The Role of Traffic in Modifying Air Quality in a Medium-Sized City, Szeged, Hungary

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Abstract: The aim of the study is to analyse how traffic modifies air quality at Szeged, Southern Hungary. Measurement of air pollutants (CO, NO, NO₂, NOₓ, SO₂, O₃ and PM) is performed by a monitoring station in the downtown. Annual, summer and winter half-year averages of SO₂/CO, NOₓ/CO, NO/NO₂, PM/CO ratios and those of CO between 1997 and 1999 are calculated. Furthermore, air quality differences between Saturday and weekday (Saturday – weekday), holiday and weekday (holiday – weekday) as well as holiday + Saturday and weekday [(holiday + Saturday) – weekday] are computed. Temporal course of daily averages for CO, NO and NO₂ concentrations in every 30 minutes are shown on weekdays, Saturdays as well as on Sundays and holidays. Whole-day traffic census is made at the junction in clear weather. Diurnal course of CO, NO, NO₂ and O₃ concentrations as well as that of wind speed and wind direction in every 30 minutes is shown on the day of the traffic census. Relation between traffic and CO concentrations on the day of the traffic census is also presented.

Keywords: air quality, concentrations of main air pollutants, traffic census, transportation, vehicle unit factor

1. Introduction

Human activity contributes considerably to the accumulation of air pollutants. Basic reasons of the ever worsening air quality are industrial activity and the increase of urban population and, in connection with this, increasing ratio of built-up areas. One of the main pollution sources is motor vehicle traffic, which heavily affects air quality in densely urbanised regions. In Hungary, traffic is responsible for the following ratios of the total emissions: 70 % for CO, 55 % for NOₓ and 14 % for PM (particulate matter) (Ministry for Environment, 1999). Air pollution is harmful to the buildings, technical devices and may cause serious health damage, as well. The nature and importance of air quality problems depend on the size of the city as well as geographical (climate, local meteorological conditions at the moment, geographical position and relief) and social (existing environmental regulations, urban planning choices) factors (Mayer, 1999).

Transport system of Szeged is overcrowded. Among vehicles, motor cars give the overwhelming part (84 %) of traffic. During an eleven-year period (between 1990 and 2000) traffic density has not changed considerably. However, rate of vehicle types, taking part in the traffic, changed basically. More and more vehicles run with substantially reduced emissions as well as they are equipped with exhaust catalysers. Consequently, contrary to the stagnating traffic density, emission rates of air pollutants decreased importantly. As an example, CO emission in 2000 is only 35-40 % of that measured in 1990 (Pitrik, 2000).
Public transportation at Szeged is carried out by Tisza Volán Inc. At the end of 2000, the company had 47 single public buses and 58 articulated public buses. An important part of traffic air pollution comes from buses. In order to reduce this, Tisza Volán has been operating test buses since 1999, which run on gas. From technological point of view, two systems are applied in practice. These are as follows: LPG = Liquid Petrol Gas (e.g. in Vienna) and CNG = Compressed Natural Gas (e.g. in Szeged). Recently, the company operates 8 CNG single buses and 19 CNG articulated buses. Ratio of buses running on gas is continuously increasing.

One of the great advantages of CNG buses is that their exhaust gas emissions, depending on the components, are 35-85% less than those for the most severe "Euro 3" emission guidelines. Emissions of exhaust gas components, which have not been regulated at the moment, are also the least for gas-on-run buses. Soot and sulphur dioxide emissions for gas-on-run buses are less than 20% of those for diesel buses of similar category. These components (soot and sulphur dioxide) are responsible for London-type (winter) smog. Recently, all public buses of Tisza Volán meet "Euro 2" emission guidelines (Table 1.).

Table 1. Emission guidelines and data of motor types recently operating

<table>
<thead>
<tr>
<th>guidelines</th>
<th>CO emission limits (g/kWh)</th>
<th>NOₓ</th>
<th>PM</th>
<th>notes</th>
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<td>Euro 0</td>
<td>12.3</td>
<td>2.6</td>
<td>15.8</td>
<td>-</td>
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<td>1.1</td>
<td>8.0</td>
<td>0.36</td>
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<td>7.0</td>
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<td>Euro 3</td>
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<td>5.0</td>
<td>0.10</td>
</tr>
<tr>
<td>Euro 4</td>
<td>1.5</td>
<td>0.46</td>
<td>3.5</td>
<td>0.02</td>
</tr>
<tr>
<td>Rába G10 DE UTSLL 190 compressed gas motor with catalyser</td>
<td>0.29</td>
<td>0.44</td>
<td>2.07</td>
<td>0.05</td>
</tr>
<tr>
<td>Rába D10 UTSLL 190 Euro 2 diesel motor</td>
<td>1.38</td>
<td>0.636</td>
<td>6.557</td>
<td>0.126</td>
</tr>
</tbody>
</table>

1Environmentally friendly diesel motors. They are recently operating at Tisza Volán as types of Rába D10 motor family.
2Initiated in EU and Hungary in 1998. Recently it is valid for Hungary.
3Initiated in EU in 2000 October. In Hungary it has yet been a plan.
4Planned guidelines. Planned date of introduction in EU is 2005 October.

Note: the above-mentioned guidelines are related to type examination and serial production of motor vehicles weighed over 3.5 t.

When accelerating gas-on-run buses, there is no smoke, hence this advantage is stressed in the so called "stop and go" operating, which is characteristic for urban public transportation. Another advantage of gas-on-run buses is that their evaporating CH emission is negligible. From environmental respect, further advantage of gas-on-run buses against diesel buses is less noise load for the traffic environment (-4; -6 decibel). Economic regulations are also favourable for applying gas-on-run buses. Considering prices for 2001, operating expense for gas-on-run buses is a mere 49% of that for diesel buses.

The aim of the present study is to perform time series analysis of air pollutants at the air quality monitoring station in Szeged downtown. It is investigated, how traffic modifies air quality at a busy crossing.
1.1. Geographical position, meteorology and topography of Szeged

Szeged is located in the Carpathian Basin (20°06'E and 46°15'N), at an altitude of ca. 80 m above sea level. Its population is about 155,000 inhabitants and the built-up area is around 46 km². The city is situated near the confluence of the Tisza and Maros Rivers, in southern Hungary. Szeged is the largest city in the southern part of the Great Hungarian Plain (Fig. 1.). The climate is temperate, the annual mean temperature is 11°C and the annual average sum of precipitation is 570 mm. The basis of the city structure is the boulevard-avenue system, crossed by the Tisza River. In this way, structure of the city is simple. Following to this system, motor vehicle traffic as well as air pollution are concentrated in the city.

Though Szeged is the centre of light industry in the southern part of the Great Hungarian Plain, (mill-, wood-, paprika processing industry, hemp processing, salami production), some elements of heavy industry are present as well (rubber- and paint industry, furthermore crude oil and gas mining). Industrial potential of Szeged has changed for the worse from the 1990-ies. Several companies have closed down, e.g. textile-, cable-, clothing- and canning factories, while the KÉSZ Ltd. (Light Structure Building and Servicing Ltd.) moved its centre and activity to another city. The industrial area is located mainly in the north-western part of Szeged. Thus, the prevailing westerlies and northerlies transport pollutants, originating from this area, towards the centre of the city.

2. Methodology

2.1. Instrumental Background

The monitoring station of five independent instruments is used to determine concentrations of CO, NO, NO₂, SO₂, O₃ and PM. CO is measured by non-dispersive infrared photometry using a gas filter correlation instrument (type of the instrument: CO11M-LCD). NO and NO₂ are measured in alternative mode by gas-phase chemoluminescence detection, respectively; NOₓ concentrations are given by automatic summing up of latest NO and NOₓ concentrations (type of the instrument: TE 42C). SO₂ is measured by UV fluorescent emission (type of the instrument: FHAF21M-LCD). O₃ is measured by UV absorption at 254 nm (type of the instrument: TE 49C). PM is measured by β-ray absorption (type of the instrument: FH 62 I-N).

Calibration of gas analysers occurs at two points. One of them is the 0-point, which is set automatically, in every 24 hours. Whereas the other calibration point is set once in every second week by a verified sample. Calibration of the O₃ instrument is performed by gas phase titration. Verification of PM measurements occurs once in every quarter of a year.

A personal computer serves to perform instrumental control and data storage. Data are produced primarily as one-minute averages from ten-second measurements. Then, thirty-minute averages are calculated and stored.

The database of the study are 30-minute averages of verified long-term air pollution data from the above-mentioned air quality monitoring station at Szeged downtown, for the
period between January 1, 1997 - December 31, 1999. This station is located at a busy crossing (in the intersection of Kossuth Lajos blvd. and Damjanich street - Teréz street) (Fig. 1.). This crossing is one of the most busy traffic junctions at Szeged.

The crossing has traffic lights, so vehicles should occasionally wait for a while, coming from any direction. Measurements started at January 1\textsuperscript{st}, 1997 and are performed at a distance of about 10 m from the main road. A small thermal power station is found behind the monitoring station. Furthermore, a two-storey building is located at a corner of the crossing, in the direct neighbourhood of the monitoring station. This building, through spreading of the pollutants, influences local concentrations. Air sampling, which is taken about 10 m distance from this building, is performed at a height of 3 m from the ground.

The monitoring station measures 30-minute averages of relevant meteorological elements. Temperature (type of the instrument: THS-611), humidity (type of the instrument: THS-611), global radiation (type of the instrument: RS 81-I) as well as wind speed (type of the instrument: WS-12 H+) and wind direction (type of the instrument: WS-12 H+) are taken into account on analysing air quality parameters. Measurement of both wind parameters and global radiation is performed at a height of 6 m from the ground, while that of temperature and humidity at a height of 3 m above the ground surface.

2.2. Traffic Census

Peak hours at the crossing are at about 8-10 a.m., 1-2 p.m. and 4-5 p.m. On a weekday, about 30,000 (84 \%) motor vehicles and vans, 1,500 (4 \%) buses, 3,000-3,500 (8.4-9.8 \%) lorries, 900 (3 \%) motor bykes and 20 (0.06 \%) low speed vehicles (e.g. tractor) proceed through the crossing here. A great number of motor cars (38 \%, as an average for Hungary) are equipped with exhaust catalysts.

In order to clarify potential effect of traffic to the concentration of air quality parameters, measured at the monitoring station, traffic census was performed at the crossing during a one-day period, from 9\textsuperscript{30} a.m. September 12\textsuperscript{th}, until 9 a.m. September 13\textsuperscript{th}, 2000. During this period (calm weather, undisturbed radiation conditions) a continuous traffic census was made and the 30-minute totals of motor cars were recorded according to vehicle types. Technical background of the traffic census was adopted from the procedure used by the State Highway Managing Public Utility Company of Csongrád county. During the traffic census vehicle types were separated, which (with their so called "vehicle unit factors" in inhabited areas) were as follows: motor vehicle and van (1.0), single public bus (1.8), articulated public bus (2.5), light lorry (1.4), single heavy lorry (1.8), trailer truck (2.5), motor byke (0.7) and slow motor vehicles (e.g. tractor) (2.5). On the basis of the traffic census, the number of motor cars within each vehicle type was multiplied with their own factors and then the results were summarized for each vehicle type. In this way, vehicle factor totals were received in each 30-minute period during this 1-day (24-hour) time interval. The time series of this vehicle factor totals was one of our databases. The vehicle unit factor refers to the role of the given vehicle in traffic; namely, it shows that what kind of role the given vehicle plays in decelerating or accelerating traffic, relative to a motor vehicle or van. In this way, the vehicle factor totals relate directly not to the concentration of the air quality parameters; however, this factor might be in significant correlation with that.

In this study, temporal distributions of CO, NO, NO\textsubscript{2} and O\textsubscript{3} concentrations are analysed at the air quality monitoring station. In addition, the time series of the vehicle unit factor totals as well as those of wind speed and wind direction are brought into connection with the above-mentioned air quality parameters.
3. Results and Discussion

Analysis of 30-minute average concentration data of O\(_3\) shows its values between 25-70 μg m\(^{-3}\) (Fig. 2.). Even O\(_3\) peaks are well below the guideline for a clean atmosphere [30-minute limit value of O\(_3\) for inhabited area is 110 μg m\(^{-3}\) (Hungarian Standard, MSZ 21854-1990), which corresponds to 56 ppb (basis of the conversion: t = 20 °C, p = 1013 mb). Maximum O\(_3\) concentrations occurred around noon. At the same time, in the only period (between 9\(^{30}\) a.m. and 8\(^{00}\) p.m.) when breeze was observed (north and north-east winds), NO\(_2\)/NO ratio was greater then unity. Whereas, in the evening and at night the situation is reverse. In this latter case NO\(_2\)/NO < 1. However, ratio of NO\(_2\)/NO depends not primarily on wind speed but, through ozone concentration, on radiation and NO emissions. Daytime, the ratio NO\(_2\)/NO > 1 can be explained by the rapid oxidation of NO (NO + O\(_3\) → NO\(_2\) + O\(_2\)) (intensive ozone producing processes). While the turn of this ratio in the evening and at night indicates decrease of oxidation capacity of the atmosphere (following nightfall, photochemical processes, leading to ozone formation, stop). This is independent of decrease in wind speed resulting from energetic reasons, generally in the evening hours (Bogo, et al., 1999; Matzarakis, et al., 1999).

In order to determine average daily courses of CO, NO, NO\(_2\), and O\(_3\) concentrations, 30-minute profiles of these pollutants were calculated for weekdays, Saturdays and Sundays+holidays, respectively, for the period 1997-1999 (Fig. 3.). Daily courses of CO, NO and NO\(_2\) concentrations show characteristic, synchronous double waves. Maxima occur between 6\(^{30}\) and 8\(^{30}\) a.m. (primary maximum) and between 6\(^{00}\) and 8\(^{00}\) p.m. (secondary maximum), while primary minimum can be observed between 1\(^{00}\) and 4\(^{00}\) a.m. and the secondary minimum between 12\(^{00}\) and 14\(^{00}\) p.m. These daily courses, on the one hand, can be traced back to traffic origin of CO and NO, since maxima occur during mourning and evening peak hours. On the other hand, they indicate that origin of NO\(_2\) depends clearly on NO emissions. Daily course of ozone is opposite with those of the other three pollutants. A significant negative correlation is calculated between O\(_3\) and NO at the 0.1 % probability level (r = -0.738). This can be explained by the increasing NO emissions during peak hours as well as by day-time photochemical processes producing ozone. The extremely reactive NO depletes O\(_3\) quickly. During weekends, the concentration of these gases is much lower (that for ozone is higher) and their time courses have less amplitudes (those for ozone do not change). During the night the concentration of all gases reaches very low values. This can be explained by decreasing emissions, decrease of speeds of chemical reactions (O\(_3\), NO\(_2\)) leading to originating of air pollutants as well as horizontal dilution. Keeping on O\(_3\) consuming thermal chemical reactions after sunset plays a role in decreasing O\(_3\) concentration at night.

On the day of the traffic census there were moderate northerly winds from 9\(^{30}\) a.m. until 8 p.m. Beyond this period no winds blew. Daily courses of CO and NO show characteristic synchronous change (Fig. 2. and 4.). Their correlation coefficient: r = 0.919, which is significant at the 0.1 % probability level. As CO and NO are dominantly of traffic origin, daily course of their concentrations and that of the vehicle unit factor might be expected similar (Fig. 2. and 4.). However, daytime they show opposite connection and their courses are parallel only during night and early in the morning (Fig. 2. and 4.). The daytime temperate breeze reduces CO and NO concentrations, at the same time during night, when stability of the atmosphere increases (wind speed decreases), CO and NO concentrations increase in the surface layers, contrary to the decreasing emissions.

The concentration of CO and NO\(_x\) correlates strongly (r = 0.919) during the day of the traffic census (Fig. 5.). Values of CO/NO\(_x\) ratio indicate important role of traffic (Makra and Horváth, 1999).
Fig. 2. Concentrations of NO, NO₂, O₃ and CO, as 30-minute averages, at the air quality monitoring station, Szeged downtown, from 9:30 September 12 until 9:00 September 13, 2000. Wind speed and wind direction are also shown.
Fig. 3. Average 30-minute profiles of CO, NO, NO$_2$ and O$_3$ for weekdays, Saturdays and Sundays + holidays at the air quality monitoring station, Szeged downtown, for the period 1997-1999.
Fig. 4. Traffic density and concentration of CO, as 30-minute averages at the air quality monitoring station, Szeged downtown, from 9th September 12 until 9th September 13, 2000. Wind speed is also shown.

For further calculations, average concentrations of the examined pollutants were tabulated (Table 2a.). According to them, annual, summer and winter half-year average ratios of the various pollutants and surrounding pollution sources were computed (Table 2b.).

The station is located close to a highway. Consequently, CO averages are higher for the whole year and the summer and winter half-years, than those in districts with less traffic. As SO$_2$/CO ratio is little, it shows that there are no factories near the station discharging SO$_2$. Near to industrial districts, average annual CO concentration is low and NO$_x$/CO ratio is high. At the monitoring station the annual ratios of NO$_x$/CO do not reach values of Liu (1991) considered for industrial districts. If NO/NO$_2$ ratio is higher than 2, this means that air quality near to the station is influenced considerably by traffic (Liu, 1991). Calculating the above-mentioned ratio, effect of transport on air quality seems to be not important in the surroundings of the monitoring station. (In formation of ratio NO/NO$_2$, oxidation capacity of the atmosphere has an important role as well, which can clearly be observed between the difference of the summer and winter ratios.) Considering the results, there are no significant differences among ratios of the periods in a given year except for the NO/NO$_2$ ratio in all the three examined years (Table 2b.) (Makra and Horváth, 1999). (It should be noted that decision criterion on the above-mentioned ratios is relative. Results of Liu (1991) are considered as
A study was conducted to investigate the difference in concentration of pollutants between weekday and non-weekday (including Saturday, Sunday and holiday) by using the 1997, 1998 and 1999 data from the automatic environmental station. In Hungary, working time is 40 hours per week. It was speculated that the air quality might change during weekends. It was found that the variation of traffic contributed mostly to the change in daily air quality. The results coming from the automatic environmental monitoring station also indicated that daily average concentrations of CO, NO\textsubscript{x}, O\textsubscript{3}, SO\textsubscript{2} and PM all were higher on weekdays and lower during weekends (Table 3a-c.). However, the O\textsubscript{3} daily average exhibited the opposite trend; it was higher on Saturdays, Sundays and holidays but lower on weekdays. The reaction between O\textsubscript{3} and NO is fast. O\textsubscript{3} increases as NO decreases on Saturdays, Sundays and holidays and vice versa (Fang and Chen, 1996).

![Fig. 5. Concentration of CO and NO\textsubscript{x}, as 30-minute averages at the air quality monitoring station, Szeged downtown, from 9\textsuperscript{th} September 12 until 9\textsuperscript{th} September 13, 2000.](image)
4. Conclusions

- Concentration of both CO and NO are in reverse connection with wind speed. As probably both pollutants are predominantly of traffic origin in the crossing, their concentrations should be changed synchronously, which meets our expectations.

- Daily average concentrations of CO, NOx, SO2 and PM are higher in weekdays and lower during weekends. Considering average daily courses of CO, NO and NO2 concentrations, their greatest differences can be observed between 6-9 a.m. and 6-10 p.m., which include peak hours. The concentration of O3 presents an opposite trend.

- Since no industrial effect can be detected and the role of traffic is not essential, air pollution in the examined crossing is not substantial. Considering average annual concentrations, SO2 is one-tenth of the limit value, NO2 and NOx are half of that, respectively, while PM is just below the limit, though it exceeds that in the winter half-year. Only CO is considerably beyond the limit value (about 2.5 times higher than that). [Average annual air quality limit values for inhabited area are as follows: CO: 2000 μg m\(^{-3}\) (1,714 ppm); SO2: 70 μg m\(^{-3}\) (26,222 ppb); NO2: 70 μg m\(^{-3}\) (36,519 ppb); NOx: 100 μg m\(^{-3}\) (52,170 ppb); PM: 50 μg m\(^{-3}\) [(Hungarian Standard, MSZ 21854-1990) (basis of the conversion: t = 20 °C, p = 1013 mb)]. In Chapter 3, paragraph 5, on the basis of NO/NO2 no essential effect of traffic on air quality was concluded in the surroundings of the monitoring station. At the same time CO, among the examined pollutants, exceeds considerably the air quality limit value, which clearly indicates role of traffic. As a comparison, average annual concentration ratios of some pollutant gases at the urban air quality stations Stuttgart-Bad Cannstatt (st), with heavy traffic (Mayer, 1999) and Szeged (sz) are as follows: NO(st)/NO(sz) ≈ 4; NO2(st)/NO2(sz) ≈ 2; O3(st)/O3(sz) ≈ 2. (The number of residents in Stuttgart is about three times higher than that for Szeged. As regards the number and type of vehicles and the used gasoline, there are no data at disposal.)

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<th>automatic station</th>
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<th>O3</th>
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*3-3 months between January-March and October-December in all the three examined years

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