STUDY ON LOCAL SCALE DISPERSION WITHIN IMPACT AREA OF A MAJOR POLLUTANT SOURCE

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Etude au niveau local sur l'impact de la dispersion des polluants d'une source majeure de pollution. La politique dans le domaine de l'environnement demande une connaissance approfondie du niveau de la pollution de l'air. Une grande attention a été accordée à la compréhension du processus de dispersion des polluants émis dans l'atmosphère. Afin d'évaluer la qualité de l'air dans la zone d'impact de l'usine pétrochimique d'Arpechim (la ville de Pitesti), on a développé un modèle de dispersion au niveau local. Les concentrations moyennes annuelles et leurs paramètres de statistique correspondants pour le SO_2 et NO_X ont été saisis en utilisant un modèle gaussien appliqué à une base de données météorologiques de 5 ans. Le domaine des concentrations estimées annuellement présente une élongation dans la direction prédominante du vent, toutes les valeurs étant en dessous des limites autorisées par la législation roumaine. La bonne corrélation entre les valeurs observées et simulées prouve que le modèle pourrait être utilisé comme instrument afin d'estimer les concentrations des polluants.

Key words: air pollution, dispersion of pollutants, meteorological conditions, Piteşti.

1. INTRODUCTION

The dispersion of the pollutants released in the atmosphere by the multiple or single pollution sources, with continuous or accidental emission is an important subject of research. The modelling of the pollutants dispersion consists in the estimation of the pollutants concentration at the ground and in the height, function of the sources' characteristics, the meteorological and topographical conditions. The physical and chemical processes of the pollutants in the atmosphere and the interaction of these with the ground's surface must also considered.

The aim of this paper is to evaluate the air pollution around the Arpechim Piteşti petrochemical plant. The time average concentrations of the: SO_2, NO_x and CO are computed. The climatological gaussian model for pollutants' dispersion was used. The physical and mathematical framework is presented in Section 2. For the model validation, the computed values were compared with the measured pollutant concentration values in Section 3. In the end of the paper are presented a few concluding remarks.

Rev. Roum. GÉOPHYSIQUE, **50**, p. 107–118, 2006, Bucureşti

2. PHYSICAL AND MATHEMATICAL FRAMEWORK

To evaluate the pollutant's concentration by the Gaussian model, the equations of Novak (1976) are used:

a) For unlimited mixing, so doesn't exist a thermal inversion or the atmosphere is stable the Gaussian solution for a continuous point source is:

$$\overline{C}(x,y,z)=\frac{Q}{2\pi\sigma_y\sigma_z\overline{u}}\exp\left(-\frac{y^2}{\sigma_y^2}\right)g(z,H)$$
$$g(z,H)=\exp\left[-\frac{1}{2}\left(\frac{(z-H)^2}{\sigma_z^2}\right)\right]+\exp\left[-\frac{1}{2}\left(\frac{(z+H)^2}{\sigma_z^2}\right)\right] \quad (1)$$

b) If the value of the dispersion parameter $\sigma_z > 1.6\ h_s$, and the atmosphere is unstable or neutral:

$$\overline{C}(x,y,z)=\frac{Q}{\sqrt{2\pi}\sigma_y h_s}\exp\left(-\frac{y^2}{2\sigma_y^2}\right) \quad (2)$$

In this case, the pollutant is uniform mixed in the planetary boundary layer, and the concentration doesn't depend on the *z* height.

c) If the atmosphere is unstable or neutral, and the dispersion parameter value is $\sigma_z < 1.6\ h_s$:

$$\overline{C}(x,y,z)=\frac{Q}{2\pi\sigma_y\sigma_z\overline{u}}\exp\left(-\frac{y^2}{2\sigma_y^2}\right).g(h_s)$$
$$g(h_s)=\sum_{k=-4}^{k=+4}\left\{\exp\left[-\frac{1}{2}\left(\frac{(z-H+2kh_s)^2}{\sigma_z^2}\right)\right]+\exp\left[-\frac{1}{2}\left(\frac{(z+H+2kh_s)^2}{\sigma_z^2}\right)\right]\right\} \quad (3)$$

Consequently, in the case of the thermal inversions, the pollutant can't be dispersed on the vertical according to the equation (1), due to the reflection at the inversion surface.

The *main meteorological parameters* that determine the pollutants' dispersion process in the atmosphere are: the wind's direction and the atmosphere's stability.

The six stability classes of Pasquill-Gifford were used for the climatological model. The average wind speed at the *h* height of pollutant's source is calculated with the equation:

$$\overline{u}(h)=\overline{u}_h x\left(\frac{h}{h_0}\right)^p \quad (4)$$

where h_0 is the height where is measured the wind's speed, and the exponent p depends on the atmospheric stability class.

In the Gaussian model the dispersion parameters σ_y (in the horizontal plane) and σ_z (in the vertical plane) are calculated with the formulas proposed by Briggs (1975):

$$\sigma_y = a_1 x^{b_1}(1 + c_1 x)^{d_1} ;\ \sigma_z = a_2 x^{b_2}(1 + c_2 x)^{d_2} \tag{5}$$

The pollutant's plume rise is determined with the Briggs method (1975).
The pollutant concentration's value in a given receptor point depends on the wind's direction and intensity and on the stability of the atmosphere.

3. RESULTS AND DISCUSSIONS

3.1. RESULTS OF THE MODEL

The statistical parameters (averages, bias, Pearson coefficient, MAC (maximum admissible concentration)) of the concentrations field are computed by Gaussian dispersion model. The dispersion coefficients used in this model had been determined by measurements, for the distances between 10 m and 20 km.

- *Input data*

The contributions of the pollutants' sources on the ARPECHIM plant, at the pollutants' concentrations (SO_2, NO_x, CO) in Piteşti town zone, on a 30 × 30 km grid with the step of 1 km were considered. The meteorological data averaged on the last 20 years were used.

The pollution sources characteristics, for that it calculated the pollutants' concentrations, are presented in the Table 1.

Table 1

The pollution source characteristics for which the pollutant concentrations are calculated

The stack	The stack's characteristics		The gases' parameters		Rate of emission		
	Height H (m)	Diameter D (m)	Temp. ^oC	Emission speed (m/s)	NO_X (g/s)	SO_2 (g/s)	CO (g/s)
C121A	60	3.2	250	0.7	0.88	0.02	3.6
C121B	35	2	250	1.8	9.02	0	0.75
C 481	25	0.5	500	1	0.03	0	0.03
C121	60	3	210	2.4	3.84	0	0.72
St.-Kess 1	15	1.2	125	4.9	0.95	0	0.23
St.-Kess 2	15	1.2	125	4.9	1.02	0	0.2
C 102 A	18	1	124	13.2	1.7	0	0.37
C 102 B	18	1	113	11.2	1.53	0	0.02

Table 1 (continued)

C 102 C	18	1	145	11.2	1.76	0	0.02
C 102 D	18	1	207	10.4	1.49	0	0.02
C 102 E	18	1	119	12.8	1.95	0.05	0.04
HS 301C	56	5	280	0.6	11.65	26.27	24.07
HS 301S	56	5	280	1.1	61.57	46.43	50.59
P3	20	0.6	140	0.3	0.06	0.3	0.4
CR 15/1	32	1.7	165	4.5	4.21	0	0.04
CR 15/2	32	1.7	165	4.6	3.27	0	5.04
CR 15/3	32	1.7	165	4.4	3.7	0.03	8.53
CR 15/4	32	1.7	165	4	2.99	0	0.02
CR 15/5	32	1.7	165	4.5	4	0	0.08
CR 15/6	32	1.7	165	4.3	4.81	0	0.03
C 101	28	1.2	260	4.5	1.08	0	0.36
C 102	26	1.1	323	5.3	1.26	0	0.39
7H1	100	5	250	1.6	6.04	24.11	0.63
7H2	100	5	250	1.6	5.62	28.36	0.07
8H1	100	5	250	1.6	8.74	40.3	1.91
9H1	100	5	250	1.6	6.79	56.42	4.31
10H1	40	1.9	375	0.7	0.39	0.08	0.88
10H2	40	1.4	363	0.7	0.22	0.23	0.03
16H1	40	2.7	336	0.7	0.9	0.82	0.29
16H2	40	1.7	238	1.6	0.4	0.73	0.79
CO Boyler	60	2.9	250	7.1	9.66	73.75	3.89
FH3	70	3.6	150	0.8	1.67	145.87	13.15
110C1	25	0.6	380	7	0.23	0	0.76
19H1	19	0.7	143	0.5	0.03	0	0.08
22H1	31	1.3	230	1.5	0.15	1.03	0.29
Bitumen	80	1.1	150	2.1	0.13	66.73	1.87
Babcock 1	80	6	210	0.5	8.4	47.47	0.89
Babcock 2	80	6	210	2.2	36.52	145.48	0.12
Babcock 3	80	6	210	2.2	33.15	144.19	1.23
Babcock 4	80	6	210	2.2	27.7	32.17	1.65
Babcock 5	80	6	210	2.2	33.03	142.6	1.53

The values presented as emission debits represent average values measured at stacks during year 2001. It was considered that the sources had a continuous and constant emission along the 2001-year, equal to the emission debit's average value.

The dominant wind direction in Piteşti town zone is NW, along to the Argeş river.

- *Annual mean concentrations*

The SO_2, NO_x and CO concentration values obtained by using the climatological model show (Table 2):

– for SO_2, the maximum admissible concentration (MAC) for 30 minutes is 750 μg/m^3, and annual MAC is 60 μg/m^3. In Fig. 1 is presented the annual mean concentrations distribution for SO_2. The annual maximum concentration's value is 68.9 μg/m^3 in the vicinity of the Arpechim plant. The SO_2 concentrations from nearby localities of Arpechim plant are between 0 and 40.6 μg/m^3 in Oarja village's north; the annual MAC isn't exceeded in any locality near Arpechim;

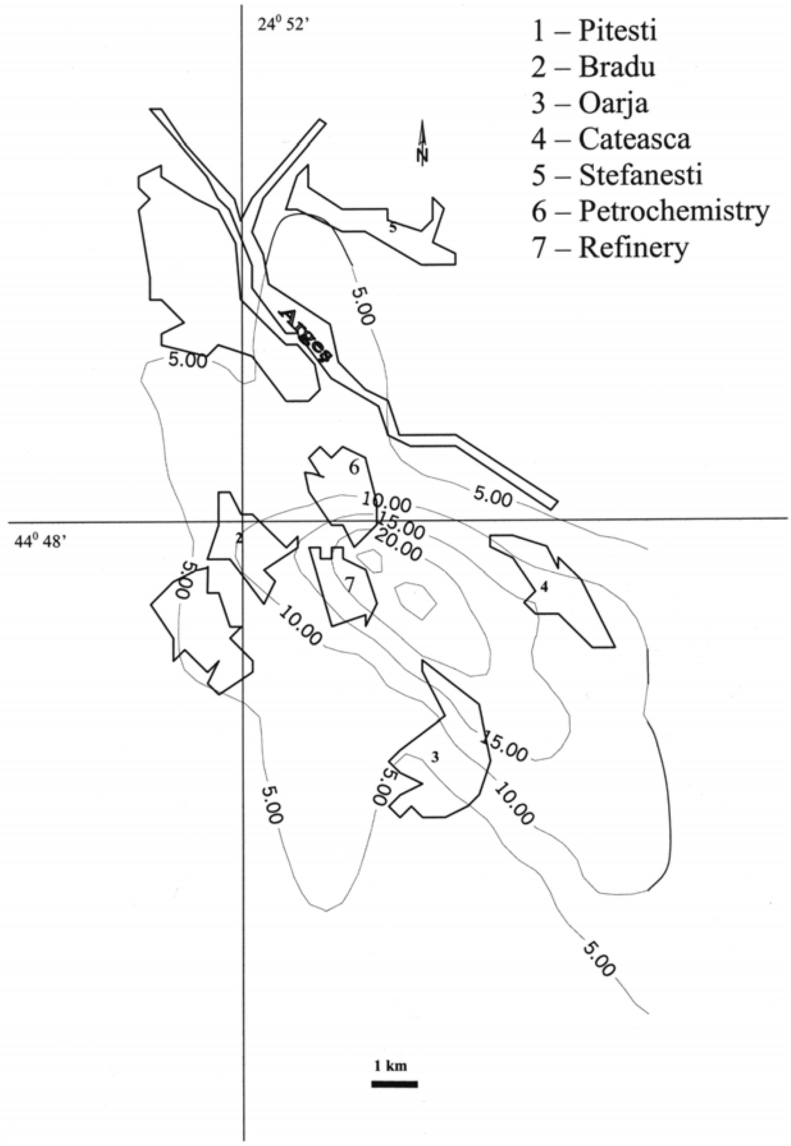

Fig. 1 – The spatial distribution of the SO_2 pollutant concentrations.

– the maximum admissible concentration (MAC) for 30 minutes for NO_x is 300 μg/m^3, and the annual MAC is 40 μg/m^3. In Fig. 2 is shown the annual average concentrations' distribution for NO_x. The annual maximum concentration's value is 27.5 μg/m^3 also obtained near the Arpechim plant. The NO_x concentrations from nearby localities of Arpechim plant are between 0 and 20 μg/m^3 in the Căteasca village's west. The annual MAC isn't exceeded in any locality near Arpechim.

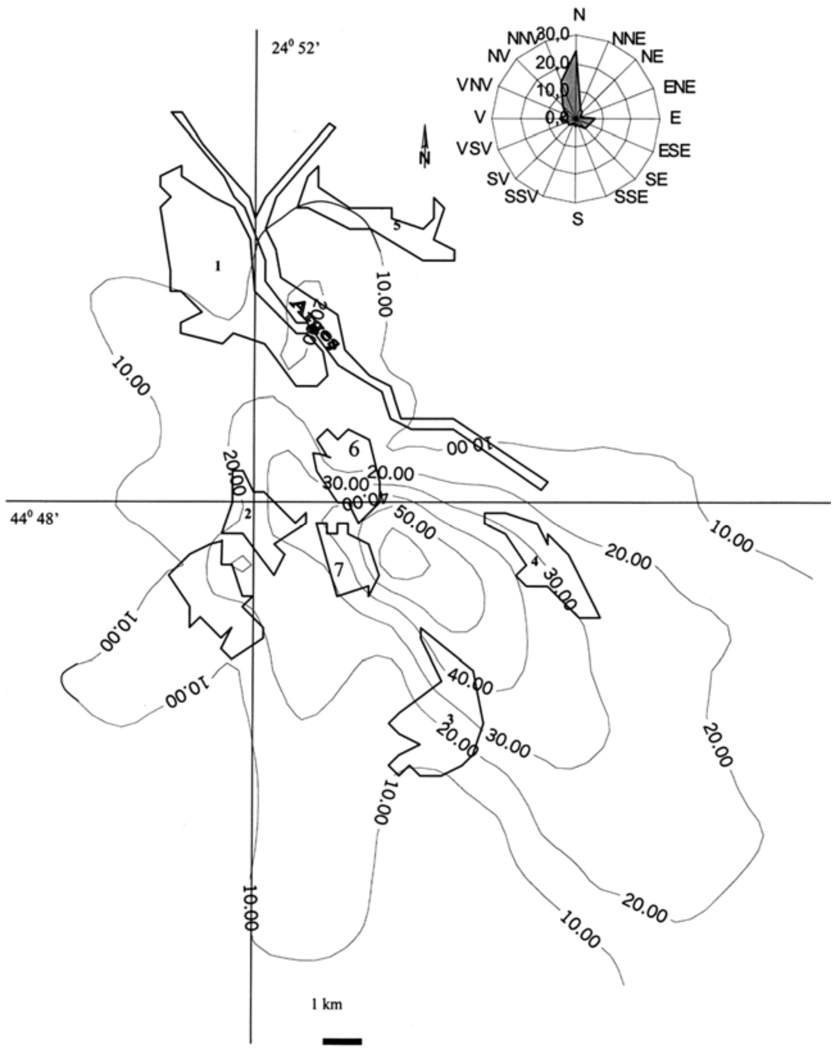

Fig. 2 – The spatial distribution of the NO_x pollutant concentrations.

For CO doesn't exist an annual MAC, and MAC for 30 minutes is 6000 μg/m^3.

Fig. 3 shows the annual average concentrations distribution for CO. This concentration's maximum value is 14.4 μg/m^3, obtained in near the Arpechim plant. The CO concentrations from nearby localities of Arpechim plant are between 0 and 10 μg/m^3 in the Căteasca village's west. The annual MAC isn't exceeded in any locality near Arpechim.

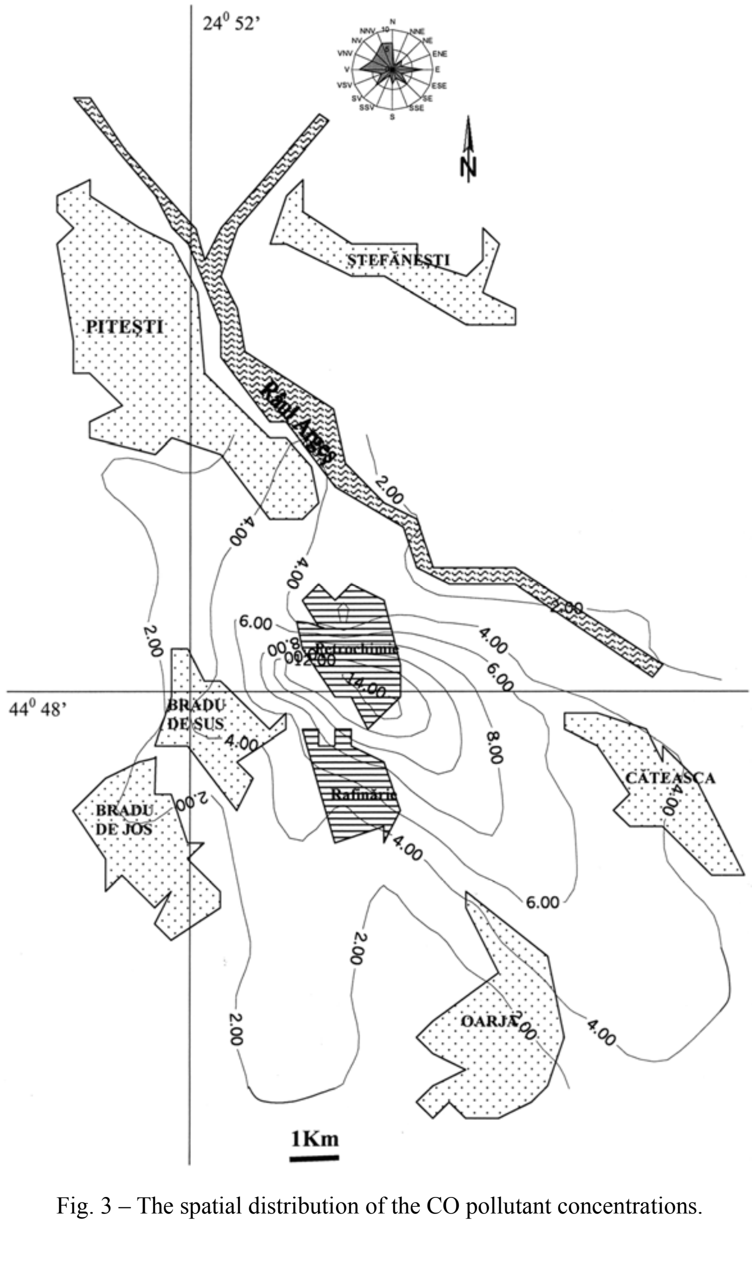

Fig. 3 – The spatial distribution of the CO pollutant concentrations.

3.2. THE MEASURED CONCENTRATION VALUES OF THE POLLUTANTS

During year 2001 it was performed measurements of the concentration pollutants around the Arpechim plant. The annual mean values of concentrations are presented in Table 3 for Oarja, Prundu and Bradu.

Table 2

The annual computed concentration values of pollutants

Site	SO_2 [μg/m^3]	NO_x [μg/m^3]
Oarja	42.6 ± 1.2	22.1 ± 1.7
Bradu	28.9 ± 1.4	14.1 ± 0.6
Prundu	50.6 ± 3.1	19.7 ± 0.7

Table 3

The annual measured concentration values of pollutants

	SO_2 [μg/m^3]	NO_x [μg/m^3]	CO [μg/m^3]
Annual MAC	60	40	
Range of estimated values	0 – 68.9	0 – 27.5	0 – 14.4
Oarja	40.6	18.5	4.4
Bradu	28.9	12.8	5.2
Prundu	17.9	8.3	4.2

In Fig. 4 are presented the SO_2 measured values' histograms in the Oarja and Bradu villages and in the Prundu district (the nearest by Arpechim) from Piteşti.

The measured average concentration in the Oarja village is 42.6 μg/m^3, in Bradu village is 28.9 μg/m^3, and in Prundu – Piteşti is 50.6 μg/m^3.

In Fig. 5 are presented the NO_x measured values' histograms in the Oarja and Bradu villages and in the Prundu district.

The measured average concentration in the Oarja village is 22.1 μg/m^3, in Bradu village is 14.1 μg/m^3, and in Prundu – Piteşti is 19.7 μg/m^3.

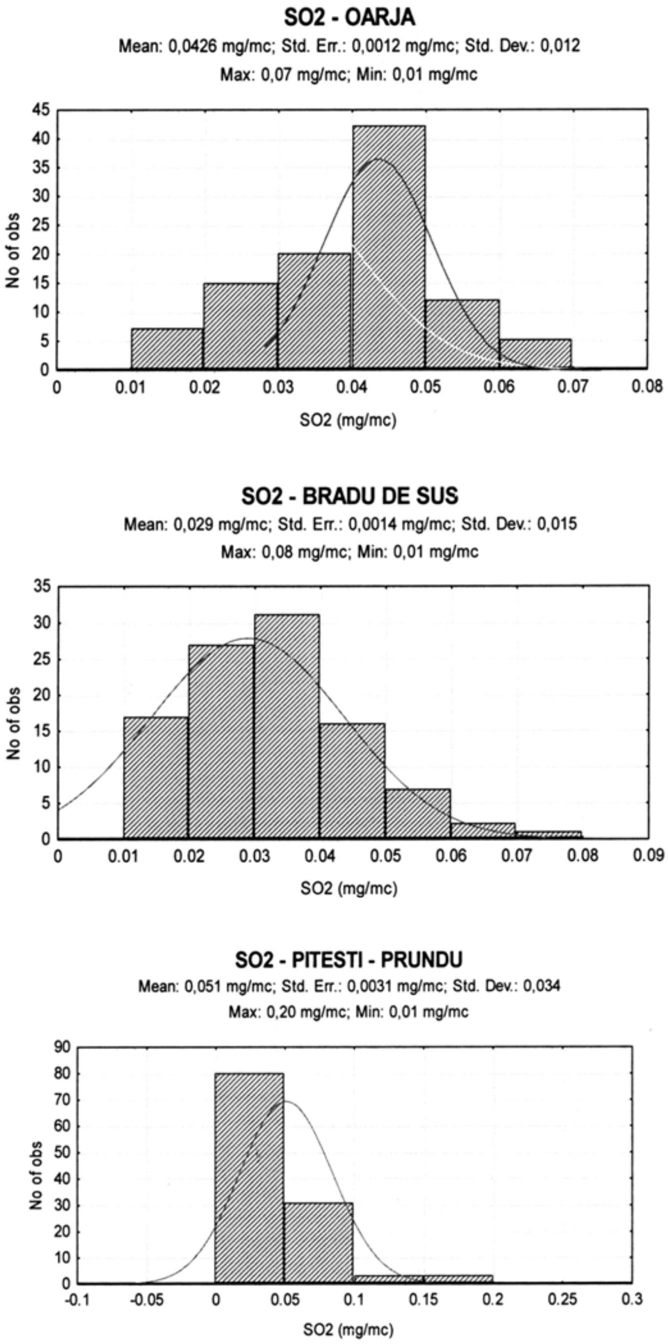

Fig. 4 – The SO_2 measured values' histograms in the Oarja and Bradu villages and in the Prundu district (the nearest by Arpechim) from Pitești.

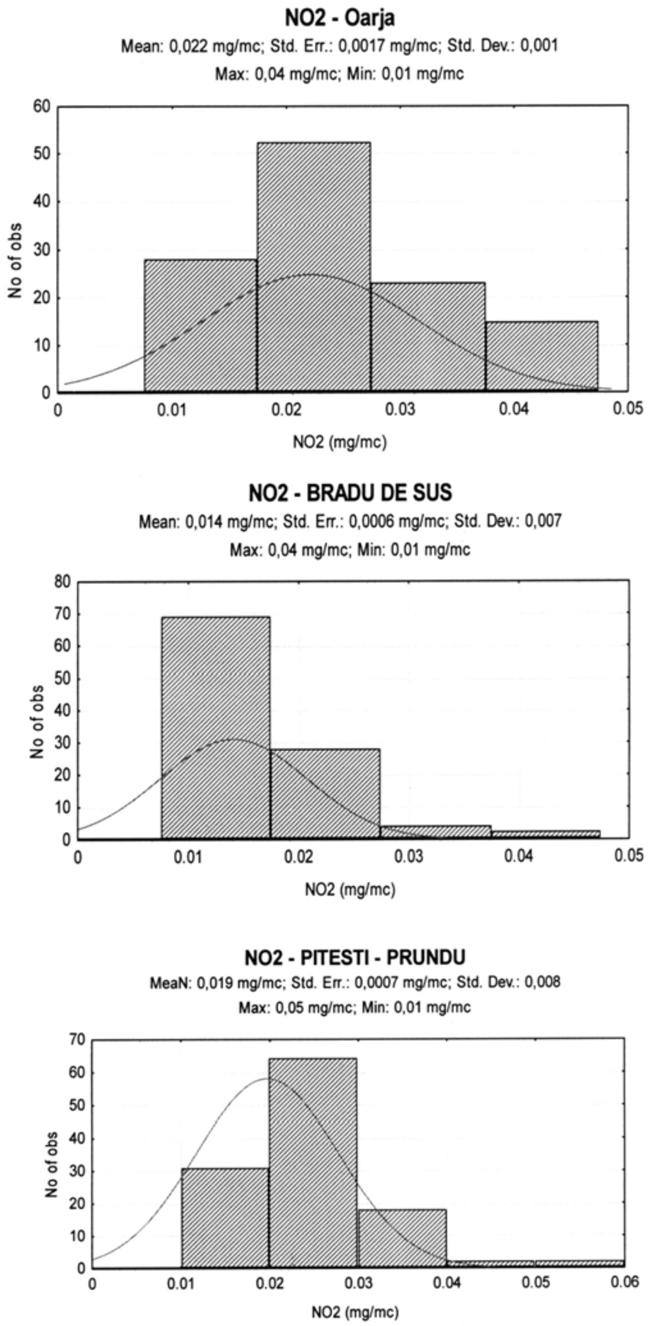

Fig. 5 – The NO_2 measured values' histograms in the Oarja and Bradu villages and in the Prundu district (the nearest by Arpechim) from Pitești.

4. CONCLUSIONS

For all the analysed pollutants, the curves of equal concentration present a longish on the NW–SE direction, and the concentrations' maximum appear in the south-eastern part of the Arpechim plant.

The pollutant plume dispersion in the Piteşti town zone is along the main wind's direction, parallel to the Argeş river.

In any point from the localities found in the Arpechim plant's influence zone, doesn't exist exceeding of the annual average concentrations for any examined pollutants.

The zone with the greatest pollution level is near the Arpechim plant, at about 2 km SE from that. In this zone it doesn't exist residential districts.

In the Prundu district, the measured values are a little greater than the values foreseen by the mathematical model. This difference can be explained by the influence of the road traffic in the zone against the air's quality. The used model calculates only the sources' contribution found on the Arpechim plant at the atmospheric noxes total concentration.

There is a good correlation between the measured concentrations' values and these calculated by using the climatological model.

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Received: October 10, 2005
Accepted for publication: January 4, 2006