STUDIA UNIVERSITATIS BABES-BOLYAI, CHEMIA, LIV, 1, 2009

Dedicated to Professor Liviu Literat, at his 80th anniversary

NO_2 DISPERSION PROCESS SIMULATION IN URBAN AREAS BY ANALITICAL-EXPERIMENTAL METHODS

DANA SILAGHI-PERJU[a], HARIETA PÎRLEA[b], GHEORGHIȚA JINESCU[c], GABRIELA-ALINA DUMITREL[b], DELIA PERJU[b]

ABSTRACT. In the current global context when the accent on environmental pollution problems are more and more pressing, the study of nitrogen dioxide emissions reduction possibilities as well as the modelling ways of the phenomenon that accompany the dispersion of this pollutant in its cycle in nature is current and of a particular importance. According to this approach, in the paper is presented a simulation method of nitrogen dioxide pollution level in a certain reference point. The contribution of each pollution source at the global pollution in that point is also specified.

Keywords: *atmospheric pollution, NO_2 dispersion process, modelling, simulation*

INTRODUCTION

It was determined that large cities are subjected to a higher degree of air pollution due to industrial activities, traffic and heating systems. Timişoara is a city that belongs to this category. Therefore, knowing the level of pollution, and, more precisely, the origin of pollution, is highly important for finding ways to reduce or counteract the negative effects that it induces.

In the following paper, simulation at a certain reference point of the pollution level by nitrogen dioxide is carried out, stating the percentage share held by each pollution source taken into consideration. In order to do this, concentrations of nitrogen dioxide were estimated at a certain reference point coming from: micro power plants, the two thermal power plants in

[a] *Universitatea POLITEHNICA din Timişoara, Facultatea de Inginerie Mecanică, Blv. Mihai Viteazu, Nr. 1RO-300222 Timişoara, Romania, dsilaghi@mec.upt.ro*

[b] *Universitatea POLITEHNICA din Timişoara, Facultatea de Chimie Industrială şi Ingineria Mediului, Piața Victoriei, Nr. 2, RO-300006 Timişoara, Romania, harieta.pirlea@chim.upt.ro*

[c] *Universitatea Politehnica Bucureşti, Facultatea de Chimie Aplicată şi Ştiința Materialelor, Str. Polizu, Nr. 1, RO-011061 Bucureşti, Romania, jinescu_gheorghita@yahoo.com*

Timişoara and road traffic. The reference point chosen in the study was set in the center of the town, on Mihai Viteazul Boulevard, at the headquarters of the Environmental Protection Agency Monitoring Laboratory Timişoara. This point was chosen due to the fact that here there have been made measurements of the concentrations of nitrogen dioxide by the Environmental Protection Agency Timişoara, and the values obtained, based on sets of mathematical models, were compared with the latter.

RESULTS AND DISCUSSION

In order to simulate the NO_2 dispersion processes in the urban area, the emissions coming from stationary and mobile sources were considered.

The stationary sources which were taken into account for this study are: micro power plants, and the city's two thermal power plants, CET Center and CET South. In the present paper, the generic "micro power plant" refers to the following sources of heat:

⇒ residential micro power plants - providing heat for homes,

⇒ small capacity industrial plants – providing heat in the industrial sector,

⇒ stoves that operate with gas.

The simplified assumptions used for the NO_2 emission estimation coming from micro power plants are:

- micro power plants were treated as 5 stationary point sources of pollution;
- all micro power plants were considered to be of medium class, without filters, having a 90% efficiency (Hermann type);

The algorithm used in the calculus of NO_2 emissions coming from micro power plants is presented in the Figure 1 [1]:

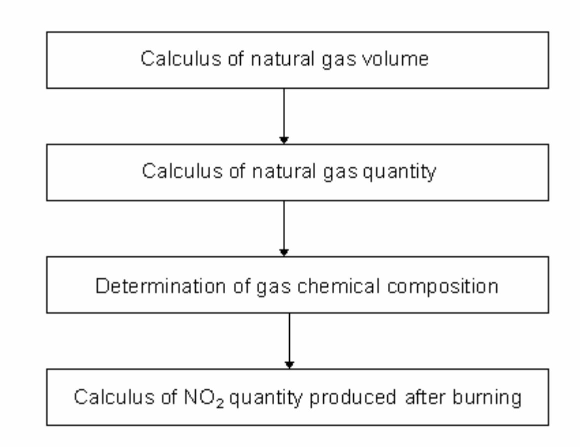

Figure 1. Algorithm used in the calculus of NO_2 emissions coming from micro power plants.

As concern the estimation of NO_2 emission coming from the two thermal power plants of the city, the simplified assumptions were:

- CET Center and CET South were studied as two stationary point sources of pollution;
- The NO_2 emission for each thermal power plant was calculated as the sum of NO_2 emissions coming from all power plant boilers.

The data coming from Colterm Timisoara, were generated according to the Romanian standards by EMPOL software [2-7].

The values of NO_2 emissions coming from the micro power plants and the two thermal power plants of the city were used in the Gaussian model [8,9] in order to compute, in the reference point, the concentrations of nitrogen dioxide emissions from the stationary sources for each day of the months: January, April, July and October 2004.

As a result of these data, there have been performed monthly averages, as presented in Table 1.

Table 1. Concentrations of NO_2 at the reference point, from the 7 stationary sources [μg/m^3]

Month	Conc. derived from micro power plants					Conc. derived from Cet's		NO_2 total conc
	North	South	East	West	Center	CET Cente	CET Sout	
01	1.02E+0(	1.17E-02	1.83E-02	1.03E+00	1.45E+00	3.49E+00	4.55E-02	7.06E+00
04	7.22E-10	6.96E-02	2.88E-02	9.33E-02	4.99E-05	4.92E-01	1.06E-02	0.69E+00
07	1.75E-09	1.27E-02	1.79E-03	1.08E-01	5.39E-06	1.65E-03	5.34E-04	0.13E+00
10	5.51E-09	4.61E-01	2.65E-01	2.44E-01	7.64E-04	1.12E+00	0.00E+00	2.09E+00

It has been determined that, at the reference point, the highest value of the concentration of nitrogen dioxide derived from stationary sources has been recorded in January. Of the stationary sources, CET Center is the source with the largest share of pollution in the city center. CET South has an almost undistinguishable influence, and, out of the micro power plants, the biggest influences have those situated in Centre and Western part of the town.

In Figure 2 a), b), c) and d), the percentage share that each of the 7 sources of pollution by nitrogen dioxide at the reference point is shown, derived from stationary sources.

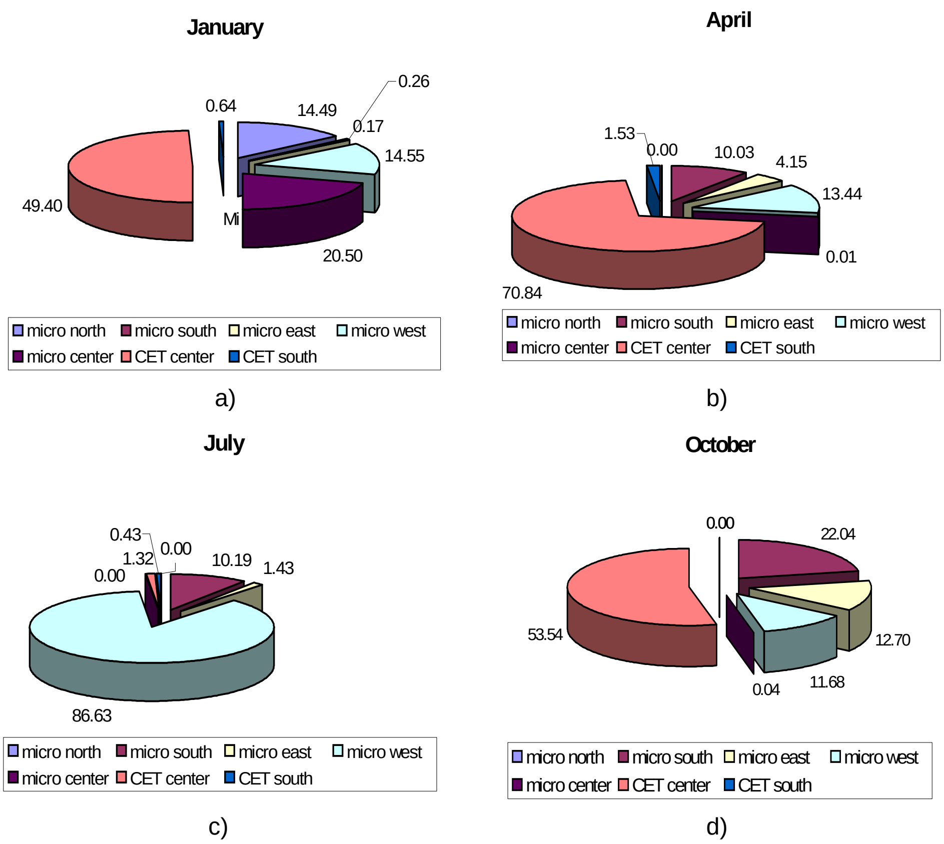

Figure 2. The percentage share held by each of the 7 stationary pollution sources with nitrogen dioxide.

From Figure 2, it can be noted that in the months in which temperatures require the operation of the two thermal power plants, the largest share of pollution from the stationary sources comes from CET Center. The influence of the second thermal power plant is not significant because it is located outside the city and the preponderant direction of the wind in Timişoara is not towards the reference point taken into account.

By ***mobile sources*** one can understand all motorized means of transport, noted generically by “road traffic”. The parameters needed to calculate the concentration of nitrogen dioxide at the reference point taken into account from mobile sources are:

• the quantitative emission of nitrogen dioxide coming from road traffic. In order to establish the value of this emission, it was considered that all of Timişoara’s fleet and the transiting vehicles are equipped with EURO 3.

The current legislation provides that for cars equipped with EURO 3 the NO_2 emission standard is 0.5 [g/Km] [10].

• dispersion area volume. Since the emission standard estimated by specialized laws is expressed in [g/Km], it was necessary to establish an area of dispersion having a 1 Km length. It is known that the sensor for the analysis and detection of nitrogen dioxide is located at a height of 3 m. The device with which the measurements were made belongs to the Environmental Protection Agency Timişoara and it is located inside its Monitoring Laboratory. The width of the road in this area of the city is 15 m. Therefore, the area of dispersion is located on Mihai Viteazul Boulevard, also the site of the reference point taken into account, and has the following characteristics: length - 1 Km, width – 15 m, height – 3 m, thus the volume of dispersion is 45 000 m^3.

• the number of cars transiting the dispersion area taken into account in the time required the sensor to sample for an analysis. The sensor's time sequence is 60 s.

In order to estimate the concentrations of nitrogen dioxide emissions coming from mobile sources (road traffic) at the point of reference the relation (1) [8] was used:

$$C_r = \frac{N \cdot 10^6}{V} \cdot n \qquad (1)$$

where:

C_r – the concentration of NO_2 in the reference point coming from traffic, [μg/m^3]

N – the European emission standard, [g / km], N = 0.5 g / km

V – volume of the dispersion area, [m^3], considered 45 000 m^3,

n – number of mobile sources [pcs].

The algorithm presented above was applied for the same months of 2004, as in the case of stationary sources. Out of the values obtained, monthly averages were made of the concentrations of nitrogen dioxide emissions from mobile sources (road traffic), and these are presented in Table 2. In calculating these values, the number of mobile sources was chosen according to the traffic specific of each month.

Table 2. Concentrations of NO_2 at the reference point, coming from road traffic

Month	Number of mobile sources/time sequence [pcs]	Concentrations of NO_2 at the reference point, coming from road traffic [μg/m^3]
January	6.5	72.22
April	4	44.44
July	2.25	25.00
October	3	33.33

One can notice that the concentrations values of nitrogen dioxide coming from road traffic at the reference point are considerably higher than from those coming from stationary sources.

The simulation of the pollution process by nitrogen dioxide in the city of Timişoara, at a given point of reference, is done by estimating the concentrations of nitrogen dioxide at that point of reference - described at the beginning of this paper, coming from stationary and mobile sources. For this, the balance equation was derived for this pollutant:

$$C_{ref} = C_1 + C_2 + C_3 + C_4 + C_5 + C_6 + C_7 + C_r \qquad (2)$$

where:
C_{ref} – total concentration of nitrogen dioxide in the reference point, [μg/m^3].
C_1, C_2, C_3, C_4, C_5 – NO_2 concentration in the reference point resulted from the north, south, east, west and center microplants [μg/m^3].
C_6, C_7 – NO_2 concentration in the reference point resulting from the Center CET and South CET, [μg/m^3].
C_r – NO_2 concentration in the reference point resulting from the road traffic, [μg/m^3]

The total concentration of nitrogen dioxide at the point of reference for the months taken into consideration, calculated using a mathematical model [8] is presented in Table 3.

Table 3. The nitrogen dioxide concentrations values at the given global reference point

Month	NO_2 concentration in the reference point resulting from the stationary sources [μg/m^3]	NO_2 concentration in the reference point resulting from the road traffic [μg/m^3]	NO_2 concentration in the reference point [μg/m^3]
January	7.06	72.22	79.28
April	0.70	44.44	45.14
July	0.13	25.00	25.13
October	2.09	33.33	35.42

Comparing the influence of stationary and mobile sources on nitrogen dioxide pollution at the given reference point, it has been determined that mobile sources have an overwhelming weight in relation to the stationary ones (> 90%). In Figure 3 the share of stationary and mobile sources at NO_2 pollution globally at the given reference point is presented.

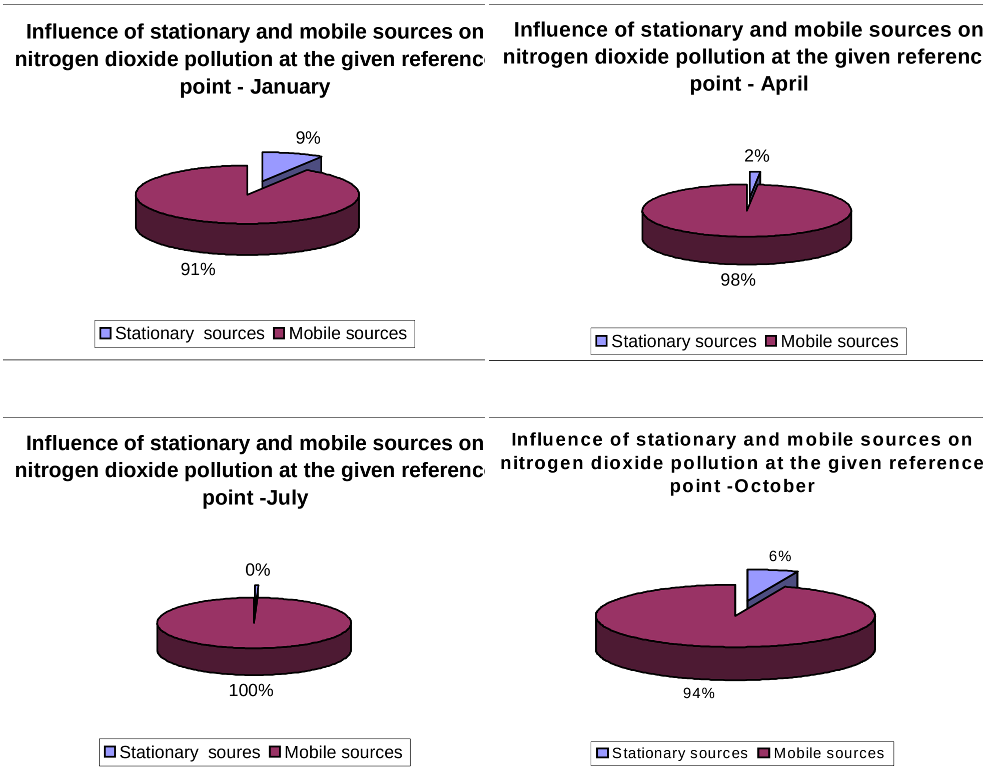

Figure 3. The share of stationary and mobile sources at NO_2 pollution at the reference point.

From the graph, one can notice that, in April and July, the stationary sources have a negligible influence on nitrogen dioxide pollution in the town center.

Testing the mathematical model accuracy has been achieved by comparing the results obtained by applying the model with the experimental ones, provided by the Environmental Protection Agency Timişoara (Table 4).

Table 4. Mathematical model testing

Month	Measured NO_2 concentration in the reference point [µg/m^3]	Calculated NO_2 concentration in the reference point [µg/m^3]	Relative error, %
January	81.48	79.28	2.70
April	50.00	45.14	9.72
July	28.11	25.13	10.60
October	31.23	35.42	-13.42

The small differences between the results as well as the values of relative errors confirm that the case study presented in this paper was properly addressed and the developed mathematical models characterize well enough the processes that accompany the NO_2 pollution phenomenon from Timisoara city.

CONCLUSIONS

At studied reference point, the major influence on nitrogen dioxide pollution is held by mobile sources. The share of this pollution is >90%.

Regarding the stationary sources, the largest share of nitrogen dioxide pollution is held by the micro power plants from the city center and CET Center.

By comparing the results of the mathematical model characterizing the global pollution with nitrogen dioxide with the experimental data, one can notice a good conformity between them, thus proving that the case study has been properly addressed.

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