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Examination of Air Pollutants Influence on Human Health on The Frequency of Hospital Admissions in Hungary

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ABSTRACT

Many studies have shown that the increased atmospheric concentration of pollutants has an intensified health risk on lung-, heart- and cardiovascular disease sufferers, as well as the increasing willingness of morbidity and mortality. Therefore, the monitoring of the air pollutants is particularly important. The goal of the recent study was to show a complex picture about Veszprém county's air quality situation and to discover the relationships between the selected air pollutants (PM_{10}, CO, NO_2, SO_2, O_3) concentration and the picked health diseases (cardiovascular diseases, respiratory diseases, gastrointestinal disorders, ischemic heart disease, cerebrovascular disease, and chronic lower respiratory diseases). Ambient air pollution and hospital admission data for the research were obtained for 2005–2013. According to the calculations; it was found that there was a moderate relation between the air pollutants concentrations and the health diseases.

Keywords: Air Quality, Health Effect, Public Health, Diseases, Regression Analysis.

1. INTRODUCTION

Clean air - as a fundamental component of the environment - is essential for a safe and healthy life, because it is one of the movers of the metabolism of human body, without which life can be maintained up to only several seconds. In the atmosphere, the processes of that fastest-moving medium plays a central role in the humans' daily lives, in addition to business and economic activities. The result of the increased urbanization, motorization and industrialization is that the atmosphere became more and more polluted, so the concentration of air pollutants exceeds the health limits, which is an increasing public health issue.

According to a recently published study [1] around 6.5 million deaths are attributed each year to poor air quality, which makes air pollution to the world's fourth-largest threat to human health, behind high blood pressure, dietary risks and smoking. Several studies have demonstrated [2] [3] [4] [5] [6] that the increased atmospheric concentration of air pollutants means increased health risk of respiratory- and cardiovascular disease sufferers.

There are numerous previous studies [7] [8] [9] [10] [11] [12] [13] which concerned that high atmospheric concentration of air pollutants can be attributed to the growing willingness of morbidity and mortality. Many researchers investigated also the spatial distribution and the temporal trends of air pollutants [14] [15] [16] [17] [18] which can determine the quality of life, especially in cities. Various analytical methods are used to find a relationship between health issues and air pollutants.

Linear modelling, mostly linear least squares regression analysis is by far the most well-known analytical method in the field of behaviour-, social-, public health and natural sciences [19] [20]. The analysis is extensively used and confirmed by many experiments in the works of [21] [22] [23]. In the presented study it was of interest to examine whether the frequency of hospital admissions was affected by ambient air contaminants present in Veszprém county.

The authors examined and determined the strength of the relationships between the selected air pollutants concentration in the ambient air and the picked health diseases.

2. METHODOLOGY

2.1 Study area

Most part of Veszprém County stays in the Transdanubian Mountains, which means not too high mountain ranges and hills [24]. The topography determines the environmental status of the settlements and the within state of the environment too. In the case of the settlements - which located in the pool or in the ditch system which separates the mountain range - inversion meteorological conditions can occur more easily, so the air pollutants can settle easily in calm weather in the area. Though the county has a relatively small spatial extension, it has a widely diverse climate. The spatial distribution of precipitation is varied. The highest annual precipitation values are measured in the higher regions of Bakony-hills between 650-850mm. The number of hours of sunshine can be relatively uniform, which occurs every year between 1960-2000 hours. The typical wind direction commonly is north or northwest and the average wind speed value is around 3 m/s throughout the county [24] [25]. The county is rich in natural resources and due to the found mineral resources (brown coal, bauxite, and manganese ore), it is one of the most important raw material provider's parts of the country. Based on the significant amount of resources it could be found mines, power plants and an aluminium smelter in the county [26]. Other notable mineral deposits are limestone, dolomite, basalt, tuff, and also marl [25]. However, during the extraction, transportation and procession of these mineral and energy resources the level of one or more air pollutants were constantly above the limit, so the county's industrial area was heavily contaminated qualified in the terms of air quality [24]. Nowadays, the air quality of Veszprém County is basically determined by industry - mostly chemical plants, whose main profile is to manufacture fertilizers and pesticides - public heating and traffic-related emissions.

2.2 Data

The hospital admission data of various diseases were provided by the National Healthcare Services Center. For this study, daily counts of hospital admissions were extracted for cardiovascular diseases (International Classification of Diseases [ICD-10], codes 100-199), respiratory diseases (codes Joo-J99), gastrointestinal disorders (codes K00-K93), ischemic heart disease (codes I20-I25), cerebrovascular disease (codes I60-I69), and chronic lower respiratory diseases. For the calculation of the Veszprém County population exposure the Hungarian Air Quality Network database was used. The county has three air quality monitoring stations (Ajka, Veszprém, Várpalota), which are fully automated and monitor ambient levels of five pollutants including sulfur dioxide (SO_2), particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide (NO_2), carbon monoxide (CO), and ozone (O_3). For this study, hourly air pollution data were collected from each of the three monitoring stations for each day. After calculating the hourly mean of each pollutant based upon data obtained from all the three stations, the yearly average levels of these pollutants were then calculated. Ambient air pollution and hospital admission data for Veszprém county were obtained for 2005–2013.

2.3 Statistical methodology

For the needs of the study, multiple linear regression analysis was used to the find relations between the variables. The base of the model – which is a widely used analysis yields a mathematical equation – is that it estimates a

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dependent variable Y from a set of predictor variables or regressors X [27] [28] [29]. The method assumes that the response variable is a linear function of the model parameters and there are more than one independent variables in the model. In the case of linear regression, the set of points designate a line with a smaller or greater precision. The position of the straight line can be quite self-explanatory in itself, because it is possible to determine whether there is a positive or negative correlation or how close correlation is (points are all relatively close to the straight line).

During the work there was a suspicion that the detected correlation was just a coincidence. Therefore, it was necessary to ascertain whether the detected correlation exists, and there is a realistic relationship between the examined parameters. To do this, it was necessary to set a null hypothesis. The null hypothesis means that the j-th explanatory variable has a regression coefficient of 0, ie any shift of j-variable does not affect the result variable. Testing this hypothesis is possible with the so-called Student Trial (T-test).

The calculated t-value, i.e. the quotient of the estimated regression coefficient and the standard error, was compared to the t-critical value in the Student Table (at a selected confidence level). If the t value was greater than the absolute value of the t-critic, then the null hypothesis was discarded, that is, the correlation and the r value was accepted. Otherwise, the null hypothesis was accepted, which means that the value of the parameter does not differ significantly from 0.

3. RESULTS

3.1 Descriptive Statistics

During the 9-year period of this study, a total of 488.000 hospital admissions for circulatory system diseases, 423.000 for respiratory system disorders, 230.000 for digestive system diseases were recorded for the 3 hospitals in Veszprém county. Mean number of circulatory-, respiratory- and digestive system disorder admissions was 148 – 128 – 69 per day over the study period. Figure 1-8 presents descriptive statistics of hospital admission for Veszprém County, by cause of disease for all ages in years between 2005-2013. It is visible, that in case of 4 diseases the registered number of cases increased at least 4%. Digestive system diseases decreased minimally over the years. However, the numbers of cases of respiratory system disorders in Veszprém County are decreased drastically (-29%).

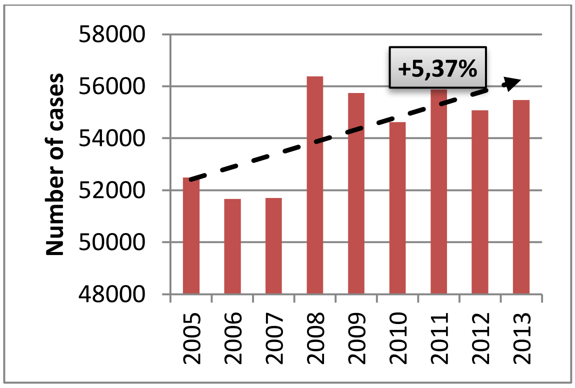

Figure 1: Circulatory system Diseases (number of cases) in Veszprém County

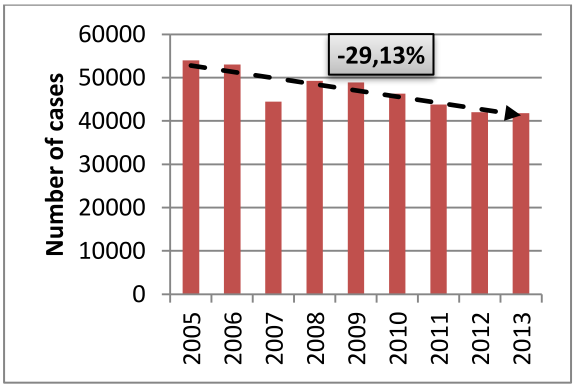

Figure 2: Respiratory system disorders (number of cases) in Veszprém County

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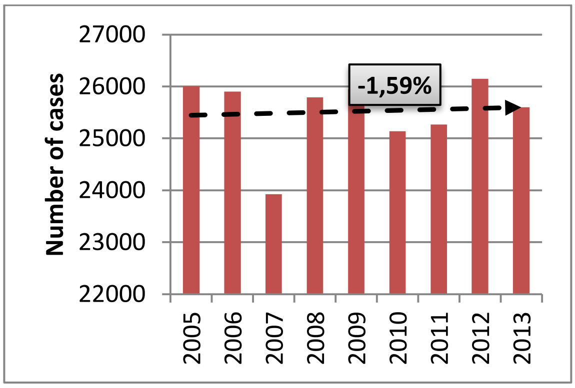

Figure 3: Digestive System Diseases (number of cases) in Veszprém County

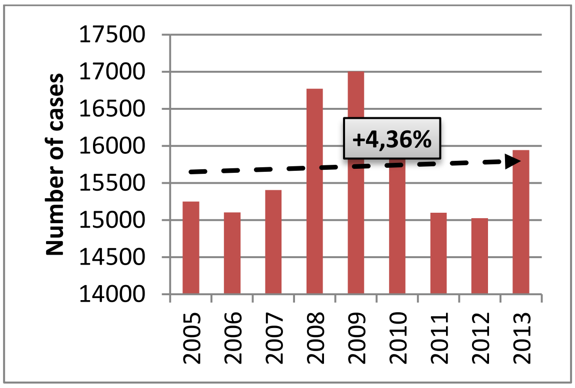

Figure 4: Ischemic heart disease (number of cases) in Veszprém County

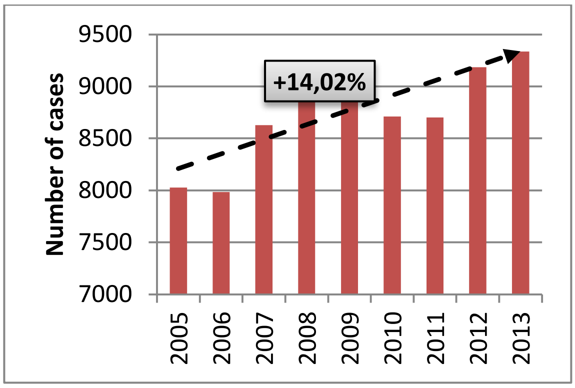

Figure 5: Cerebrovascular diseases (number of cases) in Veszprém County

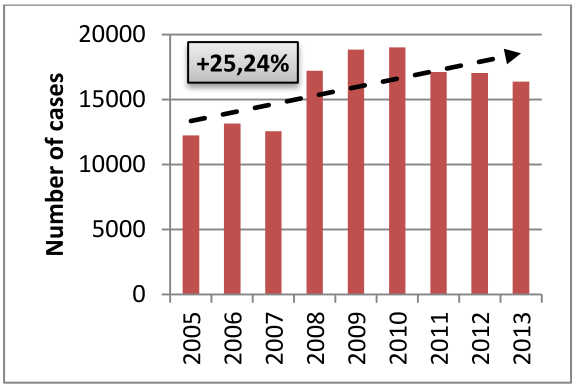

Figure 6: Chronic lower respiratory diseases (number of cases) in Veszprém Count

In the case of PM_{10} over the selected examined period it can be observed a decreasing tendency (Fig.7.). Comparing the year 2005 with 2013 more than a 40% concentration decrease can be noted. The highest annual average concentration was in 2006 (34.03 µg/m^3), while the lowest average concentration was measured in 2013 (20.35 µg/m^3). In the examined period the annual concentration of PM_{10} was under the limit value, thus, the annual limit has not been exceeded (40 µg/m^3). Considering the 24-hour limit value (50 µg/m^3) the number of exceedances exceeded the maximum 35 cases in 2005, 2006, 2010 and 2011 (Fig. 8.).

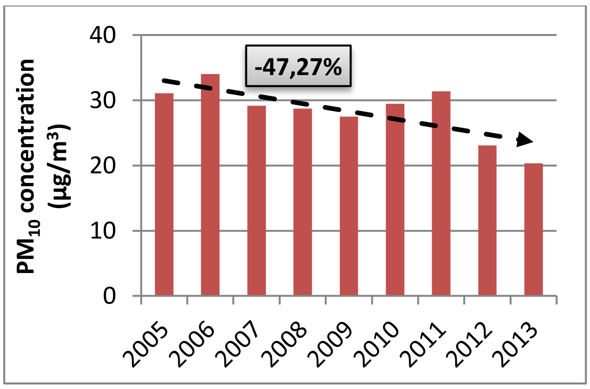

Figure 7: PM_{10} yearly average concentration in Veszprém County

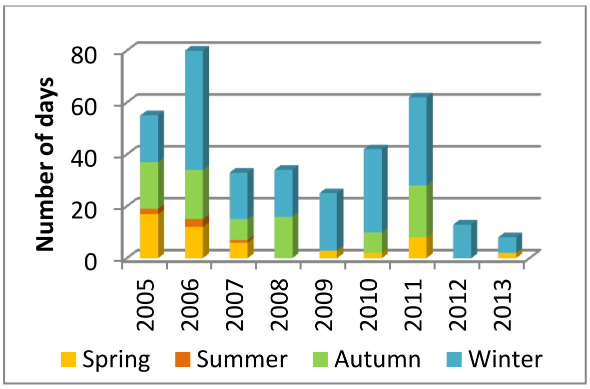

Figure 8: The number of days exceeding the health limit values of PM_{10} in Veszprém county (2005-2013)

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In the reviewed period an approximately 10% reduction can be observed in the case of O_3 (Fig.9.). The annual average concentrations were almost the same level; they were varied between 65-75 µg/m^3. The annual concentration of O_3 was under the limit value in all cases, thus, the annual limit has not been exceeded (120 µg/m^3).

Considering the target value (120 µg/m^3) for human health there were no more than 25 days of exceedance per calendar year averaged over three years (Fig. 10.).

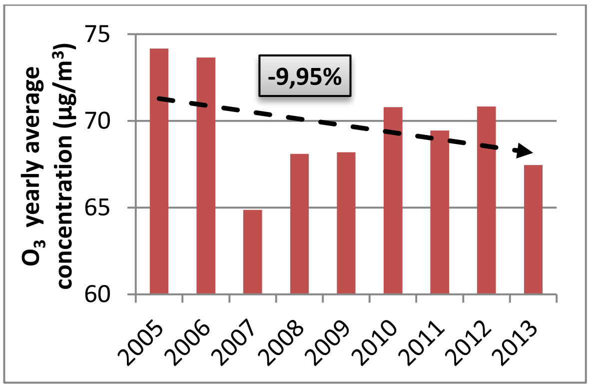

Figure 9: O_3 yearly average concentration in Veszprém County

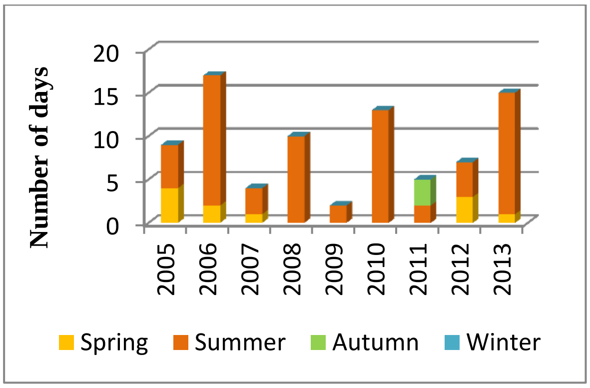

Figure 10: The number of days exceeding the health limit values of O_3 in Veszprém county (2005-2013)

In Veszprém County the annual mean concentration of sulphur-dioxide during the measured period returned to the 2013 baseline levels after several years of lower concentrations (Fig. 11.), although it does not come close to the limit value. The concentration remained well below the 50 µg/m^3.

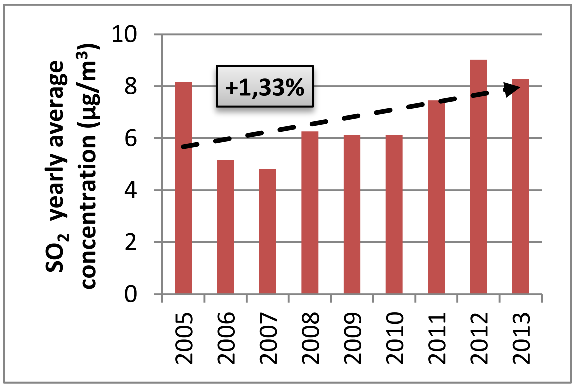

Figure 11: SO_2 yearly average concentration in Veszprém County

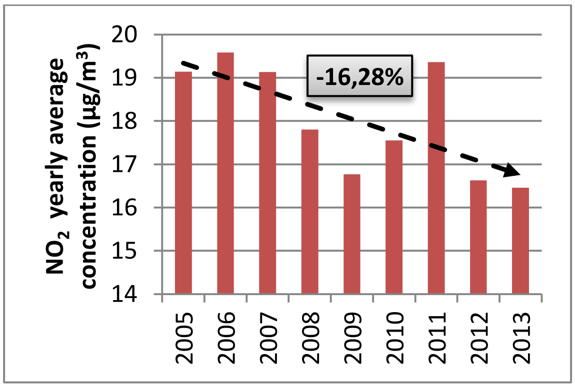

Figure 12: NO_2 yearly average concentration in Veszprém County

The annual mean concentration of nitrogen-dioxide (Fig. 12.) showed a continuous variation during the selected period of time. In the year of 2011, the value increased slightly higher, but still not exceeded neither the annual limit value (40 µg/m^3) nor the 24-hour limit value (85 µg/m^3).

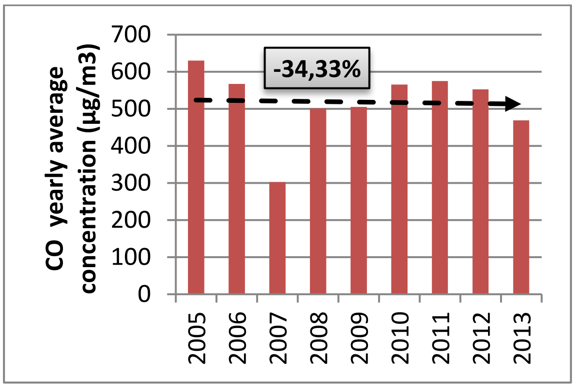

Figure 13: CO yearly average concentration in Veszprém County

The county's carbon-monoxide concentration (Fig. 13.) was nearly on the same level in each year, except 2007 when a greater decrease (302,46 µg/m^3) and in 2005 when the highest value (629,48 µg/m^3) was observed. The CO concentration in Veszprém county never crossed the annual limit value (3000 µg/m^3).

3.2 Pearson product moment correlation coefficient

Since the objective of the study was to examine the health effect changes related to the air pollution concentration, linear statistical modelling was used. Table 1 presents the statistics of the Pearson product moment correlation coefficient (R), which measures the strength and the direction of a linear relationship between the selected variables.

Table 1: Linear correlation coefficients of the selected parameters

R	**CO**	**NO_2**	**O_3**	**PM_{10}**	**SO_2**
Circulatory system Diseases	0.176	0.644	0.297	0.486	0.421
Respiratory system disorders	0.420	0.494	0.620	0.706	0.347
Digestive System Diseases	0.755	0.339	0.638	0.138	0.542
Ischemic heart disease	0.197	0.530	0.425	0.222	0.250
Cerebrovascular diseases	0.326	0.839	0.653	0.800	0.304
Chronic lower respiratory diseases	0.175	0.682	0.227	0.369	0.177

From the considered air pollutants, the strongest relationship was obtained in the case of PM_{10} and NO_2 with cerebrovascular diseases, where R>0.8. The weakest relationship was discovered between digestive system diseases and PM_{10}. The R value was close to 0, which means that there was a random, nonlinear relationship between the two variables.

To verify the previous results the coefficient of determinations (R^2) were used, which denotes the strength of the linear association between the selected variables and represents the percent of the data that is the closest to the line of best fit (Table 2).

Table 2: the coefficient of determinations of the selected parameters

R^2	Circulatory system diseases	Respiratory system disorders	Digestive System Diseases	Ischemic heart disease	Cerebrovascular diseases	Chronic lower respiratory diseases
PM_{10}	0.237	**0.498**	0.019	0.049	0.640	0.136
CO	0.031	0.176	**0.570**	0.039	0.106	0.031
NO_2	**0.415**	0.244	0.115	**0.281**	**0.704**	**0.465**
SO_2	0.177	0.120	0.293	0.062	0.092	0.031
O_3	0.088	0.384	0.408	0.181	0.427	0.052

Fig. 16-19 presents the strongest relationships between the yearly hospital admissions by cause (circulatory-, respiratory-, digestive-, ischemic heart-, cerebrovascular- and chronic lower respiratory diseases) and the annual air pollutants concentration for Veszprém County. According to the analysis, it can be stated, that the strongest relationship with circulatory system diseases was observed in the case of NO_2. Fig. 14 shows the scatter diagram of the data, from which could be concluded a negative connection. In case of PM_{10} and O_3 a similar week and negative connection was noticed. In contrast CO and SO_2 showed a week and positive connection. It can be identified that in the case of respiratory diseases the strength of the connections was moderate, but less than 0.5. Fig. 15 shows the scatter diagram of PM_{10} with respiratory disease, where the upward trend indicates that higher values of PM_{10} were related to higher levels of respiratory system disease. The other pollutants (CO, NO_2 and O_3) showed also a week or moderate positive connection, except NO_2 which had a week and negative connection.

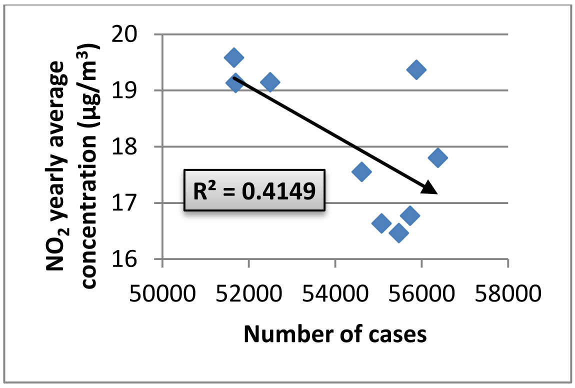

Figure 14: Relation between NO_2 and circulatory hospital admission in Veszprém County

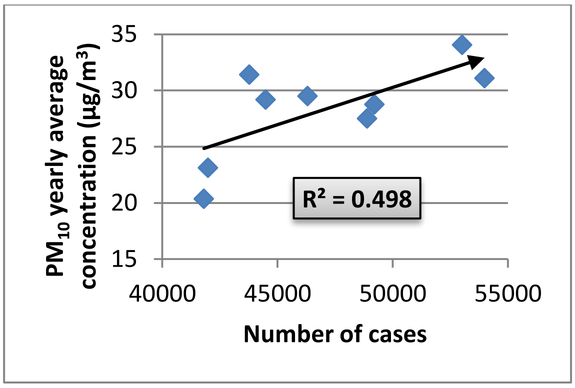

Figure 15: Relation between PM_{10} and respiratory hospital admission in Veszprém County

The connection between digestive system diseases and air pollutants were moderate or week. The strongest relationship (Fig. 16.) was noticed with CO. The other pollutants showed week connections. PM_{10} and NO_2 showed a negative connection, while SO_2 and O_3 showed a positive connection. In the case of ischemic heart disease all of the relations with the selected air pollutants were week and negative. Fig. 17 shows the scatter diagram of NO_2 due to ischemic heart disease for the data during the period 2005-2013.

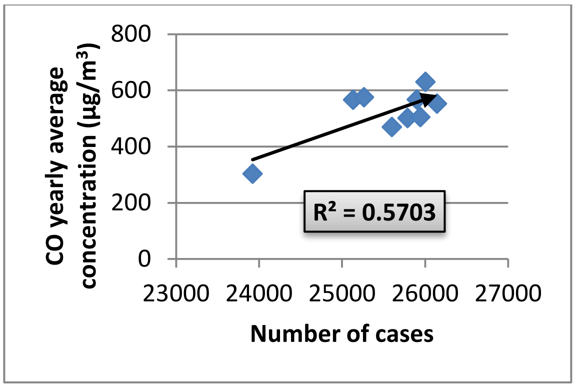

Figure 16: Relation between CO and digestive system diseases in Veszprém County

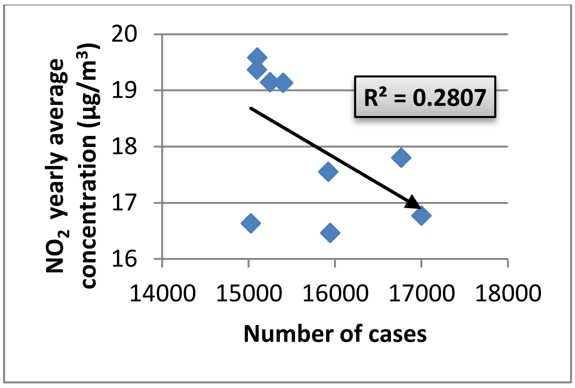

Figure 17: Relation between NO_2 and ischemic heart disease in Veszprém County

The calculation certified that there is a connection between cerebrovascular diseases and air pollutants. Fig. 18 shows the strongest relationship (NO_2), which was also negative. Similar connection was observed in the case of PM_{10} too. Week and negative connections were detected in the case of CO and O_3. In addition, SO_2 had a week and positive connection. Moderate and week connections were detected between chronic lower respiratory diseases and air pollutants. NO_2 showed the strongest relationship, which is visible on Fig. 19. PM_{10} and O_3 had week and negative relationship with that disease, but CO and SO_2 showed a positive connection.

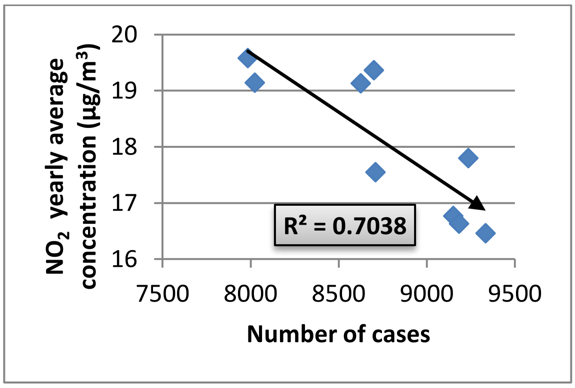

Figure 18: Relation between NO_2 and cerebrovascular diseases in Veszprém County

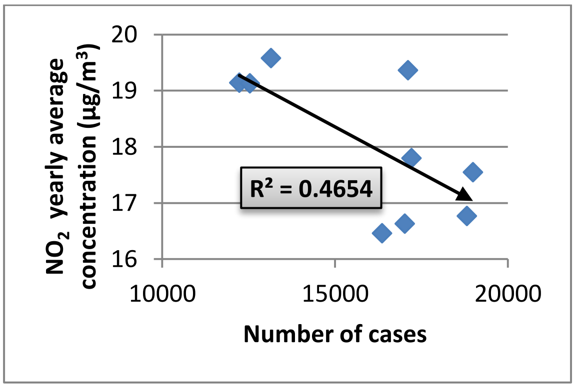

Figure 19: Relation between NO_2 and chronic lower respiratory diseases in Veszprém County

4. GRAPHICAL EXAMINATION

The health of the Hungarian population compared to the neighbouring countries and to the European Union countries - despite to the more favourable statistics in the recent years - was still very bad [30]. An unfavourable phenomenon was that the population has been steadily declining for several decades and intensified the ageing of the population.

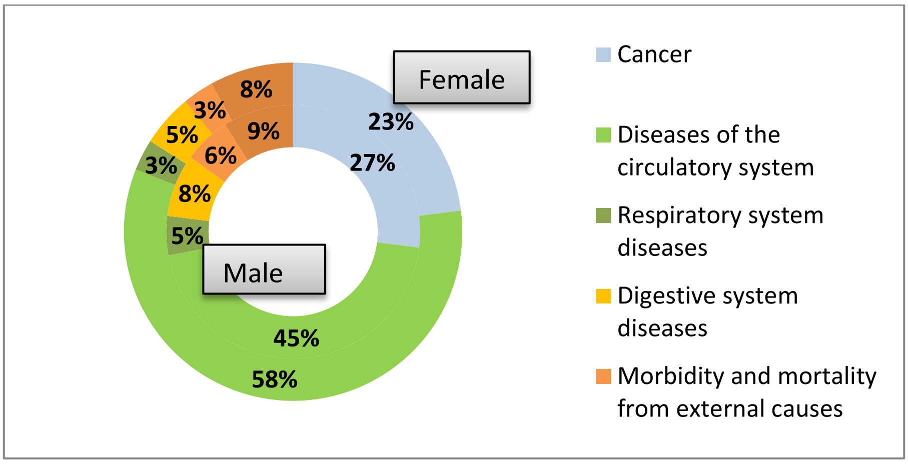

Figure 20: Mortality structure in Veszprém County (2005-2013)

As shown in Fig. 20 in Veszprém county mortality mostly caused by cardiovascular diseases, which followed by deaths due to cancer tumours in the second place [31]. Itself is a good indicator and shows the public health significance that the circulatory system diseases occur 58% of the males and 44% in the case of females in this group. Another unfavourable phenomenon is the rise of the allergies, asthma, the number of chronic respiratory diseases, and the increased frequency of lung cancer from year to year (Fig. 21.) [30].

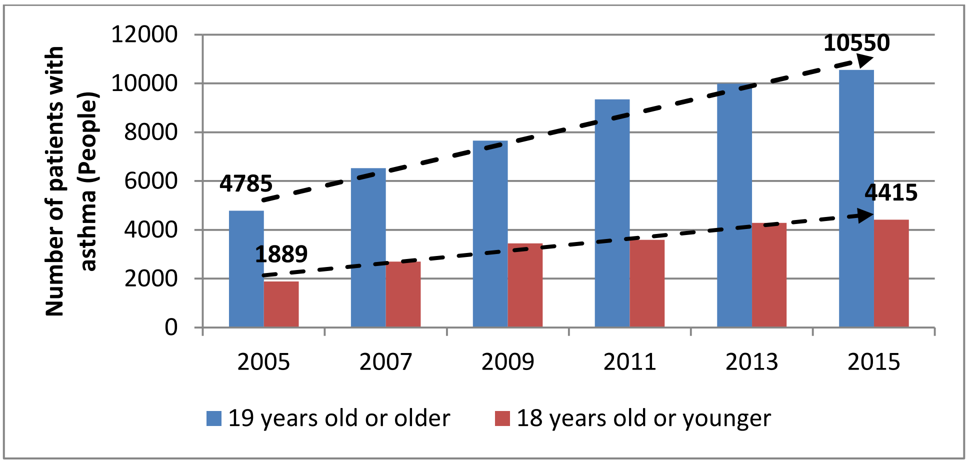

Figure 21: Number of patients with asthma in Veszprém County (2005-2015)

Finally, the association between air pollutants and hospital admissions were additionally examined graphically which is visible on Figure 22-26. The maps show how far the population of the county (divided to female and male group) was concerned with the various illnesses. It is visible that in all cases the standard mortality rate was much higher on the left side of the county, where most of the industrial parks can be found, than on the other part of the county.

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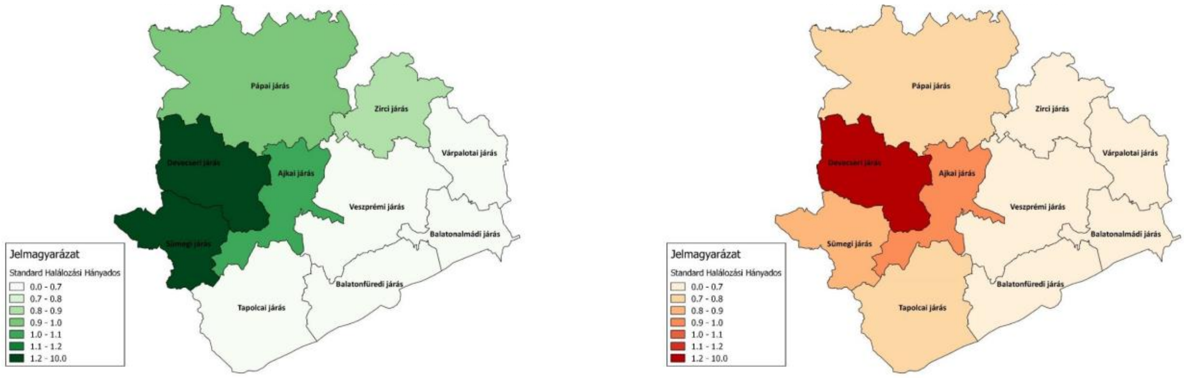

Figure 22: Mortality of Veszprém county's population caused by diseases of the respiratory system disorders (2009-2013) a) male population b) female population

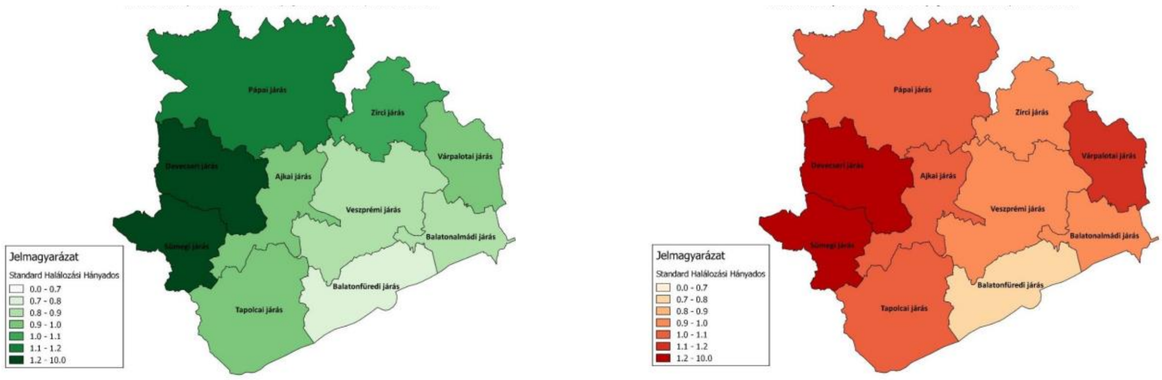

Figure 23: Mortality of Veszprém county's population caused by diseases of the circulatory system (2009-2013) a) male population b) female population

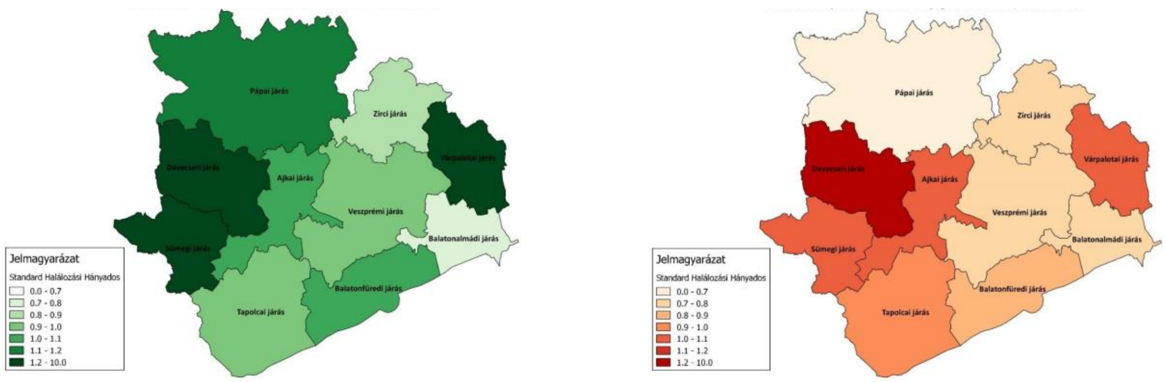

Figure 24: Mortality of Veszprém county's population caused by diseases of the digestive system disorders (2009-2013) a) male population b) female population

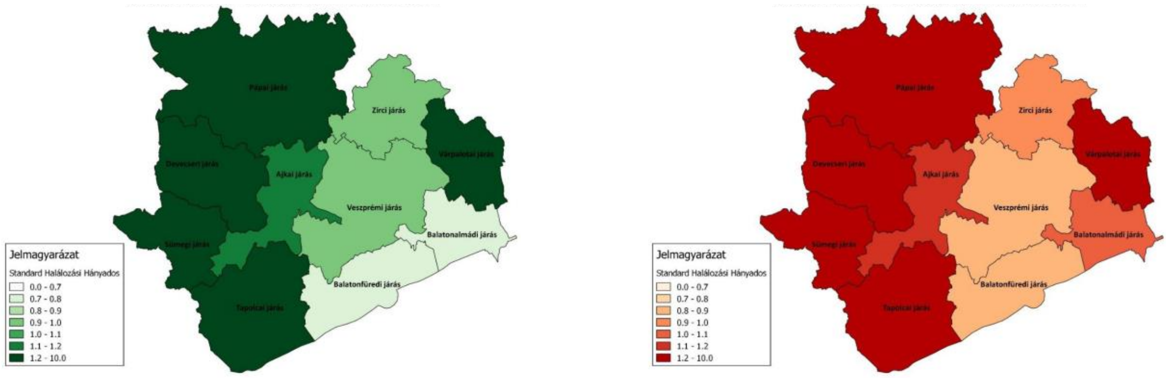

Figure 25: Mortality of Veszprém county's population caused by diseases of the cerebrovascular diseases (2009-2013) a) male population b) female population

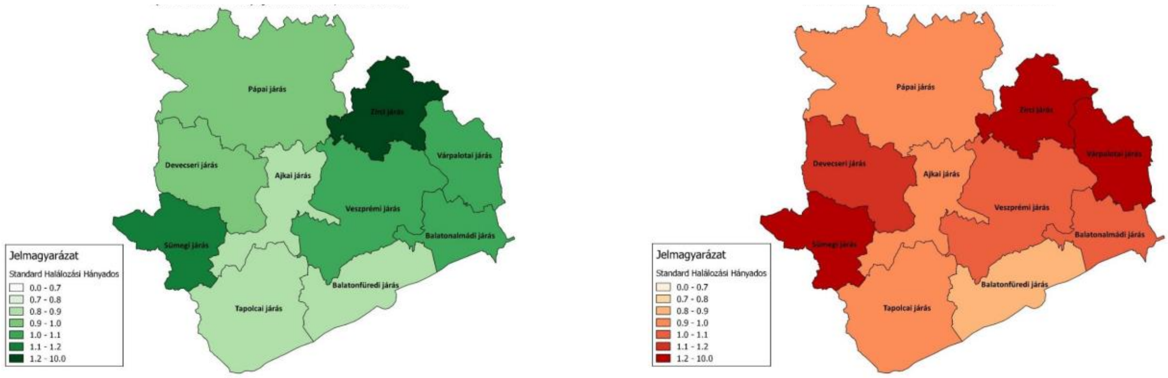

Figure 26: Mortality of Veszprém county's population caused by diseases of the ischemic heart disease (2009-2013) a) male population b) female population

5. DISCUSSION

The level of pollution, thereby its' impact on human health depends on numerous factors, such as the part of the day, the season, the prevailing wind direction, moreover the quantity and type of precipitation. Many studies have investigated the relationship between air pollutants and hospitalization. The results of the presented study show that the exposure to outdoor air pollution (PM_{10}, CO, NO_2, SO_2 and O_3) is associated with cardiovascular-, respiratory-, digestive-, ischemic heart-, cerebrovascular-, and chronic lower respiratory diseases in Veszprém County between 2005 and 2013.

At Luong et al (2016) [3] and Rodopoulou et al (2014) [32] findings there was a strong, significant connection between PM_{10} levels and hospitalization for respiratory diseases, which is an opposite result than in the presented study, which shows only a moderate relationship (0.498). The reason of the different result can be the differing sources producing particles with different toxicities. Based on Capraz et al (2015) [6] cardiovascular diseases are associated especially with daily mean SO_2 and NO_2 concentrations. The strongest connection in the presented study found out in the case of cerebrovascular diseases and NO_2 level. In the study of Suissa et al (2015) [33] the consequences of O_3 pollution on the respiratory system and mortality were documented and confirmed the relationship between O_3 exposure and ischaemic stroke, with which our study has yielded similar results.

6. CONCLUSION

In this study, the connection between the selected air pollutants (PM_{10}, CO, NO_2, SO_2, O_3) with hospital admission causes by cardiovascular-, respiratory-, digestive-, ischemic heart-, cerebrovascular-, and chronic lower respiratory diseases in Veszprém County was examined by using a descriptive and graphical approach. Based on the results of the regression calculations it can be stated, that there is a relationship between the concentration of air pollutants and the number of registered diseases. The calculations showed that among the diseases, the strongest connection and the biggest impact of air pollutants had on cerebrovascular diseases. In case of particulate matter and nitrogen-dioxide the strength of the relationship was more than 60%. If the number of the cases and the air pollutants are examined separately, it can be stated that, NO_2 has the greatest impact on cardiovascular diseases, ischemic heart disease, cerebrovascular, and chronic lower respiratory diseases, while PM_{10} influenced respiratory diseases; moreover, O_3 had a significant impact on digestive system diseases. In some cases (e.g. ischemic heart disease) a downward trend was noticed, which is an opposite result compared with the literature, which is probably explained by the low annual average concentration values of the air pollutants, as well as the short test interval.

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