DESCRIPTIVE ANALYSIS OF URGENT MEDICAL INTERVENTIONS BASED ON AIR POLLUTION IN SLAVONSKI BROD, CROATIA

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ABSTRACT

Air pollution is a big public health problem. Short term and long-term exposure to air pollutants have different health effects. The purpose of this research is to determine whether PM10, PM2.5, H2S and meteorological parameters have impact on frequency of urgent interventions in ERs (Institute of Emergency Medicine of Brod-Posavina County and Integrated Emergency Hospital Admission) in 2016 in the area of Slavonski Brod. Data were collected from four sources: Institute of Emergency Medicine of Brod-Posavina County, Integrated Emergency Hospital Admission, Meteorological and Hydrological Service data and Croatian Agency for Environment and Nature. During 2016, 56349 interventions in ERs were recorded. Weak but statistically significant positive correlation was established between PM10 (correlation coefficient 0.103; p 0.043) and PM2.5 (correlation coefficient 0.106; p 0.043) with the number of interventions in ERs. The correlation of mean relative humidity was statistically significant but negative (correlation coefficient -0.109; p 0.038). Connection between minimum and maximum temperature, H2S and mean pressure values was not established. These results point to the importance of reducing air pollution with PM10 and PM2.5 in Slavonski Brod.

Keywords: particulate matter, PM2.5, PM10, pollutants, hydrogen sulphide.

1  INTRODUCTION

A great risk for global health, recognized by governments, institutions and citizens, is air pollution [1]. It is estimated that 6 million of premature deaths in 2012 is caused by polluted air [1]. The reasons for premature deaths are mostly ischaemic heart disease and strokes then chronic obstructive pulmonary disease or acute lower respiratory infections and lung cancer [2]. Air pollutants have short term and long-term influence on human health.

People can be exposed to PM10 and PM2.5 for hours and days and for months and years. Both exposures include: respiratory and cardiovascular morbidity, such as aggravation of asthma, respiratory symptoms and an increase in hospital admissions; mortality from cardiovascular and respiratory diseases and from lung cancer [3], [4]. Particulate matter influence on spontaneous miscarriages, autism diseases, attention disorders, dementia and brain tumours has also been studied [5]–[8]. Short-term exposure to PM10 has big influence on respiratory health, for mortality, and long-term exposure even bigger [4]. Daily mortality caused by all reasons increases by 0.2–0.6% per 10 µg/m3 of PM10 [4]. PM2.5 is even a riskier element than PM10 [4]. Increased concentrations of PM2.5 were associated with increased risks at lag days 0-1 of all-cause mortality (0.26% increase per 10µg/m³), non-accidental deaths(0.25%), circulatory deaths (0.39%), respiratory deaths (0.43%), intentional self-harm deaths (1.94%) and nervous system deaths (0.9%), although the observed increase was not statistically significant for the final one rarer cause of death [9].
Especially vulnerable groups are people with pre-existing lung or heart disease, children and older people [4]. A safe level of exposure or a threshold below which adverse health effects do not occur does not exist as a proof [4]. There is evidence of connection between the concentrations of particulate matters (PM$_{2.5}$, PM$_{2.5-10}$, PM$_{10}$) and their chemical components (soluble ions) with hospital admissions because of circulatory and respiratory diseases among older people in a medium-sized city in Brazil [10]. PM$_{2.5}$ showed a remarkable connection with circulatory system diseases, and the risk of hospitalization increased by 19.6% per 10 µg/m$^3$ [1]. Exposures to PM$_{10}$, PM$_{2.5}$, and NO$_{2}$ showed a significant association with emergency admissions for ischemic heart disease and heart rhythm disturbances [11]. The estimated risk reduction for ischemic heart disease admissions was 2.44%, 2.34%, and 3.93% for a 10% reduction in PM$_{10}$, PM$_{2.5}$, and NO$_{2}$ respectively [11].

Smell of hydrogen sulphide is very annoying [1]. The average value of the threshold odour according to WHO is 11 mg/m$^3$ [12]. There are no completely finished investigations on long-term exposure to low concentrations of hydrogen sulphide. There is a research among the workers in the water and wastewater network that showed an increased number of patients with obstructive lung disease in workers in the wastewater network, exposed to higher concentrations of hydrogen sulphide, than in workers employed in water network [13].

Annual reports on air quality in Slavonski Brod, Croatia, show that the atmosphere is polluted with respect to: H$_2$S, PM$_{10}$ and PM$_{2.5}$ in 2015 [1]. A similar situation was in previous years [15]. Air pollution is in the centre of attention of citizens of Slavonski Brod since the oil refinery in neighbouring country of Bosnia and Herzegovina was put into operation in 2008. Researches on the impact of pollutants on human health in the area of Slavonski Brod are rare. Given the impact on health, the aim of this paper is to show the influence of particulate matters, hydrogen sulphide and meteorological conditions on the frequency of emergency medical interventions.

2 METHODS
The analysis in the town of Slavonski Brod for the period of time from January 1–December 12, 2016. was carried out using data from four sources:

1. System eHitna – interventions of urgent medical help of the Institute of Emergency Medicine of Brod-Posavina County (Croatian acronym ŽZHM), the branch office in Slavonski Brod. Data include field interventions of urgent medical help stuff in Slavonski Brod and ER visits.
2. OHBP data – visits to Integrated Emergency Hospital Admission (Croatian acronym: OHBP).
3. Meteorological and Hydrological Service data (Croatian acronym DHMZ) – temperature minimum and temperature maximum, mean value of air pressure and mean value of relative humidity per day.
4. Croatian Agency for Environment and Nature (Croatian acronym HAOP) data –air quality for PM$_{2.5}$ and PM$_{10}$ per day based on gravimetry and for H$_2$S per day, data from two automatic measuring stations (SL1 and SL2).

Data from ŽZHM and from OHBP were compiled and observed in order to comprehend the sum of interventions/visits per day (all interventions/visits per day without deleting duplicate records). There were no data about patients place of residence neither patients were filtered by their country of residence. Total number of all interventions/visits per day over one year was investigated. All diseases were included in the analysis. Meteorological and air
quality data were added to each day. Values of PM$_{2.5}$, PM$_{10}$ and H$_2$S were also analysed regarding the limit values (25 µg/m$^3$ for PM$_{2.5}$, 50 µg/m$^3$ for PM$_{10}$ and 5 µg/m$^3$ for H$_2$S). There was missing meteorological and air quality data from automatic measuring stations. Missing cases for correlations between number of interventions/visits and environmental variables were excluded pairwise.

Numeric variables were described by the central values and the dispersion measure, conditioned by data distribution. Shapiro-Wilks / Kolmogorov-Smirnov's assay was used to test continuous variables for normal distribution. Pearson correlation coefficient was used for testing of direction and strength of the correlation between the variables for the variables distributed normally and Spearman correlation coefficient was used in a case when the variables were not distributed normally. Mann-Whitney test was used to determine the difference of continuous variables between the two groups. In data analysis, MS Excel and SPSS 23 programme package were applied. To conduct the research, Ethics Committee of the Croatian Institute of Public Health gave the approval no. 80-436 /1-16.

3 RESULTS
In the observed period, there were 41674 interventions in OHBP and 14675 interventions in ŽZHMin. The total number of interventions in both OHBP and ŽZHMin was 56 349.

Measures of central tendency and variance of variables are shown in Table 1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of interventions</td>
<td>366</td>
<td>153.96</td>
<td>152</td>
<td>25.84</td>
<td>101</td>
<td></td>
</tr>
<tr>
<td>Number of interventions - ŽZHMin</td>
<td>366</td>
<td>40.10</td>
<td>36</td>
<td>16.05</td>
<td>15</td>
<td>107</td>
</tr>
<tr>
<td>Number of interventions - OHBP</td>
<td>366</td>
<td>113.86</td>
<td>113</td>
<td>15.70</td>
<td>75</td>
<td>200</td>
</tr>
<tr>
<td>Minimum temperature (°C)</td>
<td>365</td>
<td>5.94</td>
<td>6.2</td>
<td>7.35</td>
<td>-10.8</td>
<td>21.4</td>
</tr>
<tr>
<td>Maximum temperature (°C)</td>
<td>365</td>
<td>18.11</td>
<td>17.7</td>
<td>9.51</td>
<td>-7</td>
<td>36.5</td>
</tr>
<tr>
<td>Medium air pressure (hPa)</td>
<td>365</td>
<td>1006.97</td>
<td>1006.12</td>
<td>8.05</td>
<td>985.91</td>
<td>1029.68</td>
</tr>
<tr>
<td>Relative humidity (%)</td>
<td>365</td>
<td>77.11</td>
<td>76.81</td>
<td>10.44</td>
<td>46.35</td>
<td>98.08</td>
</tr>
<tr>
<td>SL1_ PM$_{2.5}$ ($\mu$g/m$^3$)</td>
<td>366</td>
<td>41.36</td>
<td>23.36</td>
<td>49.61</td>
<td>1.75</td>
<td>518.77</td>
</tr>
<tr>
<td>SL2_ PM$_{2.5}$ ($\mu$g/m$^3$)</td>
<td>352</td>
<td>34.73</td>
<td>21.08</td>
<td>35.94</td>
<td>2.13</td>
<td>262.55</td>
</tr>
<tr>
<td>SL1_ PM$_{10}$ ($\mu$g/m$^3$)</td>
<td>366</td>
<td>49.59</td>
<td>30.51</td>
<td>52.68</td>
<td>3.25</td>
<td>537.26</td>
</tr>
<tr>
<td>SL2_ PM$_{10}$ ($\mu$g/m$^3$)</td>
<td>350</td>
<td>40.86</td>
<td>28.49</td>
<td>35.75</td>
<td>0.43</td>
<td>266.42</td>
</tr>
<tr>
<td>SL1_ H$_2$S ($\mu$g/m$^3$)</td>
<td>350</td>
<td>1.65</td>
<td>1.37</td>
<td>1.32</td>
<td>0.15</td>
<td>11.97</td>
</tr>
<tr>
<td>SL2_ H$_2$S ($\mu$g/m$^3$)</td>
<td>330</td>
<td>2.66</td>
<td>2.63</td>
<td>1.20</td>
<td>0.95</td>
<td>15.72</td>
</tr>
</tbody>
</table>
Values on the SL1 station for PM$_{2.5}$ were within limit values during 197 days (53.83%), during 259 days (70.77%) for PM$_{10}$ and during 342 days (93.44%) for H$_2$S while on the SL2 station, values were within recommended values during 200 days (54.64%) for PM$_{2.5}$, during 266 days (72.68%) for PM$_{10}$ and during 325 days (88.8%) for H$_2$S. Values for H$_2$S on SL1 were not recorded for 16 days and values for PM$_{10}$ and PM$_{2.5}$ were recorded for every single day. 3.83% of values for PM$_{2.5}$ on the SL2 station were not recorded, 4.37% were not recorded for PM$_{10}$ as well as 9.84% for H$_2$S.

Distribution normality test (Shapiro-Wilks/Kolmogorov-Smirnov test) showed that none of the observed continuous variables were normally distributed.

Correlations between number of interventions/visits and environmental variables (meteorological data and data on PM$_{2.5}$, PM$_{10}$ and H$_2$S) as well as the significance of correlation with a level significance of 5% (p < 0) are shown in Table 2. On the SL1 station, there was a significant weak correlation (RS=0.103, p=0.049) between PM$_{2.5}$ and the number of interventions per day and weak correlation (RS=0.106, p=0.043) between PM$_{10}$ and the number of interventions per day. On the SL2 station, there was a significant weak correlation (RS=0.120, p=0.025) between PM$_{10}$ and the number of interventions. Negative statistically significant correlation with relative humidity (RS=-0.109, p=0.038) was recorded.

4 DISCUSSION

The results of air quality measurement in Slavonski Brod do not show any improvement over previous periods. The PM$_{10}$, PM$_{2.5}$ and H$_2$S values reached high concentrations (maximum 537.26 µg/m$^3$, 518.77 µg/m$^3$, 15.72 µg/m$^3$). The Croatian air quality law assesses air quality as the first (clean) or second category (polluted). Regarding particulate matter and H$_2$S, air in Slavonski Brod is in the second category (polluted). In addition to poor air quality data suggest that concentrations for PM$_{2.5}$ within the recommended values were 197 of 366 days, and for PM$_{10}$ 259 days.

Results of this study for 2016, show positive, statistically significant, but weak correlation between PM$_{2.5}$ and PM$_{10}$ concentrations and daily number of emergency interventions.

Table 2: Correlations between number of interventions/visits and environmental variables (meteorological data and data on PM$_{2.5}$, PM$_{10}$ and H$_2$S).

<table>
<thead>
<tr>
<th></th>
<th>Number of interventions per day</th>
<th>Correlation coefficient</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium relative humidity</td>
<td></td>
<td>-0.109</td>
<td>0.038</td>
</tr>
<tr>
<td>Minimum temperature</td>
<td></td>
<td>-0.038</td>
<td>0.472</td>
</tr>
<tr>
<td>Maximum temperature</td>
<td></td>
<td>0.028</td>
<td>0.598</td>
</tr>
<tr>
<td>Medium air pressure</td>
<td></td>
<td>0.019</td>
<td>0.721</td>
</tr>
<tr>
<td>SL1 PM$_{2.5}$</td>
<td></td>
<td>0.103</td>
<td>0.049</td>
</tr>
<tr>
<td>SL2 PM$_{2.5}$</td>
<td></td>
<td>0.098</td>
<td>0.066</td>
</tr>
<tr>
<td>SL1 PM$_{10}$</td>
<td></td>
<td>0.106</td>
<td>0.043</td>
</tr>
<tr>
<td>SL2 PM$_{10}$</td>
<td></td>
<td>0.120</td>
<td>0.025</td>
</tr>
<tr>
<td>SL1 H$_2$S</td>
<td></td>
<td>0.077</td>
<td>0.151</td>
</tr>
<tr>
<td>SL2 H$_2$S</td>
<td></td>
<td>0.054</td>
<td>0.328</td>
</tr>
</tbody>
</table>
registered with ŽZHM and OHBP. Number of interventions increased with the increase of concentration levels. Similar results have been obtained in some other research studies [16], [17]. Results for PM$_{2.5}$ and PM$_{10}$ for the first 8 months of 2016 are also similar [18]. The difference is related to H$_2$S which has not been statistically linked with emergency interventions during 2016 while for the first 8 months the correlation of H$_2$S with the number of emergency interventions was inconsistent [18]. The connection of meteorological parameters and air pollution with emergency interventions due to cardiovascular disease was established in Zagreb [19]. The authors found a statistically significant correlation between the number of aggravated chronic obstructive pulmonary disease in adults and the total suspended particles concentrations on the previous day [20]. Among other results, the occurrence of respiratory diseases showed positive Spearman’s correlation with the values of air humidity, PM$_{10}$ and negative correlation with the values of air temperature and pressure. The occurrence of respiratory diseases showed correlation with weather conditions and air pollutants despite the legally permitted values in the region with a humid continental climate [21] Spearman’s correlation yielded positive correlation between the occurrence of arrhythmias and air humidity on the day ($r=0.07$), and 1 ($r=0.08$, 2 ($r=0.09$) and 3 days before ($r=0.09$), palpitations and air humidity on the day ($r=0.11$), and 1 ($r=0.09$), 2 ($r=0.07$) and 3 days before ($r=0.10$), and PM$_{10}$ ($r=0.11$) particles on the day of emergency department (ED) admission; and atrium fibrillation/undulation and air humidity 2 days before ($r=0.08$) ED admission ($p<0.05$ all)[22]. There was a very weak positive correlation of the occurrence of cardiac arrhythmias with air humidity and concentration of air pollutants in the region with a humid continental climate [22]. Our research has shown a negative correlation between mean relative humidity and number of interventions. A 10 µg/m$^3$ decrease in concentration would imply 256 less hospital admissions and savings of approximately RS 220,000 in a medium-sized city [23]. Other studies also show the connection between particulate matter and hospital admissions due to stroke as well as between children pneumonia and air pollution [24], [25]. Certain pollution is associated with elevated hospital admissions due to respiratory diseases and ischemic stroke [26], [27].

The highest number of admissions (37.2%) occurred during winter, followed by autumn (24.1%), spring (23.9%), and summer (14.7%) [17]. Maximum, minimum, and mean temperatures were associated similarly with the number of hospitalization [28].

In our research, we did not find the connection of emergency medical interventions with minimal and maximum temperature. A significant negative correlation was found between cardiovascular diseases-related emergency visits and air temperature measured no more than three days prior to the visit, and the highest negative correlation coefficient was measured two days earlier [19].

The results for the first 8 months showed a weak negative correlation between minimum/maximum temperature and the daily number of patients reporting to the emergency clinic, specifically in the winter months at low temperature and low wind events, can be partially explained with increased heating on wood and charcoal a common way of heating by the local population [18].

In Croatia, the emergency health service is organized through a system of emergency clinic and the Integrated Emergency Hospital Admission. Although we did not specifically analyse the specific reason why patients visit emergency service, connections with high concentrations of PM$_{10}$ and PM$_{2.5}$ were established. These results provide basis for further recommendations and on the continuation of investigation that would lead to an adequate advisory system for general public in cases of pollutant concentrations exceeding prescribed threshold or guideline limit values.
Some countries have introduced recommendations such as the Air Quality Index [29]. Specific health advice/warning information (for example Daily Air Quality Index) for the general public and sensitive individuals (those with pre-existing illness and the elderly) is developed already for example in United Kingdom [29]. It is based on the level of the Daily Air Quality Index and are disseminated via Internet [29]. Croatian Agency for Environment and Nature publishes the index without description of health impacts [30]. Parameters that are monitored include gases (NO, NO₂, CO, O₃, H₂S, SO₂, benzene, NH₃), particulate matter (PM₁₀ and PM₂.₅), and meteorological data (wind speed and direction, temperature and pressure) [30]. If the parameter values exceed the corresponding regulation limits for three consecutive hours, the web service generates an alert for population groups at risk [30]. Incorporating health tips to vulnerable groups with the use of new technologies that make it available at any time, for example cell phones, will be a new step in protecting the health of people [18]. Such information should serve as a recommendation on how to act and avoid unnecessary exposure [18].

Considering constraints (lack of data on residence) and specifics of the sample (the domain of emergency medicine and the logging of visits), test strength and generalisation of conclusions on for the entire population of Slavonski Brod can be limited.

It is necessary to continue with further research, to jointly interpret the results of complementary surveys and to analyse further additional parameters and indicators of current pollution.

5 CONCLUSION
Statistically significant positive correlation between PM₁₀ (correlation coefficient 0.103; p 0.043) and PM₂.₅ (correlation coefficient 0.106; p 0.043) with the number of medical interventions in emergency rooms was established, though weak. The correlation of mean relative humidity was statistically significant but negative (correlation coefficient -0.109; p 0.038). These findings point to the need for further researches on this big public health issue. Also, these results point to the importance of reducing air pollution with PM₁₀ and PM₂.₅ in Slavonski Brod.

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