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THE ROLE OF THE METEO-CLIMATIC FACTORS IN THE DISPERSION OF ATMOSPHERIC POLLUTANTS

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Résumé:

The atmospheric pollution and de-pollution phenomena are influenced by a series of factors, among which, the most important are: the characteristics of the emission, the meteorological factors, the geographical factors and the anthropic factors. The meteorological factors influence the transport, depositing, dispersion or stagnation of the pollutants. In time, under the influence of the physical and chemical factors specific to the atmosphere, or through reactions with other pollutants, a pollutant usually changes its chemical nature. Among the meteorological factors with influence on the pollution, in the present paper we will analyze the precipitation and the wind. The air currents, especially the horizontal ones, are considered among the most important dispersion factors. The aim of the present paper is that of proposing a simple and efficient way of interpreting the role of wind and atmospheric precipitations in the atmospheric pollution and de-pollution. All the examples (for the predominant wind direction, for atmospheric calmness, for different precipitation characteristics and for different characteristics of the emission sources) were given for the territory of Piatra Neamț municipality.

The municipality of Piatra Neamț is situated at the emergence of the Bistrița River from the mountain area, and it stretches out over 16 km from west to east and 8 km from north to south, with altitudes between 290 and 851 m. The western part is situated on the mountain corridor of the Bistrița and the eastern part, in the Cracău – Bistrița Depression. The main polluting sources are the chemical platform situated in the central-southern part of the proper urban area.

Our research took was done in the period 1983 – 2003, by means of 15 stations for collecting the pollutants, and a meteorological network with continuous recording of the main climatic parameters, as well as a meteorological station. These were placed in very representative places, especially in the inhabited area, between 290 and 523 m altitude. These 15 stations for continuous pollutant collecting changed the samples every 12 hours (at 07 and 19 hours). Here, 9 pollutants were analyzed in the expeditionary periods. The sampling was done in the expeditionary periods cumulating 76 days (that is 152 intervals of 12 hours

each), and they were done in the most diverse meteorological conditions, so that the final results could be representative for the medium annual situation. Furthermore, expeditionary measurements with instant sampling were done for a number of 13 atmospheric pollutants in 56 points, cumulating 11 sampling days.

The 152 intervals of 12 hours each, with continuous sampling of pollutants and meteorological measurements, were taken into study, distributed in the following expeditionary periods: 8 – 14 VIII and 7 – 13 XI 1983; 29 III – 5 IV, 18 – 26 VI , 30 X – 5 XI and 15 – 22 XII 1984; 18 – 25 III, 29 – 30 III, 8 – 11 V, 9 – 16 X 1985; 27 I – 6 II, 10 – 12 IV and 23 – 29 IX 1986. The influence of wind in the atmospheric pollution and de-pollution has been analyzed for the situations of atmospheric calmness, and for the NV and SE directions, situations that are mostly frequent in Piatra Neamț, cumulating 68.4% of the whole year. Analyses have been done for each 12 hour intervals, separately for the situations with calmness and wind from NV and SE directions, for each sampling station. We were interested in finding out in which of the 152 intervals of 12 hours the wind maintained the same direction during all the 12 hours of measurements. Their number was too small for us to be able to calculate a representative average value. That is why we started to analyze the 12 hour intervals in which the respective direction was present in at least 9 of the 123 observation hours, therefore, with a constant of minimum 75% on each interval. We could use in our calculations 61 of the 152 intervals, representing 40.1%. Using this method, we obtained, for the 39 intervals of 12 hours analysed for situations with calmness, the following: of the possible total of 468 hours of calmness, in reality, 419 hours were presented, therefore, of the total time that we called calmness, the calmness had a percentage of 89.5%. For the NV direction, the percentage was 88.2% and for the south-east direction 77.5%. These percentages give indications on the veridicity of the results as well. For example, for the maps representing air pollution under atmospheric calmness conditions, we should consider the fact that in 10.5% of the time, winds with different directions were nevertheless present, and this influenced the results we obtained. The results were also influenced by the lack of constancy of the pollutant emission volume at the sources. In the following table, the characteristics of the periods with atmospheric calmness and NV and SE winds are presented in comparison with the average multi-annual situation.

Table 1. The characteristics of the atmospheric calmness and of NV and SE directions during the expeditionary analysed periods, at Piatra Neamț weather station

Directia	Medie multianuala			Medie pericade expeditionare		
	Frecventa %	% din suma C+NV+SE	viteza m/s	% din suma C+NV+SE	viteza m/s	
C	26,3	38	-	64	-	
NV	29,5	43	5,1	20	4,6	
SE	12,2	19	2,3	16	4	

Direction/Multi-annual average/Average for the expeditionary periods
Frequency
% of the sum C+NV+SE
speed

Analysing the above table, we can notice that the atmospheric calmness presented the greatest constancy in time, followed by SE direction. The NV, even if it has high frequencies, it is not constant in time, and it is very often interrupted by hours in which the wind has other directions or atmospheric calmness occurs.

We will present the way in which the calmness and the NV and SE directions manifest on the whole territory of Piatra Neamț, by comparing the situation from the meteorological observation points to the weather station in Piatra Neamț. In Săvineşti, in the centre of the depression, the wind parameters are similar to those recorded at the weather station. At I.C.H.C. Piatra Neamț, at the entrance in the mountain corridor, a channelling of air current between Pietricica and Cornagura Mountains is characteristic, with an increase of the E and SE directions. These are aggravating factors for the pollution of the urban territory. Due to the orientation of the valley, the west direction increases, while the NV direction frequency increases. The percentage of the calmness is very low and, due to the situation of the meteorological observation point in a built-up area, the average velocities are lower. Along the water course, upstream, due to the individualization of the corridor conditions, at F.H.C.''Comuna din Paris'', the percentage of SE and NV directions is similar to that at the weather station, and the complementary directions, V and E, due to the valley orientation, present an increased frequency. The calmness is very reduced here as well, and, due to the open space, an increase of the mountain – valley winds is recorded along the water course. In the central part of the city, at ''Stejarul''Station, due to the shelter towards E-SE created by the Pietricica Mountain, the SE direction frequency is low, while the NV maintains high frequencies. The atmospheric calmness is low, and the situation of this station in a built up area, causes a low average velocity. At the contact between the corridor and the depression area, the station on the Pietricica Peak is representative for the high areas, being situated 225 m above the Bistrița river flood plain. Due to the height and open space, the frequency of the two analysed directions increases as compared to the weather station, the frequency of the calmness is extremely low, and the average velocity is double. On the lower course of the Cuiejd, between Pietricica and Cozla Mountains, a reverse channelling of the air currents is produced, mainly in the second half of the night and in the morning, when, from the current of the mountain descending wind, an ascending branch detaches, on the Cuejd valley, flowing in the depression, to the north of Pietricica Peak. On the middle course of the Cuejd, in the northern

extremity of the municipality, the NV direction is maintained with high percentages, the SE diminishes a little, the calmness has lower values and the average velocity is lower due to the mountain - valley winds with lower intensities. This analysis leads to the conclusion that, in general, for the whole territory of the municipality, and, in particular for the area with low altitude, intensely populated, in which our research took place, the data from Piatra Neamț weather station are representative, and they have been used in the interpretation of the distribution of the masses for the whole territory of the municipality, also considering the local situations already presented.

The frequency of the NV winds is higher during the night and morning. The increase of the frequency starts at 18 – 19 hours, reaching the maximum at 6 – 7 hours, after which, a decrease of the frequency occurs until 11 – 12 hours in winter and 9 – 10 hours in the rest of the seasons. According to the observations at 1 and 7 hours, the NV wind frequency is different depending on the season, with a minimum value in winter (10 – 25%), an increase in spring (25 – 55%), the maximum in summer (55 – 60%), and a decrease in autumn (25%). The predominant western general circulation, through the channelling along the Bistrita valley, is integrated in the descendant local circulation during the night and morning.

The wind from SE direction is represented by the ascending component of the local periodical circulation, as a valley wind. During the year, the frequency of the SE wind increases in the transition seasons, with maximum values in April and October.

Three pollutants were selected due to their higher number of drawings as well as their higher percentage in the air pollution on the territory of the municipality. They are: sulphur dioxide, nitrogen dioxide and mercaptan. These pollutants were chosen also in order to make a clear separation in: situations with NV, SV wind and calmness, the area polluted by the main emission sources: chemical platform and industrial platform situated in the urban area. On the basis of the analysis of there pollutants, conclusions on the other types of pollutants emitted by each of the two mentioned sources can be drawn as well the dispersion of the pollutants that are common to both of them. The general situation of the pollution with the most common pollutants in the urban spaces (chlorine, ammonia, nitrogen dioxide and sulphur dioxide), in situations of NV, SE winds as well as calmness, were analysed. On the maps, the average concentrations from the observation points for each category of pollutants were represented, for the three chosen situations: atmospheric calmness, NV wind and SE wind. The isolines mark the areas with equal concentration.

Nitrogen dioxide is a pollutant specific to the chemical platform in the SE extremity of the municipality. In the situations with calmness and NV wind, the intense pollution of the south-eastern extremity of the municipality is noticed, and

in the situations with SE winds, the area with high concentrations covers the area from the chemical platform to the Pietricica Peak. Due to the emission at high altitude of this pollutant, high concentrations are recorded in the case of SE winds and in the high areas.

The mercaptans represent a pollutant specific to the industrial platform situated in the central-southern part of the city. In situations of calmness and NV winds, the polluted area is concentrated around the source and the SE wind causes the transport of the pollutants over the intensely populated areas of the city.

The sulphur dioxide is a pollutant common to the two sources. By analyzing its distribution in different wind situations, problems such as the dividing of the responsibility in the polluting of different areas by pollutants which are emitted by both sources, could be solved. The calmness situations lead to the unification of the polluted areas. In situations with SE wind, the only intensely polluted area is the one between Pietricica and Cernegura Mountains. Besides the local pollutants, the pollutants from the chemical platform are added as well. In situations of NV wind, the polluted area for each source is clearly defined, with a prolongation to the south-east.

When cumulating the pollutants (chlorine, ammonia, nitrogen dioxide and sulphur dioxide), due to the intense emissions from the chemical platform, in situations of calmness, the area most intensely polluted in situated around this source. For situations with NV wind, twp areas of intense pollution are present around the main pollution sources of the municipality. In the case of SE direction, the intense polluted area surrounding the chemical platform extends towards the city. The series of 5 maps indicating the cumulating of the pollutants could represent the distribution in territory of the general pollution in the three situations, as most of the pollutants, besides those analysed in this paper, belong to the two sources as well.

The situations which facilitate the pollution in the inhabited areas are, in the present case, those with atmospheric calmness. The highest frequency is recorded in January, February, November and December – months with a frequency of the atmospheric calmness higher than 33%, in which the negative effect of the thermal inversions is felt as well. During the day, the situations with calmness correspond to the hours when the circulation mountain – valley is changed. In the situations with atmospheric calmness, there are conditions for strong pollution on the industrial platforms as well as in the neighbouring inhabited areas. The frequency of the SE direction is the highest in the months of February, April and November, and, in general, in the transition seasons, when it reaches average values of about 15%. During the day, the SE direction is predominant between 11–18 hours. In the situations with SE wind, a powerful pollution occurs in the sub-urban localities in the north-west of the chemical platform and on the Bistrița valley upstream the industrial platform in the city. Over here the

concentrations are high due to the cumulated influence of the two main sources. In the situations with SE wind and prolonged atmospheric calmness, a careful control on the emissions from the sources should be made.

Besides the wind, the thermal characteristics and the atmospheric precipitations have an important role in the de-pollution the atmosphere. The role of precipitations is unanimously recognized, but it is treated, in the field literature, mainly under the form of the chemical reactions that occur in the atmosphere when the pollutants get into contact with water. According to Willet, the rain washes up the gases and the snowfall washes up the solid particles and, according to Haagen – Smit, the atmospheric precipitations wash up only the particles with a diameter higher than 2 microns (cited by M.Barnea and P.Ursu, 1974).

The precipitations produce the washing up, the absorption and the transport of the gases to the soil. The contact with water causes the washing up of the acid gases, sulphur dioxide and nitrogen dioxide, their fixation under the form of sulphates and nitrates respectively, through addition reactions or hydrolysis:

$SO_2 + H_2O = H_2SO_3$ (sulphurous acid, that can transform into sulphuric acid by means of oxidation)

Nitrogen dioxide dissolves:

$2NO_2 + H2O = HNO_3 + HNO_2$, and when NO_2 is in excess:

$HNO_2 + NO_2 = HNO_3 + NO$

Ammonia, through hydrolysis:

$NH_3 + H_2O = NH_4^+ + OH^-$

These reactions lead to the self-cleaning of the atmosphere but, through the acid rains they have a negative impact on the soil, surface and phreatic waters as well as on vegetation.

On the quantitative results of the washing up, it is mentioned only the fact that only heavy rains with long duration are efficient. In the present paper we try to give the conclusions of our experiments that we have done on the territory of Piatra Neamț municipality.

In order to analyse the atmosphere de-pollution process, out of the 12 pollutants we have considered 4 general pollutants, most frequently present on the atmosphere of the cities: sulphur dioxide, ammonia, chlorine, nitrogen dioxide. These pollutants have been analysed for 3 sampling points, with a longer sincrone sampling period. The average concentrations for each point, for the 4 pollutants, were cumulated, in order to offer a higher stability of the results. The different chemical reactivity to water was taken into consideration as well as the possible fluctuations in the emission of each pollutant. In order to point out the role of the

different climatic parameters on the atmospheric pollution and de-pollution, the sampling were taken continuously, and the toxicological samples were changed every 12 hours (at 7 and 19 hours). In the present paper, 141 such intervals of 12 hours were considered. They are distributed in expeditionary periods that were done in the most varied meteorological conditions, so that the average of these sampling should be close to the average annual situation. Among these, in 46 periods with precipitations over 0.1 mm occured, that is 32% of the analysed time. The annual average percentage of the precipitations over 0.1 mm at Piatra Neamț weather station is 39%. The ratio between the total quantity of precipitations fallen in the 70 ½ analysed days is 4.1% higher than the same ratio between the average number of days with precipitations over 0.1 mm and the multi-annual amount of precipitations at Piatra Neamț weather station.

In the low area, intensely populated, in which our research was carried out, the difference between the annual average quantities of rainfall recorded in the depression area and those in the mountain corridor, are minimum. Therefore, the influence of precipitations in the de-pollution process can be treated unitarily. At Piatra Neamț weather station, situated in the depression area, the average annual quantity of precipitation for the period June 1983 – October 1986 had the value of 560.5 mm, and at "Stejarul" station, in the depression corridor, this amount reached 562.2 mm, the seasonal distribution being very similar.

The distribution of the average cumulated concentrations for ammonia, sulphur dioxide, chlorine and nitrogen dioxide was analysed, in 12 hour intervals in which precipitations were not recorded and in the intervals when precipitations over 0.1 mm were recorder, either as a total for the period as well as selectively, for the situations with 100% atmospheric calmness, in the 12 hours of sampling.

The average value of the concentrations in the territory, for the 4 pollutants, was graphically represented according to the values at the observation points, for the 95 intervals without precipitations. The area with high concentrations is situated in the vicinity of the main polluting source, in the south-east of the territory, and the areas with moderate concentrations occupy the whole depression area, between main source and the secondary source.

The average for the 46 intervals with precipitations over 0.1 mm, as compared to the situation in the intervals without precipitations, for the 13 sampling points, recorded a decrease with 33% of the pollutants quantity. The isolines representing the pollution degree have, in general, similar shapes but low values. The area with moderate concentrations around the secondary source, present in the urban territory, is isolated, pointing out the reduced possibilities of pollutants circulation during precipitations.

The situation is changed by the wind action, which is different in the intervals with precipitations as compared to the intervals without precipitations, as shown in the table below.

Table. 2. Average frequency and velocity of wind on directions, in the intervals with pollutants samplings

Directia	N	NE	E	SE	S	SV	V	NV	Calm	Viteza medie anuala
	Intervale fara precipitatii									
Viteza medie	3,60	1,1	2,2	3,4	3,4	3,2	4,1	4,2	0	1,8
Frecventa %	5,4	1,3	0,4	17	1,6	1,5	6	14,8	51,8	0
	Intervale cu precipitatii >= 0,1 mm									
Viteza medie	4	2,3	3,7	3,1	4	0	3,6	4,1	0	2,5
Frecventa %	10,2	1,8	1,8	20	1	0	5,1	27,7	32,7	0

Under such conditions, the comparison of the results will not lead to a clear emphasis on the role of the atmospheric precipitations in the de-pollution of atmosphere.

Eliminating the wind factor, the role of precipitations will be pointed out as a purifying agent of the atmosphere. Therefore, the situations in the intervals with 100% atmospheric calmness according to the hourly measurements will be revealed separately for the intervals without precipitations and the intervals with precipitations over 0.1 mm.

The situation in the intervals with atmospheric calmness, without precipitations, as compared with the intervals without precipitations but with considering the wind, presents a large concentration of the polluted areas around the sources.

For the intervals with atmospheric calmness and precipitations, the average concentration for the 13 sampling points was 42% lower than the intervals with atmospheric calmness without precipitations. In the intervals with precipitations under wind conditions as compared to the situation with calmness without precipitations, a strong blockage of the pollutants around the sources and a very efficient washing up in territory is noticed.

The efficiency of the washing up of the atmospheric pollutants in situations of atmospheric calmness was calculated by making the difference between the average of the 4 pollutants in the intervals without precipitations, and the intervals with precipitations. This difference was reported to the average of the intervals without precipitations, expressed in percentage and realized for each sampling point. Low values were noticed in the emission areas, especially in the urban area, with high density of the buildings. At great distance from the sources, more than 60% of the quantity of pollutants in the air is washed away.

The decrease of average concentration for each sampling point was calculated according to the main source in intervals without precipitations, as compared to intervals with precipitations, on a SE-NV profile. Due to the emission in altitude of the pollutants around the main source, in the periods without precipitations a rapid diminution is registered next to the source, followed by an increase at about 4 km distance, in the area of contact between the pollutants and

the soil. The pollutants are moved to the ground by the air currents and by a secondary emission by the source in the city. Comparatively, in the intervals with precipitations, in the depression, on plane, open field, due to the conjugated action of wind and precipitations, a lack of the maximum in the area where they usually touch the soil is noticed, the pollutants emitted at height by the main source and the diminution of the concentrations in the polluted area by the secondary source in the urban space. At the main source the values are low due to the washing up by the precipitations and to the high wind velocities during the producing of precipitations.

The same problems were analysed in situations with 100% atmospheric calmness and the conclusion was that high values of the two maximums are recorded in the intervals without precipitations and the descending zone of the pollutants around the main source is more close to the source. In the intervals with precipitations, the presence on the maximum in the descending area, at closer distance than in the periods when the wind was considered as well, is registered.

A comparative analysis of the washing degree of the atmosphere was done on a profile from the source to the periphery on SE – NV direction, by the cumulated means from the 4 analysed pollutants, for each of the 13 sampling points in 12 hours intervals with precipitations over 3 mm, for the first 12 hours after 3 consecutive intervals of 12 hours with precipitations. The intervals with precipitations over 3 mm being less, and usually non-consecutive, during them consecutive washing of the atmosphere did not occur. In the urban area, with a higher fragmentation degree of landforms with buildings, with more reduced pollution potential but with more numerous sources, the washing up is done slower in the intervals with precipitations over 3 mm, only in the next 12 hours after the intervals with precipitations over 3 mm, the average concentrations presenting a greater decrease. Coming back to high concentrations in the area around the main source is done fast, the next interval with 12 hours after precipitations of over 3 mm coming with a high pollution degree. The precipitations in more reduced quantities, but with a longer duration, appear as the most efficient, in the open spaces around the main source, their role in the de-pollution of atmosphere appearing most obviously.

The action of the precipitations with certain characteristics was analysed for the main 3 emission sources and separately for the other 10 sampling points situated in the territory, for the same 4 considered pollutants. The situation generalizes the results, the role of wind being taken into consideration as well. In the intervals with different characteristics of precipitations in which the concentrations are high in the intervals without precipitations, the strong washing up at the sources is noticed, and in the intervals with precipitations, the self-cleaning being intensified also by a strong dispersion that is produced by the high wind velocities and by the atmospheric reduced calmness. .

The results we have obtained have a practical character, and they can be used in the spatial and quantitative interpretation of the pollution phenomenon, in order to control the emissions at the units with high pollution potential, according to the effect in the territory, under the influence of the atmospheric precipitations with different characteristics.

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