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# AIR QUALITY INDICES AS TOOLS FOR ESTIMATING AIR POLLUTION IN SZEGED, SOUTHERN HUNGARY

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**Summary** – Air quality depends on physical and chemical factors and it can be influenced by meteorological processes in the atmosphere as well as by geographical and social conditions. The study aims at representing the air quality of Szeged using modified air stress indices $ASI_1$ and $ASI_2$, which characterise annual and diurnal air pollution, respectively. The analysis is based on the mean daily values of the main air pollutants ($NO_2$, $SO_2$ and $PM_{10}$) coming from the monitoring station of Szeged for the 10-year period 1997-2006. Features of $ASI_1$ and $ASI_2$, as well as mean annual concentrations and the mean diurnal cycle of the pollutant levels are presented. According to the results, the mean annual air quality index ($ASI_1$) shows small annual differences. The short-term (diurnal) air quality index ($ASI_2$) is higher on weekdays and lower in the weekend. In the weekend the improvement of air quality reaches 13%. The maximum of the mean diurnal course expressed in percentage of the health limit exceeds the 100% (limit) only for $PM_{10}$. On the other hand, the mean values of the diurnal course of $NO_2$ and $SO_2$ are far below their health limit.

*Key words*: main air pollutants, air stress indices $ASI_1$ and $ASI_2$, air pollution categories, annual and daily mean pollutants concentrations, air quality differences on Saturdays, Sundays and holidays compared to weekdays

## 1. INTRODUCTION

Air quality plays an important role in our everyday life. Polluted air is harmful for buildings, machines, technical devices and it can cause serious injury to health. Air quality, the concentration of air pollutants, depends on physical and chemical factors and can be influenced by meteorological processes in the atmosphere as well as by geographical factors (e.g. climate, local meteorological processes at the given moment, relief, etc.) and social factors (e.g. environmental regulations, urban planning priorities, etc.). Pollutants, accumulating near the sources, may have local impact (e.g. transport) but major regions might also be affected (e.g. industrial plants). Studies concerning air pollution (detection, analysis, modelling) aim at estimating the level of air pollution and also determining the concentration of air pollutants compared to their limit values, furthermore, representing the temporal course of air pollution.

## 2. TOPOGRAPHY AND AIR QUALITY IN THE SZEGED REGION

The city of Szeged is the largest town in SE Hungary (20°06'E; 46°15'N); it is located at the confluence of the Tisza and Maros Rivers characterized by an extensive flat landscape with an elevation of 79 m a.s.l. (Fig. 1). The built-up area covers a region of about 46 $km^2$ with about 155,000 inhabitants.

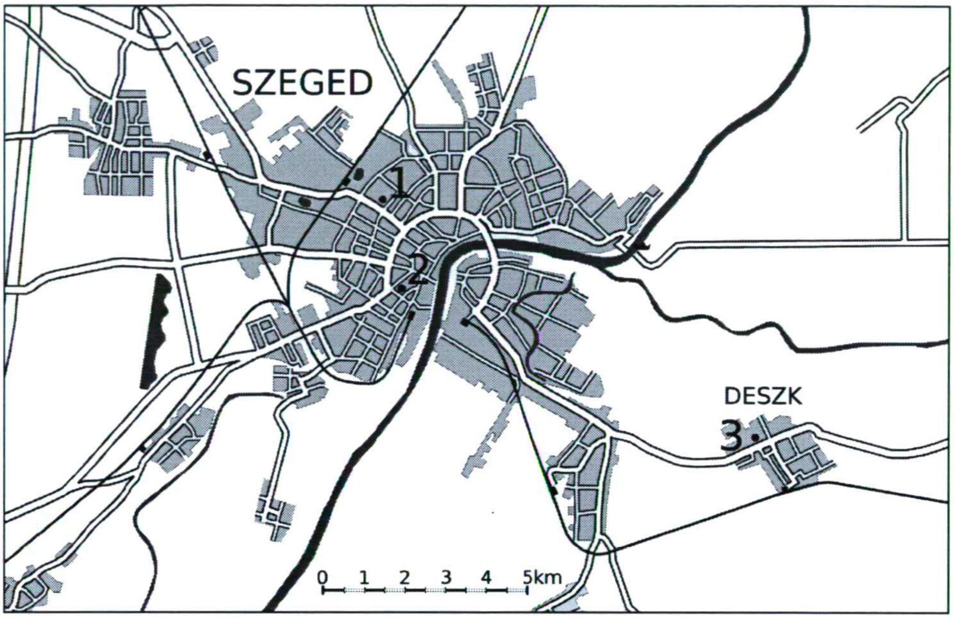



Fig. 1 The urban web of Szeged with the position of the data sources.
1: monitoring station measuring climate parameters and chemical air pollutants;
2: pollen trap measuring biological air pollutants; 3: Thorax Surgery Hospital, Deszk

Its layout is very simple; the town is characterized by boulevards, avenues and streets which are divided into two parts by the River Tisza. However, this simplicity significantly increases the concentration of the public transport in the built-up areas and, hence, the level of air pollution. The industrial area is mainly restricted to the north-western part of the city. Thus, the prevailing westerly and northerly winds tend to carry the pollutants from this area towards the city centre. The total urban spread extends well beyond the city limits and includes the largest oil field in Hungary with several oil torches located just north of the town. This oil field is also a significant source of such air pollutants as $NO_x$ and sulphur dioxide.

The power station, located in the western part of the city, is also a major source of pollution. Exhaust fumes have also largely contributed to the steady increase of nitrogen oxide and carbon monoxide in the air of Szeged. Besides, as a result of the heavy traffic, deposited dust is often suspended in the air again.

In a detailed analysis, Szeged was ranked to the 32$^{nd}$ position of 88 Hungarian cities, according to the quality of the environment and the level of environmental awareness. The city ranked to the 1st position was considered to have the best environmental conditions (Makra et al. 2002). Based on the air pollution exceedances, measured by the Regional Immission Examining (RIE) stations in 2001, the air quality of Szeged belongs to the polluted category on a three-category (normal, moderately polluted, polluted) system (Mohl et al. 2002).

In Szeged the concentrations of nitrogen-oxides ($NO_x$) as well as the ozone and the particles with less than 10 μm aerodynamic diameter ($PM_{10}$) are higher than their EU threshold values. [The daily (24 hour) concentration of $PM_{10}$ is 11-19 times higher, while its annual concentration is twice higher than the EU threshold limit legally binding since 1 January 2005!] The fact that Szeged is ranked 32nd in the order of 88 Hungarian cities gives the impression that the city has a relatively good air quality. Consequently, the information which puts Szeged into the 3rd category – taking into account the Regional Immission Examining (RIE) database – seems surprising. However, it should be noted that the above study ranked the cities based on 7 different categories (derived from 19 environmental indicators), namely: water and energy consumption, public utilities supply, traffic, waste management, settlement amenities factors and air quality. In the last category only three factors were considered: concentrations of $PM_{10}$, sulphur-dioxide and nitrogen-dioxide. Since air quality represents only one out of the seven categories and this category is characterized with only three parameters, it has a limited role in the rank of the cities. The concentrations of air pollutants are closely-related to the increasing frequency of respiratory diseases. The annual course of the air pollutant levels follows a unimodal distribution. NO, $NO_2$ and $PM_{10}$ concentrations are characterized by winter maxima and summer minima. At the same time, ozone reaches its peak values in summer, in accordance with the annual course of irradiance (Makra and Horváth 2001, Makra et al. 2001a, 2001b, Mohl et al. 2002, Mayer et al. 2004).

Around 50% of $PM_{10}$ comes from the area north-west of Szeged, which is characterized by shifting sand, loess and sand dunes. On the other hand the industrial zone can be found in the north-western part of the city. As a result, the prevailing north-west winds carry not only particles ($PM_{10}$) but also industrial air pollutants over the city. The rest of $PM_{10}$ comes from transport. Particles can also be formed with the contribution of the engines of vehicles and they can get into the air through the air currents created by vehicles (Mohl et al. 2002). The traffic in Szeged is extremely overcrowded. The proportion of motor cars is the highest in public transport: 84%. In 2000, due to the new automobiles with engines of improved emission factors, CO concentration in the city decreased to 36-40% compared to that measured in 1990. On the other hand the traffic on the highways increased by 3-70% during the same period. On an average day (24 hour period) 70-90 thousand vehicles go through the city (Mohl et al. 2002).

## 3. DATABASE

The data come from the Szeged monitoring station, which is located in the downtown, at the corner of Kossuth Lajos avenue and Damjanich street, around 10 m away from Kossuth Lajos avenue. There is a building situated also about 10 m away from the station which influences the values of the meteorological parameters. The database used for the research is the 30-minute mass concentrations of $NO_2$, $SO_2$ and $PM_{10}$ ($\mu gm^{-3}$) in the ten-year period 1997-2006.

## 4. METHODS

Air quality has several components (e.g. weather conditions, natural and anthropogenic air-pollutants, smells, noise, etc.). Each component involves several elements [e.g. weather conditions contain the following (meteorological) elements: irradiance, temperature, humidity, wind direction, wind speed, etc.).

An air quality stress index (ASI) has been developed in Freiburg, Germany for city planning. This index is the measure of the combined effect of several major air pollutants ignoring their individual values. Using both the air quality determined by the ASI formulae and the limit values of the air pollutants air pollution categories are determined based on which air quality is classified.

ASI can be determined for mean (annual) and shorter term (diurnal) air pollution. Its formula consists of the following components: sulphur-dioxide ($SO_2$), nitrogen-dioxide ($NO_2$) and particles ($PM_{10}$). Namely, they (*) are key air pollutants, (**) have the same features and (***) are measured at most of the air quality stations (Mayer 1995). The categories of air quality index (ASI) are as follows:

Category I: low air pollution; it is characteristic when none of the three air pollutants exceed their limit value and ASI < 0.5 (Mayer 1995).

Category II: medium air pollution; it is experienced when none of the three air pollutants exceed their limit value and 0.5 ≤ ASI < 1.0 (Mayer 1995).

Category III: heavy air pollution; it occurs when the concentration of at least one of the three components exceeds their limit value, but none of them exceeds double of their limit value, independently of the actual value of ASI [modified after Mayer (1995)].

Category IV: extreme air pollution; it happens when at least one of the three components reaches or exceeds the double of its limit value, independently of the actual value of ASI [modified after Mayer (1995)].

The air quality index for mean (annual) air pollution ($ASI_1$) can be expressed with the following formula:

$$AQSI_1 = 1/3 \cdot [I1(SO_2)/20 + I1(NO_2)/40 + I1(PM_{10})/30] \quad (1)$$

where I1 is the annual mean concentration of the given air pollutant ($\mu gm^{-3}$) and the denominators are the limit values ($\mu gm^{-3}$) of the given air pollutants reported in the EU air quality directives (Council Directive 1999/30/EC (1999 April 22). [The annual limit values according to the Hungarian Standard [(14/2001.V.9.) KöM-EüM-FVM joint order 1990] for $SO_2$, $NO_2$ and $PM_{10}$ are 50·$\mu gm^{-3}$, 40 $\mu gm^{-3}$ and 50 $\mu gm^{-3}$, respectively.]

It is desirable that air pollution in living and resort places should be characterized with the air pollution categories I and II, while the industrial and commercial areas often belong to categories III and IV (Mayer 1995).

The short-term (diurnal) air quality index ($ASI_2$) can be described with the following formula:

$$AQSI_2 = 1/3 \cdot [I2(SO_2)/125 + I2(NO_2)/85 + I2(PM_{10})/50] \quad (2)$$

where I2 is the independent variable belonging to the 99% value of the distribution function formed on diurnal values of the given air pollutant [namely, that $x_{0,98}$ value, for which $P(x<x_{0,98}) = F(x_{0,98}) = 98\%$], while the denominators are the daily limit values of $SO_2$ and $PM_{10}$ reported in the EU air quality directive [Council Directive 1999/30/EC (1999 April 22)] and that of $NO_2$ published in the Hungarian Standard [(14/2001.V.9.) KöM-EüM-FVM

joint order 1990] (Mayer 1995, Matzarakis and Mayer 1995). The diurnal limit values of $SO_2$, $NO_2$ and $PM_{10}$ according to the Hungarian Standard [(14/2001.V.9.) KöM-EüM-FVM joint order 1990] are 125 $\mu gm^{-3}$, 85 $\mu gm^{-3}$, and 100 $\mu gm^{-3}$, respectively).

## 5. RESULTS

Significant trends cannot be detected in the mean annual concentration time series of the air pollutants examined (Fig. 2). It is in accordance with the fact that the emissions of these substances do not show significant trends either (Horváth et al. 2001).

In Szeged there is a small fluctuation in the value of the mean annual air quality index ($ASI_1$), which does not indicate significant trend.

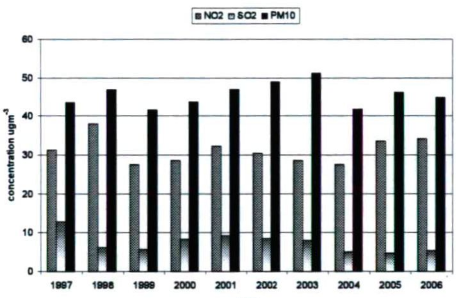



Fig. 2 Annual mean concentrations of nitrogen dioxide ($NO_2$), sulphur dioxide ($SO_2$) and particulate matter ($PM_{10}$), monitoring station, Szeged, 1997-2006

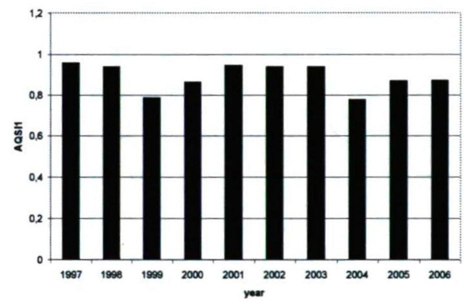


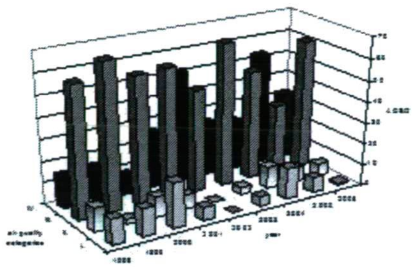

Fig. 3 Annual values of $AQSI_1$, monitoring station, Szeged, 1997-2006

The lowest $ASI_1$ values – i.e. the most favourable air quality – occurred in 1999 and 2004, whereas the two beginning years – 1997 and 1998 – were the most polluted (Fig. 3).

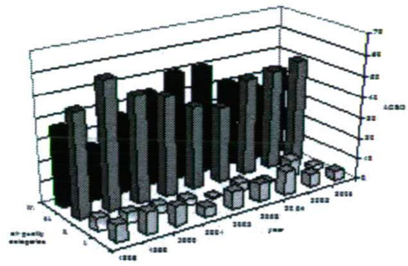
On the basis of the $ASI_1$ values, the air quality in Szeged can be put into category III in each of the 10 years, i.e. the air pollution in the city is serious, which is basically due to the fact that the annual mean concentrations of $PM_{10}$ are very high though those of $SO_2$ and $NO_2$ are below their threshold value (Fig. 2). In order to survey the diurnal air pollution of Szeged, short-term (daily) air quality index ($ASI_2$) was calculated for each day of the period examined. Then every day was classified into the given categories on daily ($ASI_2$) values and daily concentrations of the pollutants (Matzarakis and Mayer 1995). We received that the number of days with better air quality (categories I and II) is insignificant compared to those of extremely bad air quality (categories III and IV) (Table 1, Fig. 4).

Table 1 Number of days with different air pollution categories,%

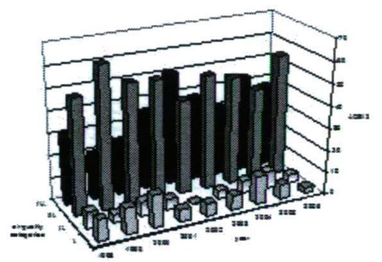
| period | air pollution categories, day | | | |
|---|---|---|---|---|
| | category I | category II | category III | category IV |
| year | 8.88 | 5.00 | 52.46 | 33.65 |
| summer half-year | 4.46 | 2.96 | 26.98 | 11.59 |
| winter half-year | 4.42 | 2.04 | 25.48 | 22.06 |



summer half-year



winter half-year



year

Fig. 4 Values of $AQSI_2$ based on air quality categories, summer half-year, winter half-year, year, monitoring station, Szeged, 1998-2006

Furthermore the number of days belonging to categories III and IV shows higher variability in the summer half-year compared to the winter half-year (Fig. 4). In certain years days in categories III and IV are more frequent in the summer half-year than in the winter half-year (Fig. 4). On the basis of the summer half-year, winter half-year and also the annual periods, there is no significant trend in the change of the air quality (Fig. 4).

Mean annual values of the weekday-, Saturday-, Sunday- and holiday diurnal air pollution ($AQSI_2$) were also calculated (Fig. 5). The higher $AQSI_2$ values on weekdays are obvious. No significant trends can be experienced in any of the three time series (Fig. 5). Afterwards, the differences between the weekday, Saturday, Sunday and holiday values of $ASI_2$ were determined on the basis of the 30-minute concentration data in the period examined. In Hungary the working hours per week are 40 hours. The starting hypothesis, according to which the diurnal air pollution indicated by the value of $ASI_2$, is modified at weekends. As a result, $ASI_2$ is higher on weekdays and smaller on weekends (Table 2, Fig. 5). Weekends were further distinguished into Saturdays, Sundays and holidays. Air pollution is decreasing in all three groups which can be most sharply experienced on Sundays and holidays (Table 2). The improvement of air quality is the smallest on Saturdays (5.0-7.5%); the improvement is only half as much as in the case of the other two groups. On Sundays $ASI_2$ values are slightly lower (which indicates a slightly cleaner air (-13%), than on holidays (-11 – -12%), but there is no significant difference between them. In the summer half-year the air quality improves considerably on Saturdays, whereas this improvement is smaller on Sundays and holidays (Table 2).

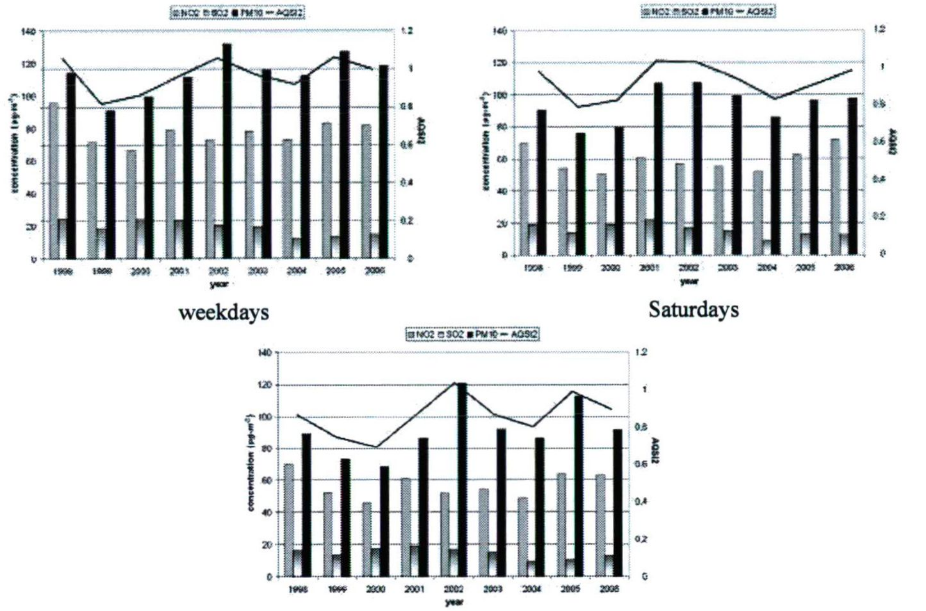



Fig. 5 Mean annual concentrations of $NO_2$, $SO_2$ and $PM_{10}$ as well as annual values of $AQSI_2$, weekdays, Saturdays, Sundays + holidays, monitoring station, Szeged, 1998-2006

Table 2 Differences of the short-term (diurnal) air quality index ($ASI_2$),%

| period | difference of the daily means (1) | (2) | (3) |
|---|---|---|---|
| year | -6.38 | -12.94 | -11.44 |
| summer half-year | -7.56 | -13.08 | -11.92 |
| winter half-year | -5.18 | -12.88 | -11.32 |

(1) air quality improvement on Saturdays compared to weekdays
[mean $ASI_2$(Saturday) – mean $ASI_2$(weekday)] / mean $ASI_2$(weekday),%
(2) air quality improvement on Sundays compared to weekdays
[mean $ASI_2$(Sunday) – mean $ASI_2$(weekday)] / mean $ASI_2$(weekday),%
(3) air quality improvement on Sundays + holidays compared to weekdays
[mean $ASI_2$(Sunday + holiday) – mean $ASI_2$(weekday] / mean $ASI_2$(weekday),%

The change of ASI2 values on different weekdays can be explained by the change of traffic on different weekdays.

The summer half-year improvement in air quality, which is significant only on Saturdays, can be attributed to the turbulent air currents typical in summer half-year, which is completely missing in the winter half-year characterised by frequent inversions.

Furthermore, the 30-minute diurnal course of the air pollutants examined ($SO_2$, $NO_2$ and $PM_{10}$) was calculated in percentage of their diurnal health limit [$SO_2$: 125 $\mu gm^{-3}$, $NO_2$: 85 $\mu gm^{-3}$, $PM_{10}$: 50 $\mu gm^{-3}$) [Council Directive 1999/30/EC (1999 April 22)] and that of $NO_2$ published in the Hungarian Standard [(14/2001.V.9.) KöM-EüM-FVM joint order 1990] (Mayer 1995, Matzarakis and Mayer 1995) for an average day and then for weekdays, Saturdays, Sundays and holidays (Fig. 6). Among the air pollutants, $PM_{10}$ indicates a clear diurnal course with a morning (8-9 a.m.) and a late evening (19-21 p.m.) maxima. $NO_2$ shows much smaller maxima in the same periods; on the other hand, $SO_2$ has no diurnal course. Accordingly, $PM_{10}$ and $NO_2$ can be considered pollutants of traffic origin and their peak values occur 1-2 hours after the traffic peak. On the other hand, $SO_2$ has apparently no connection with traffic (Fig. 6). The most definite diurnal courses with the highest peaks are found on weekdays, while the weakest diurnal course can be connected to Sundays and holidays (Fig. 6). The maximum of the mean diurnal course for $PM_{10}$ expressed in percentage of the health limit exceeds 100% (the limit) only on weekdays and Saturdays and only during the evening peak (19-21 p.m.). Mean values of the diurnal course of $NO_2$ and $SO_2$ are far from their health limit (Fig. 6). This result is not in full accordance with the fact that days of categories III and IV are predominant against those of categories I. and II. This is basically due to the mean daily $PM_{10}$ concentrations nearing the limit; however, the concentrations of $NO_2$ and $SO_2$ are small (Fig. 6) (Makra et al. 2001c, 2001d). According to the above, the 30-minute mean values of the air pollutants for the period examined are also far below their health limit [$SO_2$: mean daily concentration: 8.12 $\mu gm^{-3}$ (daily health limit: 125 $\mu gm^{-3}$), $NO_2$: 31.45 $\mu gm^{-3}$ (85 $\mu gm^{-3}$), $PM_{10}$: 46.20 $\mu gm^{-3}$ (50 $\mu gm^{-3}$)].

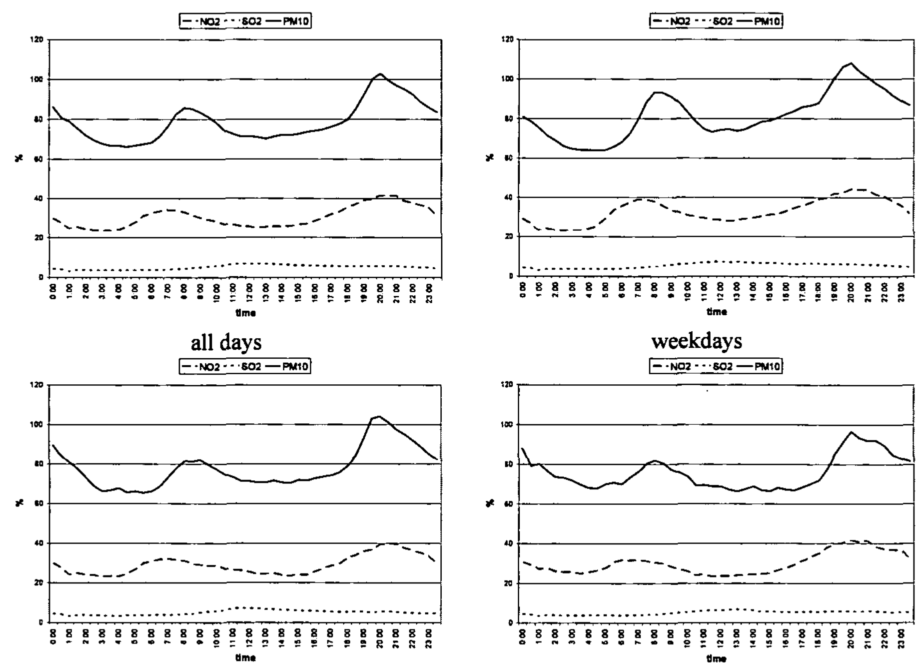



Fig. 6 Mean diurnal cycle of nitrogen dioxide ($NO_2$), sulphur dioxide ($SO_2$) and particulate matter ($PM_{10}$) in the percentage of their health limit, all days, weekdays, Saturdays, Sundays and holidays, monitoring station, Szeged, 1997-2006

## 6. CONCLUSIONS

None of the examined pollutants show a significant trend in Szeged. The mean annual air quality index ($ASI_1$) indicates small annual differences. According to that, the best air quality occurred in 1999 and 2004, whereas the most polluted air was observed in 1997 and 1998. The short-term (diurnal) air quality index ($ASI_2$) is higher on weekdays and lower at weekends. At weekends the improvement of air quality reaches 13%. The maximum of the mean diurnal course expressed in percentage of the health limit exceeds the 100% (limit) only for $PM_{10}$. On the other hand, mean values of the diurnal course of $NO_2$ and $SO_2$ are far below their health limit.

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