Kruskal-Wallis ANOVA for multiple samples. The correlation between the number of patients and each of the meteorological variables and air pollution was tested by non-parametric Spearman's rank correlation.

A value of $p < 0.05$ was considered statistically significant. Statistics 6.0 was used for statistical analysis.

Results

During the period between July 2008 and June 2010 there were 44,245 patients at the Emergency Department of Internal Medicine, Sestre milosrdnice University Hospital Center. The largest number of admitted patients was recorded in summer amounting to 11,689 patients (26.4%).

The average daily number of patients admitted in the ED was 60 (range 29-96). The highest total number of patients examined in ED was in spring amounting to 63.5 patients (range 39-83) per day. (Table 1)

The highest concentrations of NO₂ were observed in winter (130.4 µg/m³), while the lowest concentrations of NO₂ were recorded in spring (3.6 µg/m³) (Picture 1). The average daily concentrations of NO₂ were the lowest in summer 31.5 µg/m³ and highest in autumn 44.7 µg/m³ ($p < 0.001$).

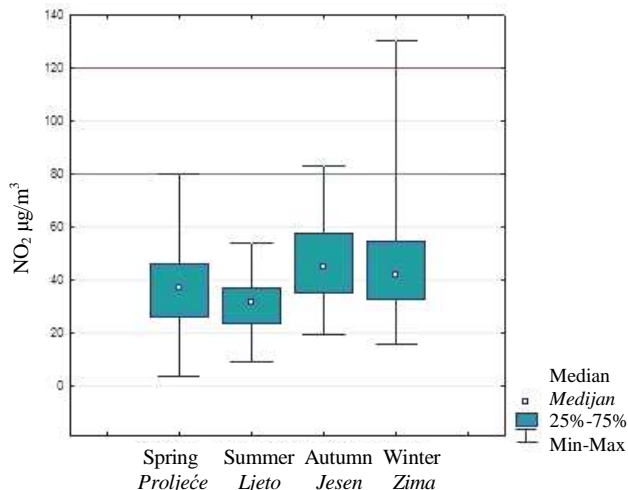
Table 1 Number of patients examined in ED in the period of July 2008 to June 2010 according to seasons (No of patients examined in summer was corrected by 20%)

Tablica 1. Broj pacijenata ispitanih u ED u razdoblju od srpnja 2008 do lipnja 2010, prema godišnjim dobima (Broj pacijenata ispitanih u ljetu je bio povećan za 20%)

	Total No of patients <i>Ukupan broj pacijenata</i>
Total / <i>Ukupno</i>	44 245 (100%)
Spring / <i>Proljeće</i>	11 561 (26.1%)
Summer / <i>Ljeto</i>	11 689 (26.4%)
Autumn / <i>Jesen</i>	10 503 (23.8%)
Winter / <i>Zima</i>	10 492 (23.7%)

In winter the temperature median was 2.6 °C (-7.9 to 14.5), in summer 22.5 °C (13.3 to 28.5), while in spring and autumn the medians of atmospheric temperature were almost equal, 13.4 °C in spring (-1.2 to 26.5) and 13.8 °C in autumn (1.0 to 25.4) ($p < 0.001$). Relative atmospheric moisture was the highest in winter, 78.9% (43.6 to 94.0) and the lowest in spring, 60.7% (37.7 to 91.4) ($p < 0.001$). (Table 2)

The correlation of the daily number of patients admitted to the ED with air pollution parameters and meteorological conditions suggested that the total number of patients in the ED was proportionally higher with a higher concentration of NO₂ in the air, ($r = 0.219$, $p < 0.001$) higher temperature, ($r = 0.164$, $p < 0.001$) and inversely proportional with the average daily moisture ($r = -0.116$, $p = 0.002$), and the average daily atmospheric pressure ($r = -0.096$, $p = 0.009$). Taking into account the time of the year, more patients were admitted in the ED during the summer months,



Picture 1 Average NO₂ concentrations according to seasons

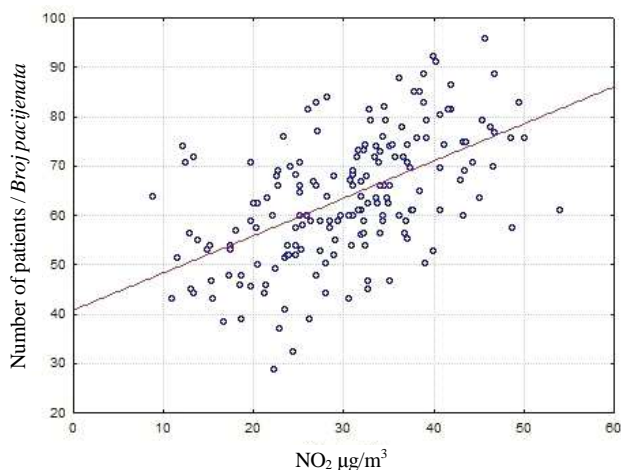
Slika 1. Prosječne NO₂ koncentracije prema godišnjim dobima

especially during the days when the value of NO₂ was high ($r = 0.569$, $p < 0,001$), (Picture 2), as well as when temperatures were high ($r = 0.195$, $p = 0.008$). It is interesting that the spring weather conditions did not present statistically significant factors associated with the frequency of appearance of patients in the ED, temperature ($p = 0.438$), moisture ($p = 0.113$), air pressure ($p = 0.268$), where as high concentrations of NO₂ proved to be a significant parameter ($r = 0.293$, $p < 0.001$). During autumn, the increased number of patients examined in the ED inversely correlated with the atmospheric pressure ($r = -0.146$, $p = 0.049$) and proportionally correlated with high concentrations of NO₂ ($r = 0.189$, $p = 0.026$). Likewise, during the winter months the atmospheric pressure inversely correlated with the increased number of patients in the ED ($r = -0.174$, $p = 0.019$), where as the NO₂ concentrations correlated proportionally ($r = 0.325$, $p < 0.001$).

Table 2 Values of meteorological characteristics according to seasons

Tablica 2. Vrijednosti meteoroloških karakteristika prema godišnjim dobima

	No of days <i>Broj dana</i>	Temperature <i>Temperatura</i> Median (range) <i>Medijan (raspon)</i>	Rel. moisture <i>Relativna vlaga</i> Median (range) <i>Medijan (raspon)</i>	Pressure <i>Tlak</i> Median (range) <i>Medijan (raspon)</i>
Total / <i>Ukupno</i>	730	13.4 (-7.9 – 28.5)	68.9 (37.7 – 95.3)	996 (966 – 1020)
Spring / <i>Proljeće</i>	184	13.8 (-1.2 – 26.5)	60.7 (37.7 – 91.4)	997 (966 – 1009)
Summer / <i>Ljeto</i>	184	22.5 (13.3 – 28.5)	61.5 (41.0 – 89.5)	996 (984 – 1004)
Autumn / <i>Jesen</i>	182	13.4 (1.0 – 25.4)	73.5 (44.4 – 95.3)	998 (979 – 1013)
Winter / <i>Zima</i>	180	2.6 (-7.9 – 14.5)	78.9 (43.6 – 94.0)	994 (971 – 1020)
Kruskal-Wallis ANOVA		$p < 0.001$	$p < 0.001$	$p < 0.001$



Picture 2. Correlation in number of patients in ED and NO_2 concentration in summer; Spearman's rank correlation: ($r = 0.569$, $p < 0.001$)
 Slika 2. Korelacija broja pacijenata u ED i NO_2 koncentraciji u ljetu; Spearmanov rang korelacije ($r = 0.569$, $p < 0.001$)

Discussion

The aim of this study was to provide answers to questions whether air pollution by NO_2 in different weather conditions is related to the number of patients admitted in the ED.

Aeropollutants are a heterogeneous, complex mixture of gases, liquids and particulate matter which are, according to epidemiological studies, connected with a higher incidence of acute and chronic internal diseases. Inhalation of air pollutants interferes with the heart activity and causes various types of arrhythmia and an increased tendency to thrombosis, affects the blood pressure and accelerates the atherosclerotic process.⁶⁻¹⁰

Numerous studies that were conducted in major European and American cities have shown a negative impact of aeropollutants (PM_{10} , PM_{25} , NO_2 , SO_2 , CO , O_3)¹¹ and meteorological conditions on the cardiac function and the function of the autonomic nervous system.^{3,12-14} A thorough investigation into the effect of NO_2 on human health and the connection between the concentrations of NO_2 in the air and the daily admission of patients in the ED has not been carried out.

Our results showed that the number of patients in the ED was directly dependent on the concentrations of NO_2 in the air throughout the observed period.

Due to the possible interference of NO_2 with the autonomic nervous system, a high number of patients had palpitations and the feeling of increased heart rate. The higher incidence of heart attack and exacer-

bations of angina pectoris are explained by a possible prothrombotic and proatherosclerotic influence of NO_2 . These results confirmed the results of the study conducted in five European cities; Augsburg, Barcelona, Helsinki, Rome and Stockholm that had shown a strong influence of aeropollutants on the morbidity and mortality of cardiovascular patients (higher incidence of heart attacks, angina pectoris, arrhythmias, heart failure and strokes).^{9,15}

Some studies indicate that long-term exposure to traffic-related air pollution may contribute to the development of COPD with possibly enhanced susceptibility in people with chronic diseases, especially asthma and diabetes.¹⁶ Also, there is an association between hospital admissions for COPD with NO_2 as well as other air pollutants, such as ozone (O_3), PM_{10} , $\text{PM}_{2.5}$, SO_2 , especially during the winter season.¹⁷

Linares et al's study from Madrid has proved that the increase of air temperature leads to the increase of the number of patients admitted in the ED.¹⁸ Likewise, the increase of air temperature has an even stronger impact on the increase of mortality from circulatory and respiratory diseases. These results suggest that people die more during heat waves and before they can be admitted to the ED. This information is crucial for the implementation of prevention plans before the arrival of the heat wave, and so as to make them as more efficient as possible in order to reduce mortality.

The results show that NO_2 was a statistically significant variable that appeared in all four seasons and affected the number of admitted patients. Even the smallest increase of NO_2 concentrations caused a rise in the number of patients in the ED.

The highest concentration of NO_2 were measured during autumn and winter, probably due to the increased use of motor vehicles and their exhaust gases. Nevertheless, the influence of NO_2 concentration on the admission acute and chronic patients to the ED was significantly more noticeable in summer than in winter due to higher values of air temperature. Despite the average low values of NO_2 concentration in summer, especially in days when the concentrations of NO_2 was higher, the number of patients in the ED was significantly higher. The earlier mentioned synergistic effect of the increased air temperature and NO_2 on the coagulation system might be the reason for this phenomenon. Due to increased respiration rate and sweating, people are more prone to dehydration because of fluid loss. Fluid loss increases blood viscosity and heart rate, and also decreases cardiac input. The combination of dehydration and the procoagulant effect of NO_2 could be the

cause of exacerbations of various internal diseases (cardiovascular, pulmonary, thrombosis, etc.)

The limitations of our study were related to the uncertainty of the impact of NO₂ concentrations on patients with certain diagnoses in the overall internistic diagnoses. In our opinion such a study could provide information about particular risk groups that are vulnerable to the elevated concentrations of NO₂.

According to these results, there is a need for further research into the importance of the photochemical processes, and of other aeropollutants, and their impact on a patient's health, especially on chronic patients.

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