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THE ROLE OF THE SYNOPTIC CONDITIONS IN THE DISPERSION OF A POLLUTION INDICATOR – THE NITROGEN DIOXIDE (NO_2) IN THE AREA OF SLATINA TOWN, ROMANIA

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Abstract

Nowadays, the higher the degree of the human society development has become, the more the degree of the environmental pollution has increased, and so, besides the beneficial effects of the technical progress, the humanity may bear the adverse effects of the industrialization. The atmosphere exerts a complex role in terms of the pollution generated by various fixed or mobile sources, manifested in three ways: receiver, conservator and vehicle. In this study, we will analyze the role of the synoptic conditions in the dispersion of the pollution indicator – the nitrogen dioxide (NO_2), highlighting the three stages in which atmosphere manifests in the area of Slatina town. This is complemented by characterizing the pollutant – the nitrogen dioxide and the main emission sources, and at the end of the paper, there are presented the conclusions of the authors. To know the way of dispersion of the pollutants in relation with the influencing factors is the starting point in finding the most appropriate means of combating the air pollution.

***Keywords*:** air pollution, nitrogen dioxide (NO_2), synoptic conditions, dispersion, Slatina.

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Introduction

The pollution of atmosphere appeared with the first human settlements development and has gradually expanded, as the industry has diversified and intensified, thus acquiring a historical character (Bogdan and Câmpean, 2006). The scale and intensity of the air pollution achieve great odds, being considered by aggregation, a global phenomenon (Bălteanu and Şerban, 2005). Due to the anthropogenic gas emissions in general, and to the greenhouse in particular, the global warming can also be added to the list of the possible climatic disasters (Stehr and Storch, 2015). The pollution of atmosphere with gases and vapors is more significant than that with powders (Constantin et al., 2016). The dispersion of pollutants in the atmosphere is not only punctual and local and it is long distance felt around, thus jeopardizing the environmental quality of life through the environmental effects on all the components and especially on the climate. The impact of air pollution on a global scale, has made economic development policies to be designed so that the environmental components may be as important as the economic efficiency (Ionac and Ciulache, 2005). Currently, there are increasing economic units which understood the importance of implementing the environmental management in the overall management of the company, aiming to reduce the negative effects and to develop the positive environmental effects (Căpuşneanu et al., 2015). In Romania, in 2005, the Government adopted the National Plan for Sustainable Development, aiming to develop the country in accordance with the sustainable development principles (Negulescu et al., 2015). A component of the environmental management is the air quality management, which includes the evaluation and monitoring of the emissions, the pollution sources and the air quality (Constantin et al., 2016). The World Health Organization (WHO) has determined five classic pollutants for the air quality, these pollutants being monitored by the Global Environment Monitoring System (GEMS) in 142 countries. These are: carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3) and the particulate matter (WHO, 2020).

In terms of pollution, the atmosphere exerts a complex role of receiver, conservator and vehicle (Bogdan and Câmpean, 2006). The pollutant dispersion is the process of turbulent diffusion, followed by the dilution of pollutants in cleaner air volumes, being conditioned by the emission characteristics, by the meteorological factors and physical-geographical factors (Farcaş and Croitoru, 2003). Consequently, the main objective of this paper is to analyze the role of the synoptic conditions in the dispersion of the pollution indicator – the nitrogen dioxide (NO_2). This analysis is complemented by a brief description of pollutant emission sources for the area of Slatina town in 2015.

Materials and methods

The nitrogen dioxide (NO_2) along with the mono nitric oxide (NO) forms the nitrogen oxides which are aggressive pollutants for the atmosphere (by participating in the greenhouse effect and the ozone depletion) and the biosphere (Rădulescu, 2008). It is an intermediary gas between the emission of the nitrogen oxide and the ozone formation, also being a precursor of the nitric acid (HNO_3), a component of the acid rain (Kurtenback et al., 2012; Rădulescu, 2008).

The nitrogen dioxide is a stable gas, brown colored that forms a link in the combustion processes, through a spontaneous reaction between the nitrogen and oxygen in the air (Trufaş, 2003):

$$N_2 + O_2 \rightarrow 2NO; 2NO + O_2 \rightarrow 2NO_2$$

It reacts with water forming the nitric acid and the nitrous acid, and the global relationship of the dissolution of nitrogen dioxide is:

$$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$$

The nitrogen dioxide is mainly derived from the burning of solid, liquid and gas fuels in various industrial plants, residentials, commercial installations, institutions and car traffic (APM Olt, 2016; ANPM, 2016). NO_2 is best used in assessing the degree of pollution of all the nitrogen oxides, because it is an end product of the fuel combustion in the furnaces and engines; a main product resulting from the reactions of other nitrogen oxides with the air and the base substances participating in creating the industrial smog.

Among the factors on which the dispersion of pollutants in the free atmosphere depends, the meteorological factors play a crucial role. They are represented by the atmospheric circulation, the degree of stability of air masses, the wind direction and speed, the precipitations, the air moisture and the intensity of solar heat.

The paper will highlight the atmospheric pollutant dispersion – NO_2 for the area of Slatina town. Slatina is the main center of the aluminum industry by the presence of SC ALRO SA in the Central and Eastern Europe, excluding Russia, being a mid-sized town in the southern Romania, situated in the lower part of the Olt Valley (Fig. 1).

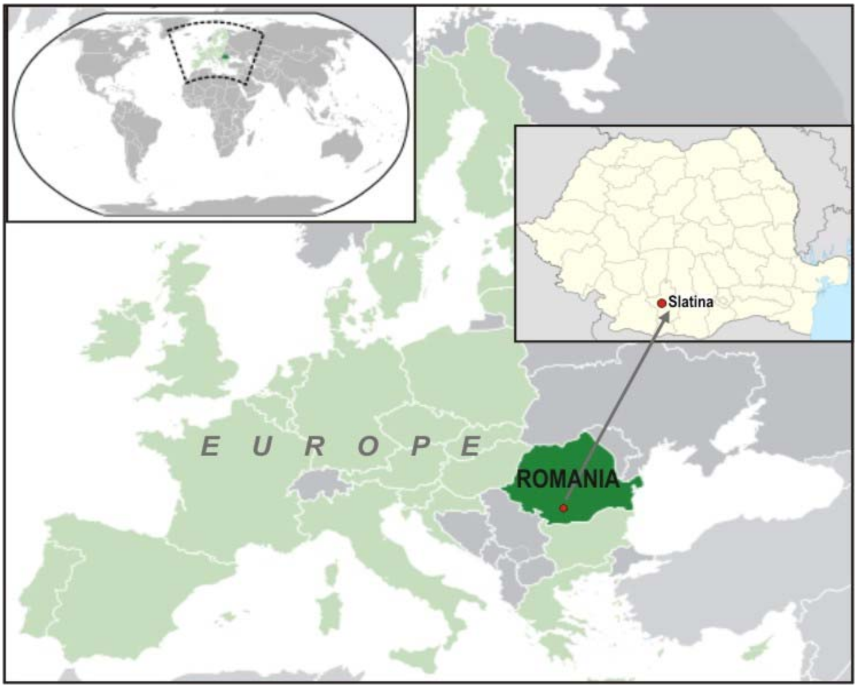


Fig. 1. The study area
Source: open source processing GIS, 2020

The industrial zone of the town is represented by the specific non-ferrous metallurgy: SC ALRO SA, SC ALTUR SA, SC ELECTROCARBON SA and SC TMZARTROM SA, these also being the major sources of pollution with nitrogen dioxide for the urban atmosphere.

Because of the non reducing annual concentrations of NO_2 by many member states of the European Union (EU) until 2010, the European Commission has extended the deadline for compliance with the ceiling of reducing NO_2 to January 1st 2015, this being the main reason for choosing the year 2015 in our analysis (Kurtenback et al., 2012; Guerreiro et al., 2014).

In order to highlight the conservative or vehicle role of the atmosphere for the nitrogen dioxide, for the area of Slatina town, in 2015, we used the daily, monthly and annual average data for the pollutant indicator – NO_2, from the automatic air quality monitoring OT-1 industrial type station, which is part of the Air Quality Monitoring Network in Romania consisting of more than 140 stations (APM Olt, 2016). These data are centralized by the Environmental Protection Agency of the Olt County (APM Olt). The pollution data were correlated with the synoptic maps from the German Weather Service in Offenbach, with the upper-air charts from the Bucharest – Afumaţi station and the climatological data from the National Meteorology Administration (ANM). The methods used for the data analysis were logical, spatial and comparative, operations in GIS, statistical analysis, bibliographic research and field observations. The ambient air quality data are interpreted in accordance with the STAS 12574/1987, MAPM Order 592/2002 and Law no. 104/2011 (APM Olt, 2016; ANMP, 2016). The NO_2 concentration in the ambient air is evaluated using the hourly limit value (VL) in order to protect the human health of 200 $\mu g/m^3$, the annual limit value for protection of the human health is 40 $\mu g/m^3$ and the alert threshold of 400 $\mu g/m^3$, calculated as an hourly average for three consecutive hours.

Results and discussion

The pollutants are maintained in the lower atmosphere and around the emission sources according to the state of the atmosphere.

The atmosphere absorbs the emissions from the chimney, being in the position of the receiver. This assumes the role of conservative emissions in the next meteorological conditions: atmospheric calm, thermic inversion and high air moisture. In the next meteorological conditions: convection heat, precipitation and wind, the atmosphere takes the role of vehicle pollutants, transforming the punctual pollution at source in a regional one (Bogdan and Câmpean, 2006).

For 2015, the annual concentration of NO_2 was 7.03 μg/m^3, representing 17.6% of the annual limit value of 40 μg/m^3. The annual concentrations of NO_2 in the period 2008-2015 is the lowest annual average. It can be noticed a decrease in the annual concentrations of NO_2 since 2012, the highest value being recorded in 2010, thus, confirming the need to extend the deadline for compliance with the ceiling for the reduction of NO_2 by the European Commission until January 1st 2015 (Fig. 2).

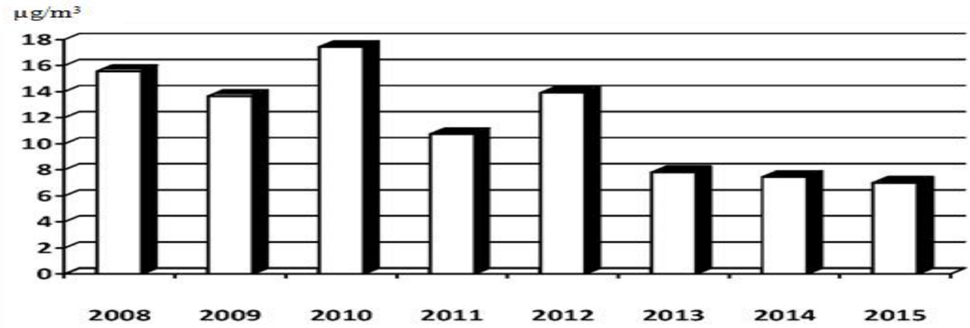


Fig. 2. The annual average values (μg/m^3) of the indicator NO_2 at Slatina, for the period 2008 – 2015

Source: processed data after APM Olt – OT-1 station, 2020

During 2015, the highest monthly average was recorded in December, of 7.90 μg/m^3, while the lowest monthly average was in April, of 6.49 μg/m^3, without being registered upper values than the hourly limits of 200 μg/m^3 for any month of the year (Table 1). The difference between the monthly maximum and monthly minimum being was 1.41 μg/m^3. It appears from Table 1, that the annual regime of the NO_2 pollutant has higher values in the cold semester of the year (October to March) due to the thermic inversions and the lower temperatures that have a frequency, duration and intensity higher than in the warm semester of the year (April – September), when the air temperature is higher, the humidity is lower and the thermic convection is more intense.

Table 1

The annual regime of the pollution indicator – NO_2 at Slatina, for the year 2015

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Monthly average (µg/m³)	6.86	6.81	6.80	**6.49**	6.77	6.75	7.10	7.00	7.08	7.04	7.63	**7.90**
Hourly limit value (µg/m³)	200	200	200	200	200	200	200	200	200	200	200	200
Monthly data capture (%)	100	100	87.0	86.2	96.7	94.5	97.3	96.2	93.3	100	99.5	99.1

Source: processed data after APM Olt –OT-1 station, 2020

In addition to the specific weather conditions of each season, we also add a primary cause in explaining the larger amounts of the monthly average concentrations of NO_2 in the months of the cold semester – a new source of pollution, represented by the chimney installations for heating the buildings (Ciulache and Ionac, 2007).

In the daily regime of the NO_2 concentrations, we will analyze the smallest and highest daily averages for the both cold and warm semester cold of 2015, in order to highlight the role the synoptic conditions have on the dispersion of this pollutant, determing the conservative or vehicle character of the atmosphere.

For the cold season of the year, the lowest daily average was registered on January 12th 2015 of 6µg/m³ (Fig. 3). During this month, for the nitrogen dioxide pollutant, there were not any excedances for the alert threshold and for the hourly limit values. This amount was recorded in the context of a very active Icelandic Depression coupled with located in an area with an extensive anticyclone over the Mediterranean Sea, on a predominantly western movement (Fig. 4a). In the first part of the day, the circulation intensifies to the west, the sky becomes mostly sunny. The thermic inversion is significant and the rapid decline in temperature with height allows the vertical mixture and the pollutant dispersion (Fig. 4b). In the night of January 12 and 13, there is a brief thermic inversion and during March 13, the conditions are similar to those in January 12. Although the vertical gradient decreases, the increasing of the vertical shear allows the vertical turbulent mixture. The relative humidity was 50 – 70% and the wind predominantly from the west removed the pollutant, so that the atmosphere acts as a vehicle for the NO_2 pollutant.

The highest daily average in the cold semester was 24 μg/m^3, registered on December 21st 2015 (Fig. 5). During this month, there were no exceedances of the alert threshold and of the hourly limit values for the NO_2 pollutant. The synoptic context was as it follows: an anticyclone expanded across the Mediterranean Sea, with the center (1030 – 1035 hPa) in the area of Romania (Fig. 6a). In the vertical section, there is a strong inversion, with -2°C to 2 m high and 8 – 10°C at 1500 m elevation (Fig. 6b). The wind was weak with a variable direction or with atmospheric calm, the air was misty and the relative humidity of 95 – 100%. All these weather conditions led the atmosphere to act as a conservator and determined the registration of the highest daily average of the NO_2 pollutant in the town of Slatina.

For the warm season of the year, the lowest daily average was registered on June 30th 2015, 5.8 μg/m^3 (Fig. 7). Within this month, there have not been exceedances of the alert threshold and of the hourly limit values. Romania was above a field of low ground pressure (Fig. 8a) with vertical thermic stratification, slightly unstable and without thermic inversion (Fig. 8b). The air temperature ranged between a minimum of 16 – 17°C and a maximum of 26 – 27°C, the wind had a burst speed of 5 m/s, and in the morning, the precipitation fell. All these conditions have favored the development of the vehicle role of atmosphere in the dispersion of the nitrogen dioxide.

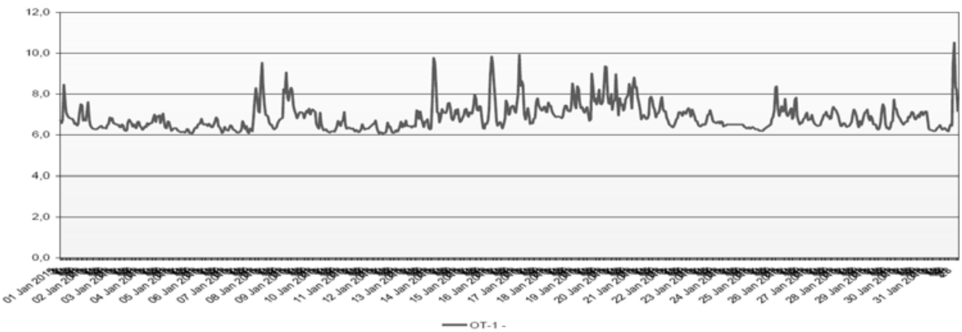
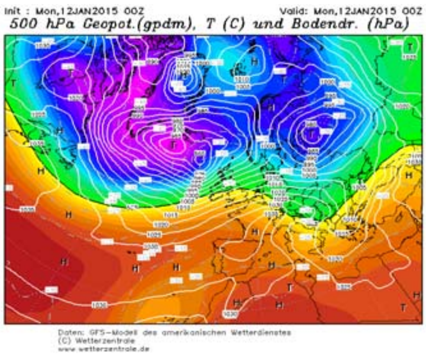
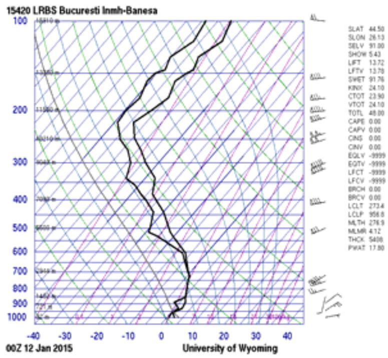


Fig. 3. The evolution of the daily average values (µg/m^3) of the NO_2 indicator, at Slatina, for January 2015

Source: after APM Olt – OT-1station, 2016



a)



b)

Fig. 4.

a) The synoptic map for Europe on 12.01.2015, at 00 UTC hour

Source: www.wetter3.de/archiv

b) The aerologic diagram from Bucharest station on 12.01.2015, at 00 UTC hour

Source: www.weather.uwyo.edu

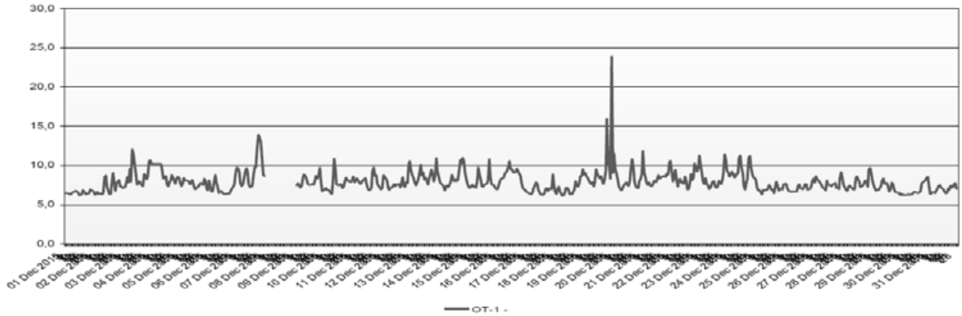
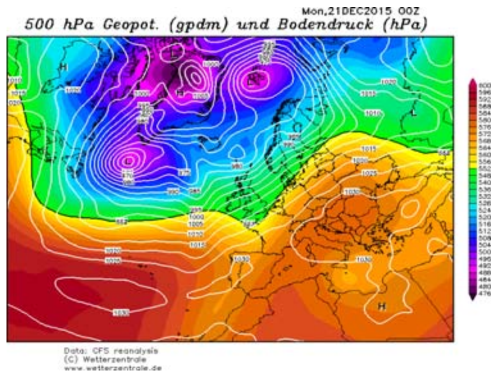
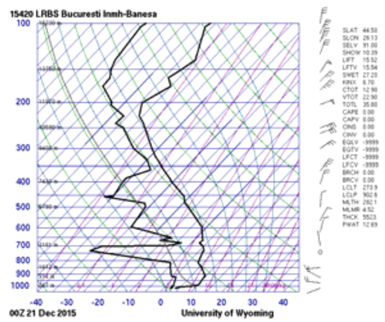


Fig. 5. The evolution of the daily average values (μg/m³) of the NO_2 indicator, at Slatina, for December 2015
Source: after APM Olt – OT-1 station, 2016



a)



b)

Fig. 6.
a) The synoptic map for Europe on 21.12.2015, at 00 UTC hour
Source: www.wetter3.de/archiv
b) The aerologic diagram from Bucharest station on 21.12.2015, at 00 UTC hour
Source: www.weather.uwyo.edu

The highest daily average in the warm season of 2015 was 13.6 μg/m³, on August 31st 2015 (Fig. 9). In August, there were no exceedances of the alert threshold and of the hourly average value for the pollutant – nitrogen dioxide, in the town of Slatina. In Romania, the synoptic situation at ground level was an anticyclone field and at altitude, at 500 hPa level, there was a hot dorsal (Fig. 10a). In the vertical plane, the atmosphere developed a thermic inversion, with the intensity of 5°C overnight and the minimum temperature of 17 –18°C (Fig. 10b). The wind was weak at a speed of 1 – 2 m/s, with variability in direction. As a result, the atmosphere has served a conservative role for the nitrogen dioxide emissions.

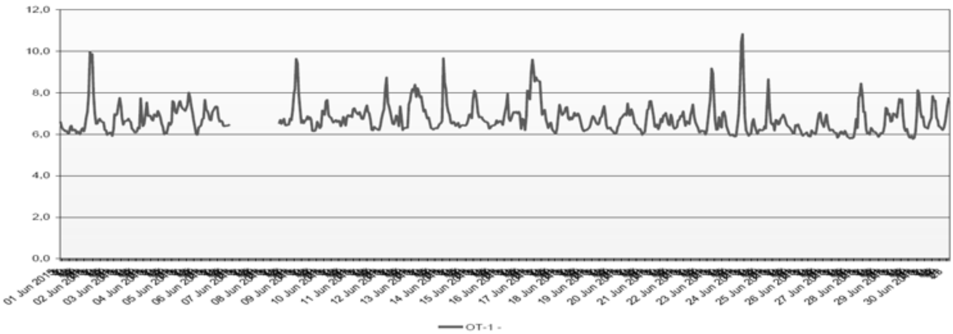
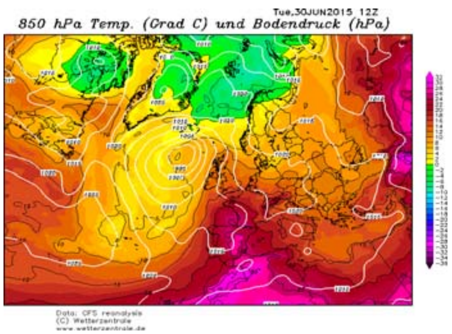
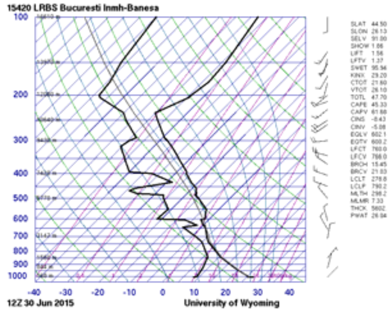


Fig. 7. The evolution of the daily average values (µg/m³) of the NO_2 indicator, at Slatina, for June 2015
Source: after APM Olt – OT-1 station, 2016





a) b)

Fig. 8.
a) The synoptic map for Europe on 30.06.2015, at 12 UTC hour
Source: www.wetter3.de/archiv
b) The aerologic diagram from Bucharest station on 30.06.2015, at 12 UTC hour
Source: www.weather.uwyo.edu

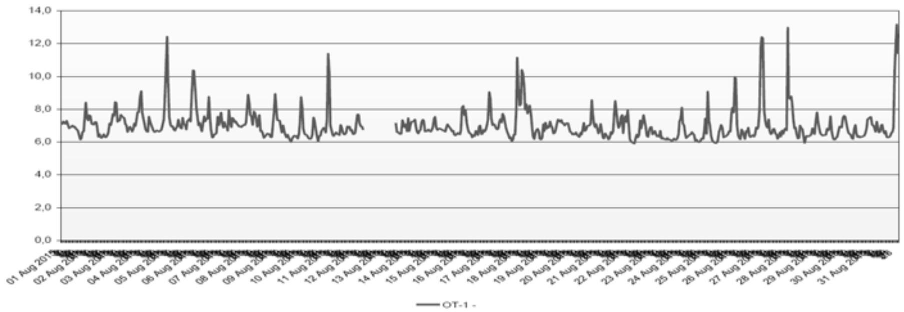
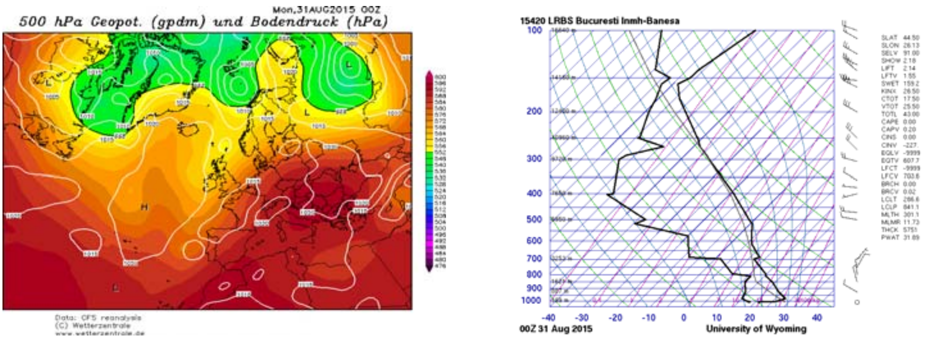


Fig. 9. The evolution of the daily average values (μg/m³) of the indicator NO_2 at Slatina, for August 2015

Source: after APM Olt – OT-1 station, 2016



a) b)

Fig. 10.

a) The synoptic map for Europe on 31.08.2015, at 00 UTC hour

Source: www.wetter3.de/archiv

b) The aerologic diagram from Bucharest station on 31.08.2015, at 00 UTC hour

Source: www.weather.uwyo.edu

Conclusions

No matter the receiver, conservative or vehicle role that the atmosphere has for the noxes resulting from the human activities, all these deteriorate in quality.

The role of the atmosphere have been highlighted by the developments of the daily average concentrations of the pollutant – the nitrogen dioxide, for the area of Slatina town in 2015. The nitrogen dioxide is a gas that is transported at long distances, having an important role in the atmospheric chemistry. The exposure to high concentrations of nitrogen dioxide causes airway inflammations, worses asthma and reduces the pulmonary functions. In all the analyzed situations, the alert threshold and the hourly limit value of the pollutant were not exceeded.

Knowing the relationship between the synoptic conditions and the air pollutant regime represent a tool to ensure the air quality management, which is part of the principles and rules of a sustainable development. From the analysis of the nitrogen dioxide pollutant distribution in time and space, for the town of Slatina, it was found a decrease of the daily monthly and yearly concentrations, following the EU directive to reduce the concentrations of the air pollutants.

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