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Analysis of urban air imission and meteorological parameters using mathematical statistical methods

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Abstract. To a certain extent, everybody can perceive the relation between the air imission and the meteorological status. To quantify these ordinary observations is rather complicated, which has more reasons. Among other things, it should be mentioned that fronts cause sudden changes in imission data, in addition there is feedback between the polluting materials emitted in the atmosphere and the meteorological characteristics, that is not only the meteorological conditions affect the transmission of the air pollutions, but also the air polluting materials have an effect on the meteorological parameters. Mathematical statistical methods are suitable to explore such relationships. The study shows the results of a research made on such problems through an urban example.

Keywords: meteorological parameters, air pollution episode, immission, mathematical statistical methods

1 Introduction

Different meteorological parameters affect in a different way the concentration of the various air pollutions, this effect depends on the summer-winter seasons. This contact is stronger in summer and weaker in winter. The windspeed has significant influence on the concentration of every air polluting susbtance, moreover the apropos of nitrogen-dioxide the signal parameters are the sunlight and the atmosphere stability, whereas next to the windspeed,

the sulphur-dioxide has significant connection with the temperature relating to heating. The atmospherical dust pollution has more significant connection with precipitation from the meteorological elements (Sándor – Baranka, 1993). The research had to be made on such a settlement, which had meteorological and imission data and it was suitable for this aim taking into consideration its size and geographical location, (distance from other significant sources).

2 Materials and Methods

2.1 The sources of immission data

The Hungarian RIV net began to operate in 1974, and the inland accomodation of the measure points was carried out with taking notice of the World Health Organisation's recommendation, which means in an analized settlement, measuring stations should be located in the centre, in the suburban and in the industrial part of the city if possible (Bozó et al., 2001). Following the WHO's lead in Jászberény, three immission measuring stations were settled, one was located in the yard of the mayor's office representing the city, one was located in the yard of the Szivárvány Nursery representing the suburban environment, one was located in the yard of SZIE ABPK representing the industrial environment (Fig. 1). The measured polluting substances were NO2, SO_2 and settling dust. The scanning of measured data is carried out daily by NO_2 and SO_2 and monthly by settling dust. If we take the characteristics of the settlement into consideration, the location of the stations can be accounted optimal. Unfortunately, the number of the stations and the analyzed components have been reduced, nowadays only one is operating in the city centre, measuring NO_2 (Table 1.). The imission data of the OLM can be freely downloaded from the homepage of the Ministry of Rural Development.

Table 1: The components of the materials measured by the RIV net, and the date of the lapse of the measuring

station		**centre**		**Szivárvány Nursery**			**SZIE ABPK**		
material	NO_2	SO_2	settling dust	NO_2	SO_2	settling dust	NO_2	SO_2	settling dust
the end of the measuring date	—	31.12. 2007	31.12. 2007	30.04 2004	30.04 2004	30.04 2004	30.11. 2006	30.11. 2006	31.12. 2007

Source: own calculation

2.2 The source of the meteorological data

The required meteorological data, which were needed to evaluate the immission data, were procured from different sources. It meant a problem, that the Hungarian Meteorological Service did not have such a measuring station, which was able to provide every meterological parameter the measured parameter was only the daily summarized precipitation. However, this station and the immission measuring station in the SZIE ABPK were at the same place. The nearest meteorological station operated by the OMSZ can be found in Jászapáti, the measured data between 01.07.2006–31.12.2007 are the daily avarage windspeed, daily summarized precipitation (manual, automata). To generate a bigger database own data have been collected. In Jászberény operated by individuals some professional meteorological stations work, which are located suiting the requirements, and the measured data can be found on the www.idokep.hu homepage. Naturally, the operation of these stations depends on the owners, which is not certainly continual. The data of the most relieable WS 2300 station signed by identifier "Felügyelő" have been collected since 01.01.2008 (Figure 1).

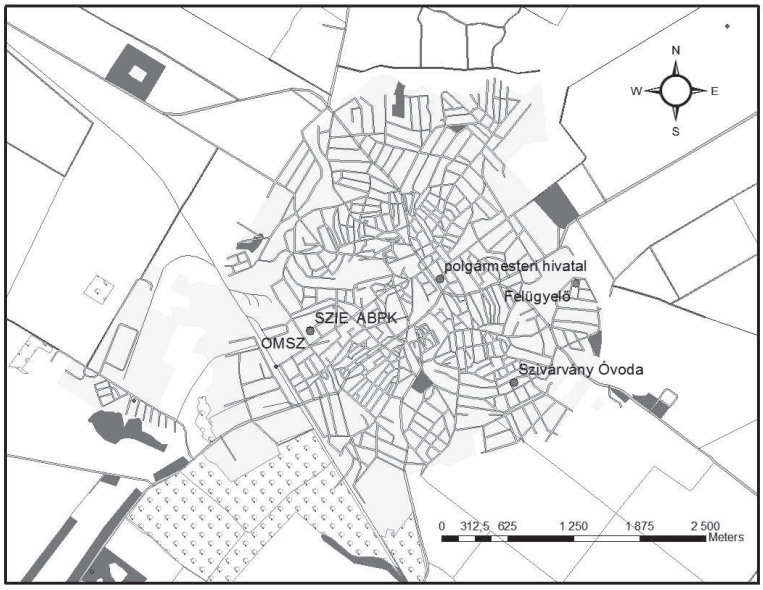

Figure 1: The imission measuring stations and the meteorological stations. Source: own design

The measured daily weather data are: minimum temperature, maximum temperature, minimum atmospheric pressure, maximum atmospheric pressure, minimum relative humidity, maximum relative humidity, sum of precipitation, the most frequent wind direction (night and daytime), average windspeed, average wind direction. Other free data have been downloaded from the OGIMET homepage. This database contains the daily minimum, maximum and average temperature, daily average relative humidity, atmospheric pressure (sea level), clouds, sum of precipitation, average windspeed, average wind direction, sunny hours from the locations of stations are: Eger, Szolnok, Budapest. The time interval is 01.10.1999–11.11.2012. Apart from the listed data from Lakes Environmental according to mixing height, wind direction and wind speed. Comparing the immission and meteorological data was only possible if we had both kinds of data. Measuring of dust and SO_2 immission stopped. It meant that there was no possibility to do certain examinations on these polluting materials.

3 Results

3.1 Connection between the NO_2 immission and meteorological data

The relation between the air quality and the meteorological data was discovered using two aspects. Either of them analyzed the general relationship between the air quality and the meteorological parameters, the other one studied occurent air pollution episodes in extreme conditions. The comparing was performed only in case the immission measuring station had enough immission data. To investigate the effect of the wind to the air quality, we took the daily avarage wind direction and also the daily average wind speed in account to find out whether the different daily average wind direction causes different daily NO_2 immission or not. Figure 2 shows that different average daily immission could be connected to different daily average wind direction, and meeting the requirements, the results of the heating periods usually exceeds the result of the non-heating periods (Figure 2.). Analyzing this variance, corresponding to the different daily wind direction, a test of independence was applied to see if it is stochastic or demonstrable. There was an additional problem. The measured NO_2 concentrations can be regarded a realization of a continuous variate, and the Chi^2-probe can be applied only in discrete case. Wrapping this problem up, the measured results were classified into discrete intervals. The statistic probe, confidence level was 95%, resulted different values, in heating

period 0,1, in non-heating period 0,01 proved the independence, so the wind direction does not influence the concentration in the inner city significantly.

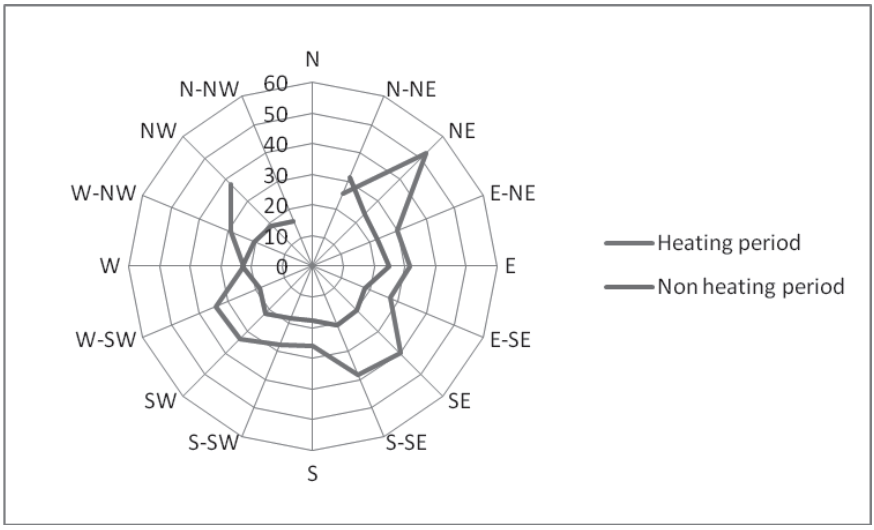

Figure 2: The avarage NO_2 immission per wind directions in heating and non heating period in Jászberény centre. Source: own calculation based on the OLM and Lakes Environmental data in interval 01.01.2011–31.12.2012.

It was very difficult to find any connection between the daily average NO_2 concentration and the meteorological parameters. The rising windspeed develops its beneficial effect primarly in heating periods, medium vehement relation can be supposed by the right of correlation coefficients but in non heating periods some slight connection can be discovered. On the other hand the maximum gust of wind and the immission values can be considered independent (Table 2.). To analyse the relation between the stability of the atmosphere and the NO_2 immission, the hourly Monin-Obukhov length data, made by interpolation technology, were converted into daily average, and these data were compared to the daily average immission. The data transformation was motivated by the temporal resolution of the OLM station's data. There is no doubt that analyzing the hourly data would have been more profitable, but the immission measuring station's data made only the comparison of daily averages possible. On the basis of the results, the data's significant relation can't be demonstrable.

Table 2: The correleation coefficients of the visualised meteorological parameteres and the NO_2 immission

correlation coefficient **NO_2 immission**	**mixing height***	**windspeed ****/***	**Monin-Obukhov length****	**Minimum tempreture*****	**Maximum tempreture*****	**Maximal gust of wind*****
non hetaing period	-0,04	-0,26 /-0,02	-0,01	-0,11	0,08	0,01
heating period	-0,15	-0,56 /-0,14	0,11	0,02	0,14	0,04

Source: own calculation based on the Lakes Environmental* (01.01.2011–31.12.2011), OMSZ**** (01.07.2006–31.12.2007),"Felügyelő"***(01.09.2008–30.09.2011),OMSZ** (01.01.2011–31.12.2011) and OLM data.

In the interest of investigating air pollution episodes each summer and winter period was analyzed. In consequence of the basin location and climatic peculiarities the most favourable conditions for the enrichment of airpolluting substances are provided by anticyclone and anticyclone border (Horváth et al, 2003). Researches of the same type have been made in order to analize the extremely high concentration of PM10 and ozone in troposphere (Ferenczi Z. 2009). In summer the air from subtropical area can be typified by extremely high daily maximum temperature, low windspeed, whereas in winter the air stem from Siberia can be characterized by extreme low daily minimum temperature, low windspeed and low mixing height. Considering the features of the city and the disposable data base, the basic research was carried out on the data of 2011. The mentioned data were provided by the daily minimum temperature and the mixing height in heating period and daily maximum temperaure and average wind speed in non-heating period. We compared the immission data of those days when the minimum temperature was not higher than -5 °C and mixing height was not more than 700 m with the data when the daily average temperature was higher than -5 °C and the mixing height was bigger than 700 m. Naturally these two masses of data are not complementary of each other and the analyses of those data which were not suitable was ignored.

In non-heating period we compared data which were characterized by at least 30 °C maximum temperature and not more than 2 m/s average wind speed. Forming the basis of the research the t-probe values showed thesame result. In heating period there is not significant difference between the expected values at 95% reliability level just as in non heating period. It would

have been practical to make the research in longer period of time interval, but with the absence of Jászberény data, we could have taken only the data of meteorological stations in surrounding settlements into consideration. Unfortunately, data of Eger, Szolnok and Budapest do not contain values of mixing height, so in heating period, the daily minimum temperature while in non-heating period the daily maximum temperature gave the basis of classification. In the former perod in the case of all stations we compared the daily immission values when the daily minimum temperature was not more than -5 °C with those data which exceeded the mentioned ones. In non-heating periods we put the data of those days when the maximum temperature was at least 30 °C into one group and those days when these data were less were put into the other group. These criteria must have been fulfilled in the case of all three stations. Those data that were not suitable for any of these criteria, were left out of the analysis. The 95% reliability level-probe values which gave the basis of the comparison did not show any differences between the group averages in non-heating periods in the case of none of these stations (Table 3.).

Table 3: Comparsion of NO_2 immission data measured in average and special meteorological conditions

t-probe	**centre****	**centre***	**nursery***	**SZIE ABPK***
heating period	0,86	0,07	0,02	0,46
non heating period	0,86	0,06	0,60	0,60

Source: own calculation based on OLM, Lakes Environmental** (2011)
OGIMET* data (from 01.09.1999 to 20.11.2001 in case of centre,
otherwise to the date of the lapse of the measuring)

In heating periods we perceived significant difference in expected data of the nursery station. Further examination should be needed to find out the reason of the previously mentioned difference, but we take the results of other stations teherefore it can be stated that it has local origin, so it was not caused by the accummulation of polluting materials in the town or in larger area. As regards the whole settlement the reason of these results is probably offered by the size of the town because the emission in the town does not grow drastically even in winter extreme conditions consequently neither the immission does. In summer the lacking emission of heating origin is probably compensated by the growing traffic but this effect does not cause significant load even in negative meteorological parameters.

3.2 Connection between the SO_2 immission and meteorological data

In the case of SO_2 the analysis was also done separately in heating and non heating periods. In both cases, the corellation coefficients, derived from the daily average temperature and immission data, show weak connection, which can be explained by the finished modernization programme of heating in winter period. In summer the cumulative SO_2 emission caused by the contingently growing electrical energy can't make its effect felt. The correlation coefficients between the daily average windspeed and the SO_2 immission mainly refer to independence (Table 4). These results show that nowadays the local emission has decreased to a negligible level that's why neither the beneficial effect of growing windspeed nor the disadvantageous effect of the decreasing temperature can prevail.

Table 4: The correlation coefficients from the excepted meteorological parameters and the sulphur-dioxide concentration

	heating period		**non heating period**	
	windspeed SO_2 concentration	temperature SO_2 concentration	windspeed SO_2 concentration	temperature SO_2 concentration
correlation coefficient	0,15	-0,27	0,02	-0,18

Source: own calculation based on OLM and OMSZ (01.0.2006–31.12.2007) data.

The analyses of the connection between the wind direction and the immission was not possible because of the breakdown of measuring SO_2 concentration. Selecting those meteorological conditions which are positive for the accumulation of polluting materials was the same as in the case of analyzing NO2. In this case we had no possibility to make calculations with 2011 meteorological data but on the basis of temperatures measured in Eger, Szolnok and Budapest the immission data could be put into groups similar to NO_2 concentration. The calculated average concentrations and the t-probe results which provide the basis of comparison show that meteorological conditions referring to anticyclone in winter period contribute to the growth of SO_2 concentration in the centre of the town. In the case of other stations, the difference is not significant. It also refers to that town emissions cause the growth of immission. In summer we can experience a contrasting effect because between the values of data significant difference can be observed only on the area of SZIE ABPK. It is probably caused by the special location of the station, since well mixed air

which is free from effects of the settlement sources arrives at the area because of the most frequent wind direction (Table 5). As opposed to the expectations in this case however, we could measure a lower average immisson in negative conditions. The reason for this is that in colder non-heating periods there is communal immission at minimum scale which affects the nursery and the centre of the city. This effect may appear in the average.

Table 5: Comparsion of SO_2 immission data measured in average and special meteorological conditions

t-probe	**centre**	**nursery**	**SZIE ABPK**
heating period	0,00	0,46	0,21
non heating period	0,00	0,02	0,57

Source: own calculation based on OLM, OGIMET data from 01.09.1999 to 20.11.2001 in case of centre, the date of the lapse of the measuring)

3.3 Connection between the settling dust and meteorological data

The settling dust data are monthly, which made the analyses of the connection between the immission and meteorological data more difficult. The quantity of the precipitation can be significantly variable in space and time, so the interpolation of the measured data is an extremely hard challenge. In consideration of the advantages and the disadvantages of the extant data we used the data which were measured in the yard of SZIE ABK in the interval of 01.01. 2005–31.12.2007. The overlaping of meteorological and immission measurement station made the search reliable. OMSZ wind and temperature data were available only in interval 01.07.2006–31.12.2007, and it was measured in Jászapáti. If the monthly averaging of this database had been made, I would have had very few datapairs, and the OGIMET data could not be representative because of the relatively big distance. So the examination was about only revealing the correlation between the monthly quantity of precipitation and the immission of the settling dust. With the help of the results (Table 6) we can state that in heating period the monthly quantity of precipitation has significant effect of the quantity of settling dust. Suprisingly, in non-heating period only the town centre data indicate the effect on the wet settling while on the area of SZIE ABPK this phenomenon does not appear. The reason for this is probably the different locations of stations and the most frequently

occurring wind direction and of course it is because of the monthly amounts and averages.

Table 6: Correlation coefficients of the 30 days settling dust and the indicated meteorological parameter

correlation coefficient	**heating period**		**non heating period**	
	city centre	SZIE ABPK	city centre	SZIE ABPK
30 days precipitation sum	0,09	0,09	0,66	-0,29

Source: own calculation based on OMSZ (01.01.2005–31.12.2007) and OLM data.

4 Conclusions

The executed research indicated fairly various issues. In the case of sulphur dioxide the analyses were made when the heating system was modernized in the settlement and flue gas cleaner in the Mátra Powerplant was installed. This powerplant is about 30 km from Jászberény. Nowadays the sulfur dioxide concentration is controlled by larger scale processes but occasionally local effects can be observed. In the case of NO_2 the effect of wind speed appears in certain occasions. The negative effects on NO_2 immission of those meteorological conditions which refer to anticyclone do not appear, with the exception of nursery station, neither in summer nor in winter. In contrast with this the growing concentration of SO_2 in winter can be seen in the case of the town centre station. In the case of settling dust, the problem was caused by the different timescale of the immission and meteorological data. The correlation coefficients indicated the effect of wet deposition in the city centre in non heating period besides these the data denoted low dust emission from heating.

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