THE FAVORABILITY FOR AEROIONOTHERAPY ON TWO TOURISTIC RESORTS FROM THE EASTERN FLANK OF ROMANIAN CARPATHIAN MOUNTAINS

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ABSTRACT

Knowing the spatiality and temporality of the air ionization levels in different Romanian tourist resorts is necessary for the real appreciation of their climatotherapeutic potential.This study captures sequences of the air ionization process in two tourist resorts in the Subcarpathians of Moloava, in correlation with the values of meteorological elements (temperature, humidity, cloudiness and wind). Measurements were carried out during three consecutive days for each resort in January, April, July and October 2022, in the time interval 7.00h - 21.00h. The concentration of negative and positive air ions was recorded hourly, at a characteristic point for each resort. The annual air ionization regime showed a maximum in July, a minimum in January and higher values in October than in April. The average air ionization values ranged from 787 air ions cm^{-3} at Bălțătești to 821 air ions cm^{-3} at Târgu Neamț, and the unipolarity coefficient (k), from a minimum of 0.78 at Tg. Neamț to 0.90 at Bălțătești. Air ionization variability was positively correlated with air temperature, relative humidity and wind speed. The average values of air ionization in April - July, when k ranged between 0.6 and 1.2, demonstrate that the atmosphere of Bălțătești and Târgu Neamț resorts can be therapeutically exploited by aeroionotherapy, in the summer season.

Key-words: *air ionization, aeroionotherapy, unipolarity coefficient, balneoclimatic tourism*

1. INTRODUCTION

Air ionization is a dynamic, continuous and variable process naturally generated by cosmic radiation, atmospheric electrical discharges, meteorological processes (Tang et al., 2011), water falls, spontaneous vegetation, etc. and strongly influenced by human activities (Mihăilă, 2014). The air we breathe contains atmospheric ions, which can influence both our mood and health (Enache, 2017). In 1751, Franklin made the first observations of atmospheric electricity, while Lemonier (1752) demonstrated that an electric charge could appear in the atmosphere, even under clear skies. Lemonier was also the first to discuss the possible effects of atmospheric electricity on humans and plants (cf. Licht, 1964).

The positive role of air ionization on humans has been researched since 1910 by Steffens (cf. Licht, 1964). In the 1930s, Ladenburg and Pantheinier continued these studies, which were deepened by Bricard in the 1950s. Subsequent studies (Winsor and Beckett, 1958; Krueger and Reed, 1976) confirmed the benefits of negative air ions in reducing the spread of viruses and bacteria, as well as in the complementary treatment of some medical conditions.

Subsequent research (Minth, 1963; Tromp, 1974; Kruger, 1976 și 1985; Gates, 1980; Breton, 1994; Daniels, 2002; Hairong, 2005; Ji, 2007; Li, 2011; Mao, 2014; Hui, 2020; Mihăilă, 2023) has validated the connection between the phenomenon of air ionization and its multiple biological effects on organisms.

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Lately, research has begun to explore air ionization in connection with tourist activity (Jianwu şi Jiayuan, 2002; Wang, 2003; Yao, 2005; Wu, 2006; Song, 2008; Tan, 2010; Deng, 2019), with a particular focus on air ionization in spa resorts, which have become focal points for aerometric analysis and bioclimatic assessments. These researches have highlighted the connection between the presence of air ions and the level of pollution, as well as the negative impact of the lack of negative air ions on health (Enache, 2017; Deng, 2019). Today, air ions are recognized as essential components of good air quality, and are a significant therapeutic natural resource with importance in health tourism and ecological assessments (Ling, 2019). However, research on the regime and spatiality of air ions is punctual, brief, both at the international level and in Romania.

Air ionization research in different cities or places of attraction for tourists started in our country relatively late (Deleanu and Elges, 1967) and then continued sporadically (Deleanu and Mozes-Lörincz, 1975; Teodoreanu et al., 1984) until the revolution in December 1989, which allowed Romanian research in the field to open up to new perspectives. After 1990 studies on air ionization in different tourist resorts or cities were few and were carried out by Enache 1990, 1999, 2005, 2017, Prisacariu et al., 2023; Mihăilă et al., 2023. For the territory of Romania, many aeroionometric studies are needed to be able to cover the existing gaps in the current research in this field. However, there are limitations in research related to the equipment, the available human resources and the fact that this kind of research is time-consuming, budget-consuming and often does not provide the expected spectacular results.

Starting from the foundation of previous research on atmospheric air ionization, this study brings the first results in the history of observations regarding the temporal coordinates of air ionization in the resorts of Bălțătești and Târgu Neamț. It is a study that, for the first time, places the air ionization from the two stations on the air ionization map in Romania which is still under construction. The main aim of the study is to identify the most favorable conditions during a day and a year for the practice of aeroionotherapy in the two resorts.

The research objectives of this study are 3: *i)* to evaluate the meteorological conditions on the days when aeroionometric measurements were carried out, in order to determine the role played by meteorological elements on air ionization, *ii)* to determine the minimum, average, maximum levels of negative and positive air ions in the most representative months of the year (January, April, July and October), and the average levels of k, in order to determine if, and when, during one year, aeroionotherapy can be practiced in the researched resorts and *iii)* to highlight the diurnal regime (hourly interval 07:00h– 9:00h) of air ionization and k, in order to identify the hourly intervals with the most favorable conditions to benefit from the aeroionotherapy properties of the atmosphere, by tourists who come for relaxation, cure and treatment in Bălțătești and Târgu Neamț resorts.

2. MATERIALS AND METHODS

2.1. Study area

Bălțătești and Târgu Neamț are two balneoclimatic resorts located in the northeast of Romania, in the subcarpathian region. The specific landscape is wooded hills and mountains. The resorts are located in the Neamț Depression and belong to the Bison Land, a tourist region known for its natural and cultural heritage: parks and nature reserves, salt springs, monasteries, memorial houses, museums (**Fig. 1**).

Bălțătești resort is located at an altitude of 457 m on the contact between the Stânișoara Mountains (700 - 800 m), well wooded, to the west and the Moldavian Subcarpathians (400-500 m), covered with deciduous forests and orchards, to the east. The resort has mineral waters (chlorinated, sulfated, iodized, brominated with a high concentration of salts) with curative and therapeutic qualities in the treatment of locomotor disorders, neurological disorders, related disorders, gynecological diseases. The average annual temperature is 8.2°C, the atmospheric circulation is moderate and marked by the presence of foehn processes, the bioclimate is optimal, and the medicinal salt of Bălțătești is appreciated in the treatment of many rheumatic and gynecological diseases.

The resort has a treatment base, the balneophysiotherapy and medical recovery sanatorium "Dr. Dimitrie Cantemir" which is equipped with modern installations for electrotherapy, showers, massages, aerosols, gynecological treatment, medical physical culture and recuperation, hydrokinetotherapy pool. The resort has an accommodation capacity of 354 beds and was visited by 5.630 tourists in 2022 (http://statistici.insse.ro/, accessed 2023).

The Târgu Neamț resort is located in the northern part of the Neamţ Depression, in the Ozana valley, at an altitude of 365 m. The resort town is guarded by hilly heights with altitudes of 400 - 500 m. In Culmea Pleșului the altitude reaches 623 m. The hilly peaks are covered with deciduous and coniferous forests. Târgu Neamț is a destination with important tourist attractions: Neamț Citadel, Ion Creangă Memorial House, Agapia, Filioara and Neamț monasteries. The tourist resort has 36 accommodation structures, which provide an accommodation capacity of 700 beds. In 2022, 21.446 arrivals and 21.521 overnight stays were recorded in the resort town of Târgu Neamț.

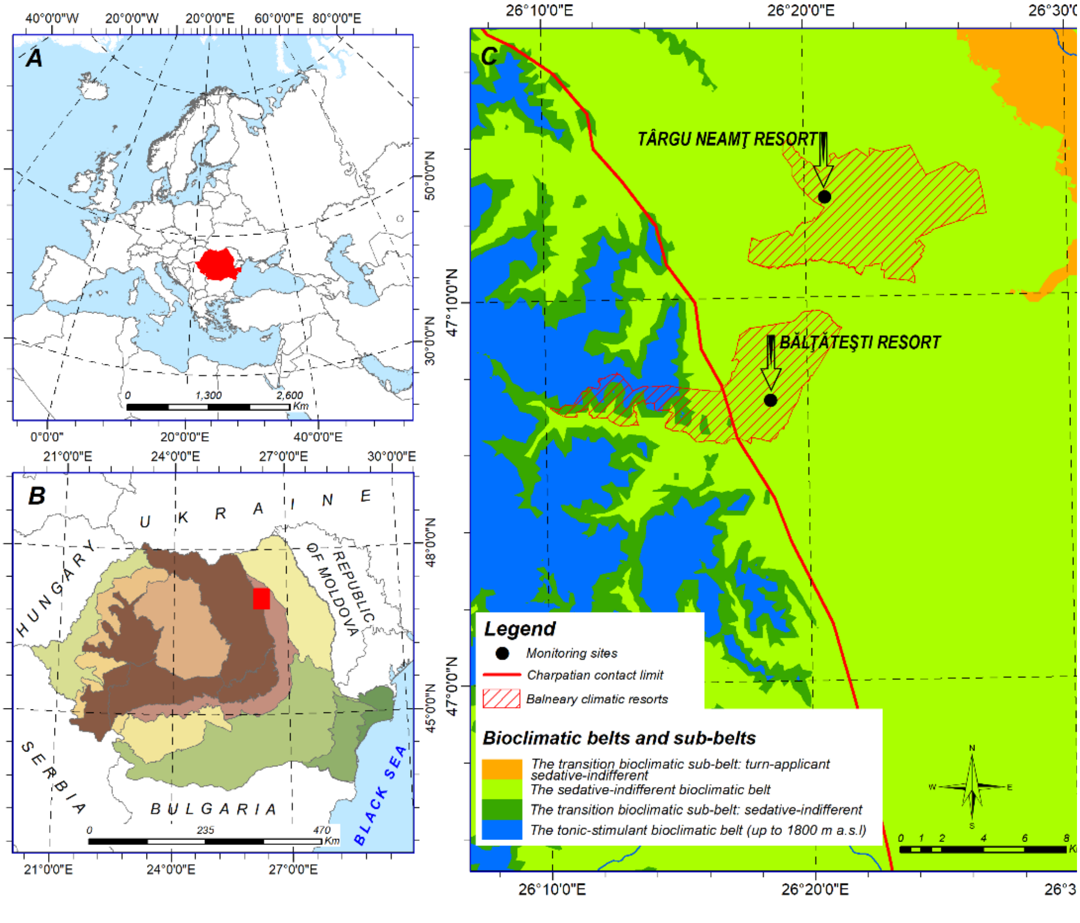


Fig. 1. Geographical localization of the places where aeroionometric measurements were made, in the tourist resorts of Bălțatești and Târgu Neamț

The locations where we carried out aeroionometric measurements in the two resorts were chosen according to the principle of their representativeness, from the point of view of our monitoring: absolute altitude (421 m in Bălțătești, respectively 376 m in Târgu Neamț), absence of water courses, and tourist and recreational relevance (both points were located in parks near tourist attractions: the Sanatorium "D. Cantemir" in Bălțătești and the Neamț Fortress in Târgu Neamț), thus ensuring a comprehensive and representative approach for these measurements.

2.2. Methods and means

Aeroionometric measurements were carried out with the PC Connectable Highly Accurate Air Ion Counter Tester COM-3200 PRO II, which is equipped to record air temperature (with an accuracy of +/-1 %,) and relative humidity, with an accuracy of +/- 5 %, in addition to air ion levels. The data obtained were then downloaded, processed and analyzed using Microsoft Excel software. The device used has a certificate attesting to the metrological verification by its manufacturer.

Measuring and analyzing air ionization is difficult because the atmosphere is not an electrically uniform environment, but is constantly changing. Moreover, air ionization is susceptible to rapid value changes, due to variations in local weather conditions as a consequence of atmospheric circulation (Enache, 2017).

For precision measurements of air temperature and relative humidity at the 1.5 m level, we used the CEM DT-171 data logger sensor and the Windmaster 2 anemometer for wind speed determination. The cloudiness was visually assessed and expressed in oktas.

The analysis of Pearson correlation coefficient values between data series of aeroion levels (negative / positive) and determined meteorological elements, highlighted the role of some of them in the air ionization process.

In order to further investigate the interaction between meteorological elements and air ionization levels, we used the principal component analysis (PCA).

2.3. Data obtained

At each observation site in the two resorts, we obtained 45 hourly values of air ionization for January, April, July and October. Average values were calculated and minimum/maximum values of air ionization (negative n- and positive n+ ions) were extracted, as well as air temperature, relative humidity, cloudiness and average wind speed.

2.4 Research methodology

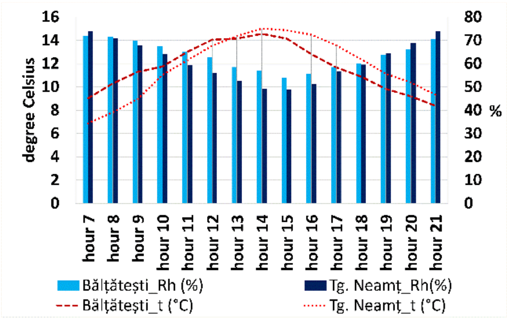
In order to determine the aeroelectric properties of Bălțătești and Târgu Neamț, we carried out measurements in each season, taking January, April, July and October as reference months. Observations were carried out for three days in each resort, hourly from 7:00h to 21:00h. Hourly determinations were carried out as follows: up to the 15th minute of each hour, we measured n-, and up to the 30th minute of each hour, we measured n+. Practically, on each time interval, in each resort, for each category of ions (n- / n+), 225 minutes of determinations were carried out, and cumulatively (in the 12 days of the 4 months considered), for each resort and category of air ions, each 2700 minutes of determinations. Due to the existence of only one air ion monitor, the measurements at the two resorts were asynchronous. By choosing in the determinations only days with stable weather, anticyclonic, without precipitation, with moderate cloudiness and with reduced atmospheric dynamics, we obtained, even in the conditions of asynchronous determinations, levels of ionization that can be analyzed comparatively for the two resorts.

3. RESULTS

3.1. Meteorological and micrometeorological conditions under which observations were made. Influence of weather on air ionization

3.1.1. Correlation between air ion levels and meteorological elements for the entire observation period based on their correlation analysis

During 2022, while the observations were being carried out, the weather was changeable in the two resorts.



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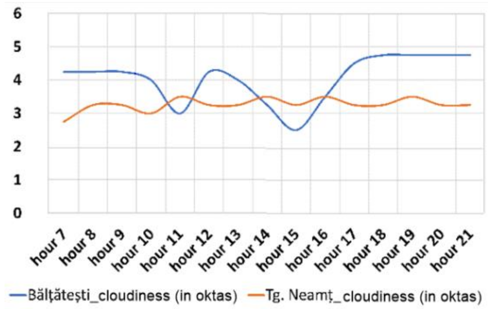

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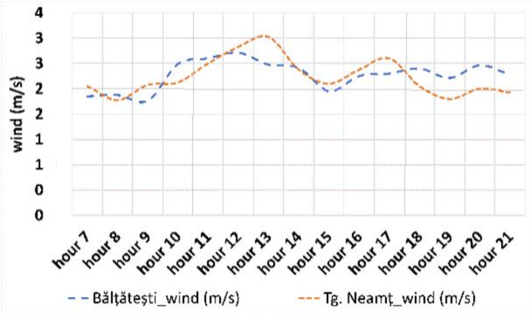

c

Fig. 2. Diurnal regime of air temperature and relative humidity - a, cloudiness - b and wind speed - c at Tg. Neamț and Bălțătești during the observation days in January, April, July and October 2022.

The air temperature showed a high variability during the whole period analyzed (between -1.0°C and 22.8°C). Although the variability of this element was high, the average temperature differences between the two resorts were small (the average temperature value was 11.4°C in Târgu Neamț and 11.6°C in Bălțătești). Relative humidity was higher in both resorts in January and October (over 70%), and significantly lower in July (50%). It is worth mentioning that the average relative humidity value during the whole period was higher in Bălțătești (63.4%) than in Târgu Neamț (54.1%). The average hourly cloudiness fluctuated during the 12 days of observations made between 2.5 and 4.2 oktas in Bălțătești and between 2.5 and 3.5 oktas in Târgu Neamț. The wind had close average values between the two resorts, its speed varying between 2.5 and 3.5 m s^{-1} (**Fig. 2**). These meteorological differentiations are due to the geographical setting at the microscale, which is different for the two monitoring points, and which had the ability to introduce these differentiations. They can be produced in the case of visual observations for cloudiness by a certain degree of subjectivity induced by the observer's attention, by his experience, or in the case of observations with sensors or other devices, by the asynchrony of the observations.

The geographical location of the two resorts in the same Subcarpathian depression, influenced both the local topoclimate and the level of air ionization. The analysis of Pearson correlation coefficient values, between the data series of (negative/positive) air ion levels and air temperature, revealed the importance of temperature in the air ionization process. Thus, in the two resorts, negative air ionization levels showed significant positive correlations with air temperature, the Pearson correlation coefficients between negative air ionization and air temperature being 0.55. Positive air ionization levels also correlated positively with air temperature, the Pearson correlation coefficients between positive air ionization levels and air temperature being 0.5.

3.1.2. Correlation between air ion levels and meteorological elements for the whole observation period, based on Principal Component Analysis (PCA)

In Bălțătești resort, the analysis of the main meteorological elements reveals that they contribute 66.3% to the total variation of air ionization (**Fig. 3a**).

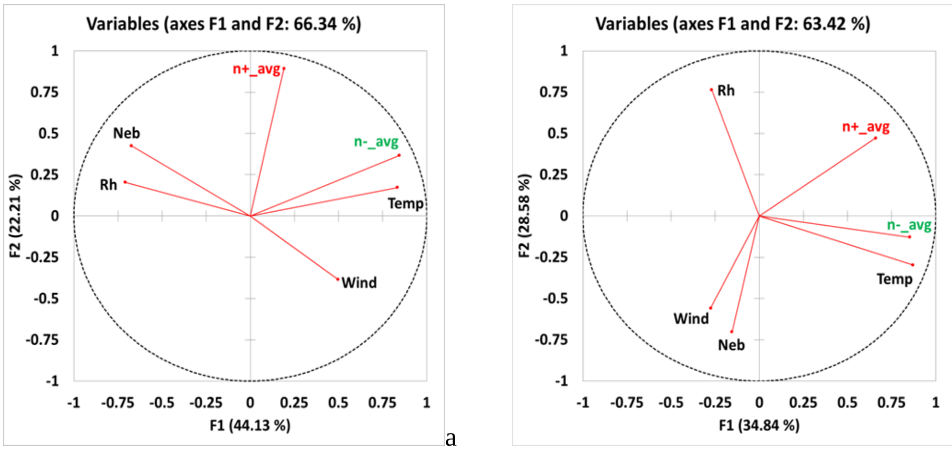

Fig. 3. Principal Components Analysis (PCA) between the levels of air ionization and meteorological elements in the tourist resorts of Bălțătești (a) and Târgu Neamț (b)

A positive association is observed between air ionization and air temperature, but also between air ionization and wind speed. Air temperature is more strongly correlated with negative air ionization, while the relationship with positive air ionization is less pronounced. A fluctuating but positive correlation in strength between air ionization and wind, is evident. Cloudiness and humidity show correlations of varying strength, but of negative sign with negative and positive air ionization.

In Târgu Neamț the influence of meteorological elements on air ionization is 63.4% (**Fig. 3b**). Also, in this resort temperature has a direct, stronger correlation with negative air ionization (weaker with positive air ionization), and wind and cloudiness were inversely correlated in value with negative and positive air ion levels. Between humidity and the air ionization process, as in Bălțătești, we note negative correlations for both air ion categories.

3.2. Air ion concentration in the air of the investigated resorts

3.2.1. Annual average values of negative and positive air ion levels, total air ionization and unipolarity coefficient

The data obtained from the two resorts show similarities in air ionization values, indicating a relatively similar natural environment. However, the slight differences observed between these two sites can be attributed to specific local factors, such as altitude and relative location to the forest (at Târgu Neamț, approx. 100 m), which, although subtle, may influence differently the air ionization processes and thus, the measurement results. The average values of total air ionization (n-+n+), during the 4 months of measurements, were 821.3 air ions cm^{-3} at Târgu Neamț and 786.6 air ions cm^{-3} at Bălțătești (**Fig. 4**). Total air ionization (n- + n+) was higher in Târgu Neamț than in Bălțătești, on average by 34.7 air ions cm^{-3}.

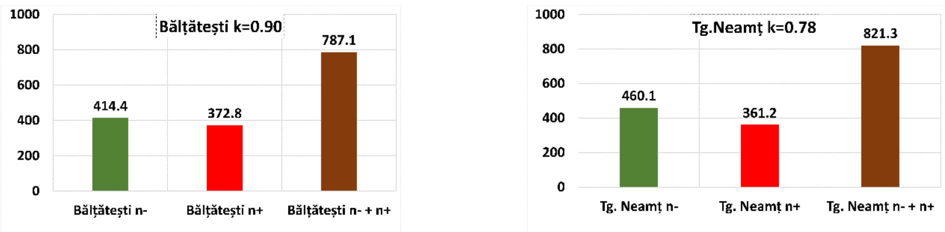

Fig. 4. Negative, positive and total air inization levels for the whole observation period from 2022 at Bălțătești and Târgu Neamț.

Negative (n-) air ionization was higher at Târgu Neamț than at Bălțătești (by 46.3 air ions cm^{-3}), and positive (n+) air ionization was higher at Bălțătești than at Târgu Neamț (by 11.6 air ions cm^{-3}).

These data indicate that the atmosphere in Târgu Neamț resort had a higher average negative air ionization, while Bălțătești resort had a higher average positive air ionization. However, the total air ionization is higher in Târgu Neamț.

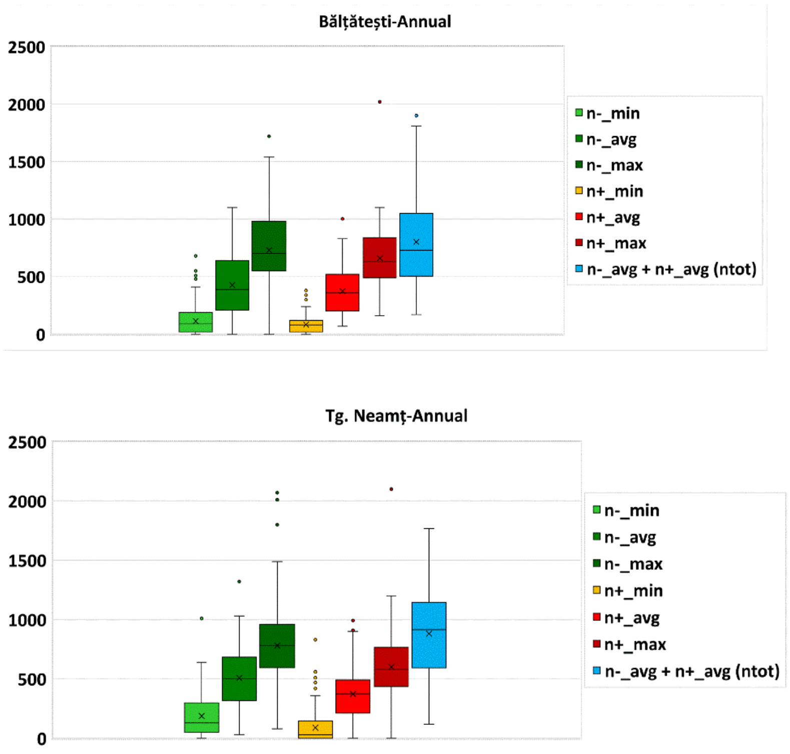

Fig. 5. Analysis of the variability of the number of negative, positive and their total number in Bălțătești and Târgu Neamț resorts during 2022

From the boxplots represented in **Figure 5**, it can be observed the whole range of air ionization values in the investigated resorts and also that the distributions of air ionization levels in Bălțătești and Târgu Neamț are almost identical. This approximate similarity of the air ionization levels is explained by the fact that the genetic and geographic determinants of air ionization are similar in the two resorts. The consequence in terms of air ionization is that local factors have a relatively similar impact on air ionization in the two studied resorts. Some differences related to the positions of 0 percentiles, lower quartiles, median quartiles, upper quartiles, 100 percentiles, outliers of positive and negative air ionization levels in the two resorts exist. The similarities, however, prevail and the differences are of nuance, rather than consistency and relevance.

3.2.2. The air ion levels in the median months of the four seasons indicate a minimum of 532 air ions cm^{-3} at Bălțătești and 418.8 air ions cm^{-3} at Târgu Neamț in January, and a maximum of 1205.8 air ions cm^{-3} at Bălțătești and 1121.2 air ions cm^{-3} at Târgu Neamț in July. Air ionization was higher in October (757.5 air ions cm^{-3} at Bălțătești, and 1054.8 air ions cm^{-3} at Târgu Neamț), than in April at both resorts (651.1 air ions cm^{-3} at Bălțătești and 690.3 air ions cm^{-3} at Târgu Neamț) (**Fig. 6**). In October, in the Subcarpathians of Moldova, there are still many warm summer days, with more active air ionization processes in the atmosphere than in April.

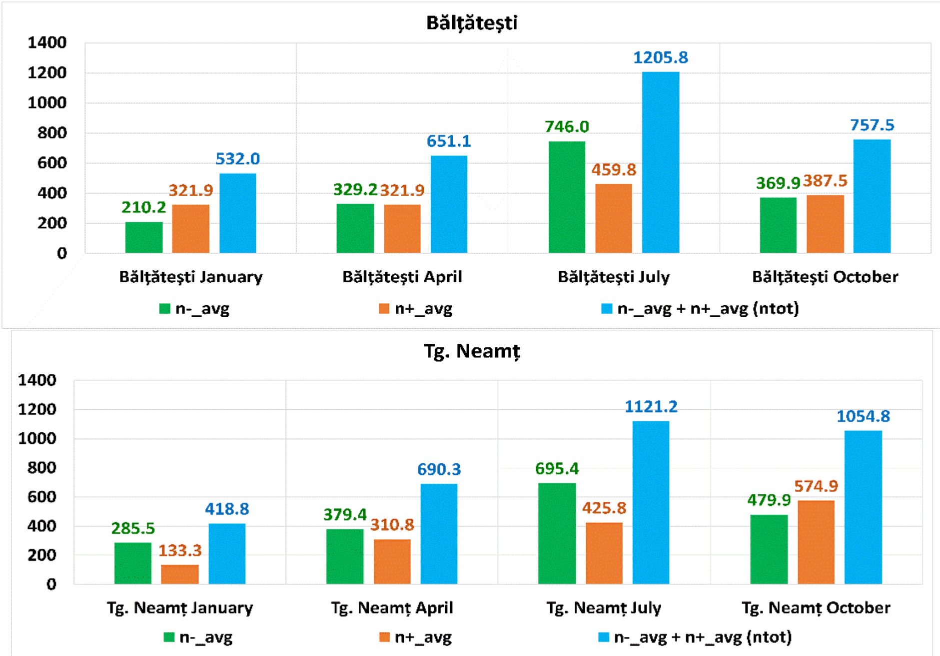

Fig. 6. Air ion levels (cm^{-3}) in the median months of the 4 seasons at Bălțătești and Târgu Neamț

The monthly values of the unipolarity coefficient k, ranged from 0.6 to 3.1 in Bălțătești, and from 0.5 to 1.5 in Târgu Neamț. The subunit values were recorded in July in Bălțătești, and in January and October in Târgu Neamț (**Fig. 7**).

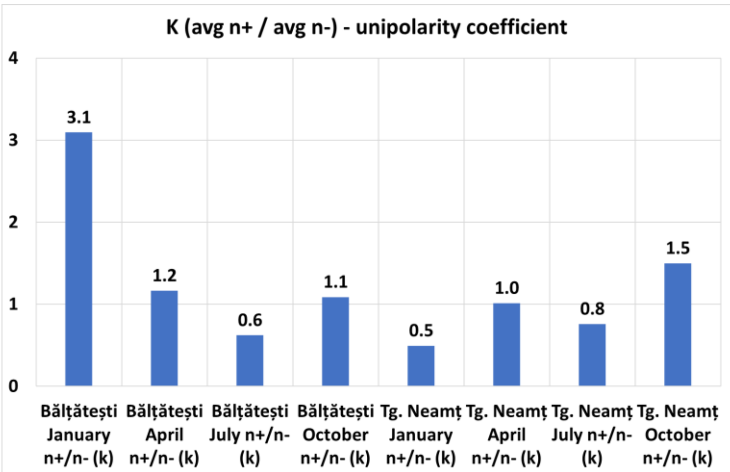

Fig. 7. Monthly values of the unipolarity coefficient k at Bălțătești and Tg. Neamț by months, in the two investigated resorts, in 2022.

A more detailed view of the distribution of air ion levels and k coefficient in the two resorts, during 2022, for the median months of each season in this year, can be followed with the boxplots (**Fig. 8** and **9**).

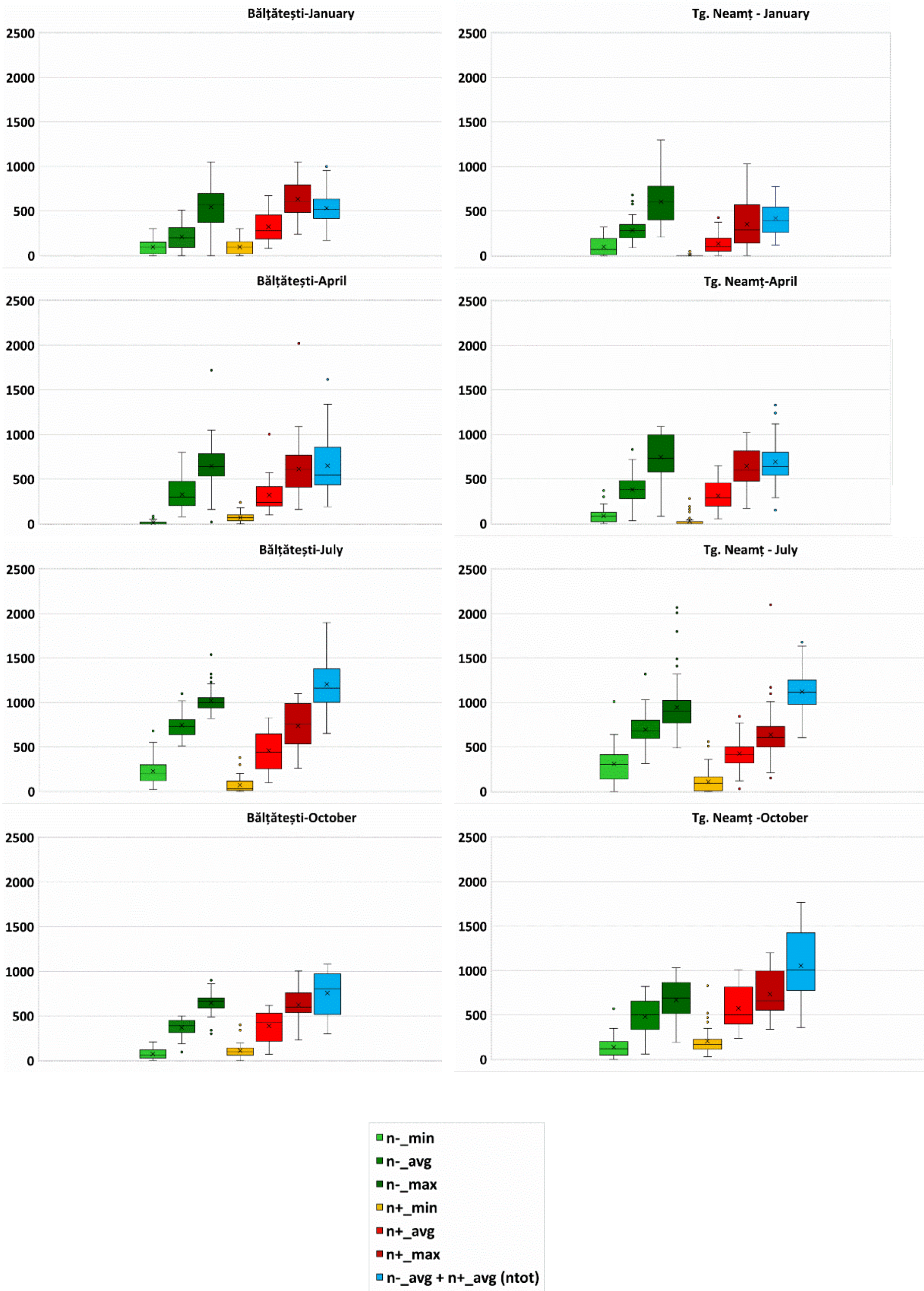

Fig. 8. Analysis of the variability of air ion levels (cm^{-3}) in Târgu Neamț and Bălțătești resorts, during the year 2022, in January, April, July, October.

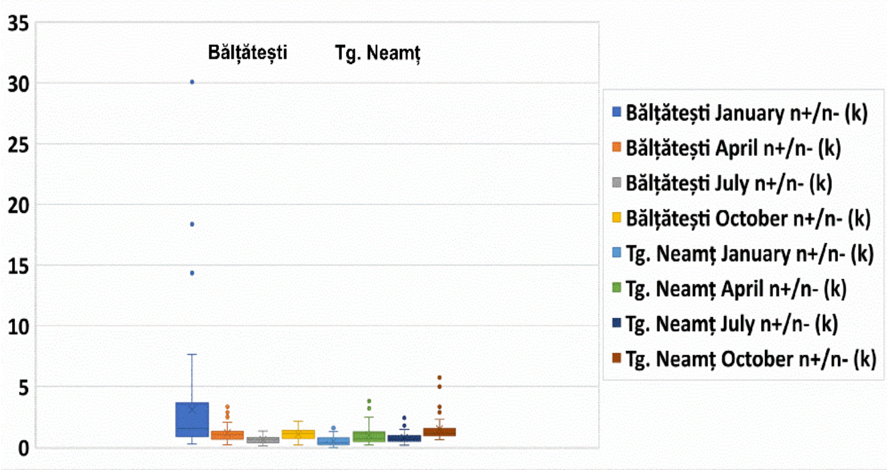

Fig. 9. Boxplot charts showing the full value spectrum of the unipolarity coefficient k, by month in the two resorts studied in 2022

The carefully analyzed **Figures 8** show the annual air ionization regime, peaking during the summer months. Negative air ionization was more intense and more variable as a process, in the atmosphere of Târgu Neamț resort, and positive in the atmosphere of Bălțătești resort. The total air ionization was very similar in the two resorts during the days of January, April and July, but, during the days of October in Târgu Neamț, it was more intense, compared to Bălțătești. From **Figure 9**, we can notice that the values of the unipolarity coefficients indicate a dominance of negative air ions during the summer months, making it favorable to practice aeroionotherapy in the two resorts. During the days of the cold season, the values of the unipolarity coefficients varied more, as can be seen from the boxplot for Bălțătești resort for January, or the one for Târgu Neamț resort for October (**Fig. 9**).

3.2.3. Daytime regime of negative, positive air ion levels, total number and unipolarity coefficient k at Bălțătești and Tg. Neamț during the whole monitoring period in 2022

The daytime fluctuations of the averaged air ion levels and the k-coefficient for all days analyzed, can be seen in **figure 10**. We observe that air ion levels tend to reach higher values in the morning and towards midday (9:00 AM - 10:00 AM at Bălțătești, respectively 11:00h-12:00h at Târgu Neamț), when the statistics shown in the graph indicate a more pronounced maximum value. Then follows a slight decrease in the rate of the air ionization process around 14.00h, a slight increase in the rate of the process at 15:00h - 16:00h, after which the air ionization process decreases slightly, gradually towards the evening hours (20.00h – 21:00h). Also, we notice a more uniform distribution of the k coefficient during the day in Târgu Neamț, against a background of subunit hourly values (with a minimum around 17:00h– 18:00 h), while in Bălțătești for the first hours of the morning (7:00h-10.00h) and for 16:00h, superunit values of the k coefficient were determined.

The diurnal regime of air ionization is carried out on similar value coordinates imposed by the quasi-similarities between the factors participating in the generation of air ions in the atmosphere of the two resorts, and the differences are most likely given by the level of shading, shielding in relation to the solar rays of the horizon, at the monitoring points, the differences in the factors generating the local topoclimatic framework, the dynamics of the weather on the days of observations, which was not synchronous, but asynchronous, because several air ion counters were not available during the monitoring.

For a more detailed analysis of the *diurnal regime* of the air ionization process, we selected July as a case study, because it allows us to focus the observation results on the period of the year with the most intense tourist movement, and with the most important effects on the air ionization treatments they can benefit from.

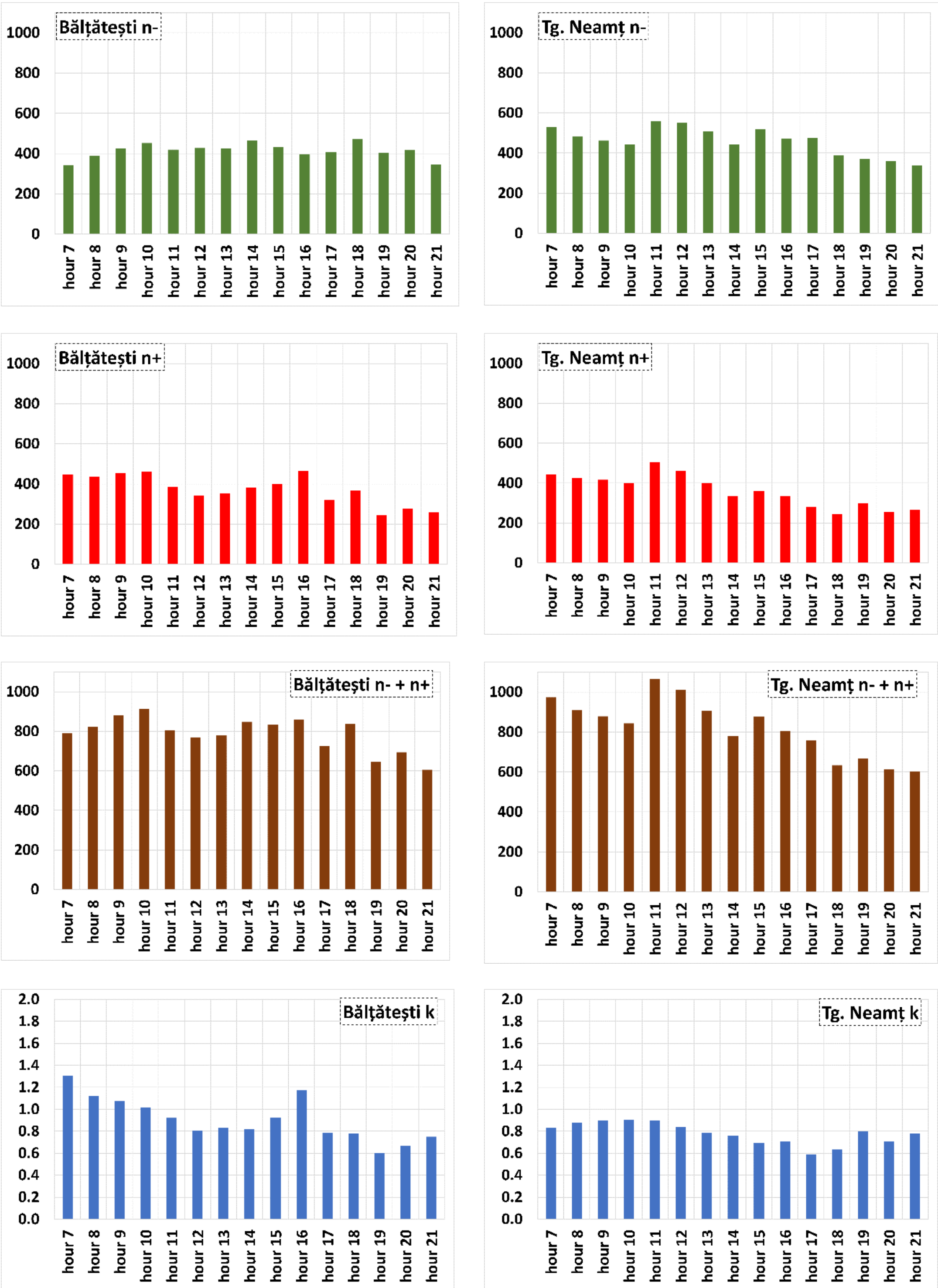

Fig. 10. Diurnal regime of negative, positive air ion concentration, total air ion number and unipolarity coefficient k at Bălțătești and Tg. Neamț over the whole monitoring period from 2022.

The month of July corresponds to the highest average values of air ionization: 1400 air ions cm^{-3} at Bălțătești and 1200 air ions cm^{-3} at Târgu Neamț (**Fig. 11**). The maximum values of total air ionization were reached in the evening (18.00h) at Bălțătești and in the afternoon (15.00h) at Târgu Neamț.

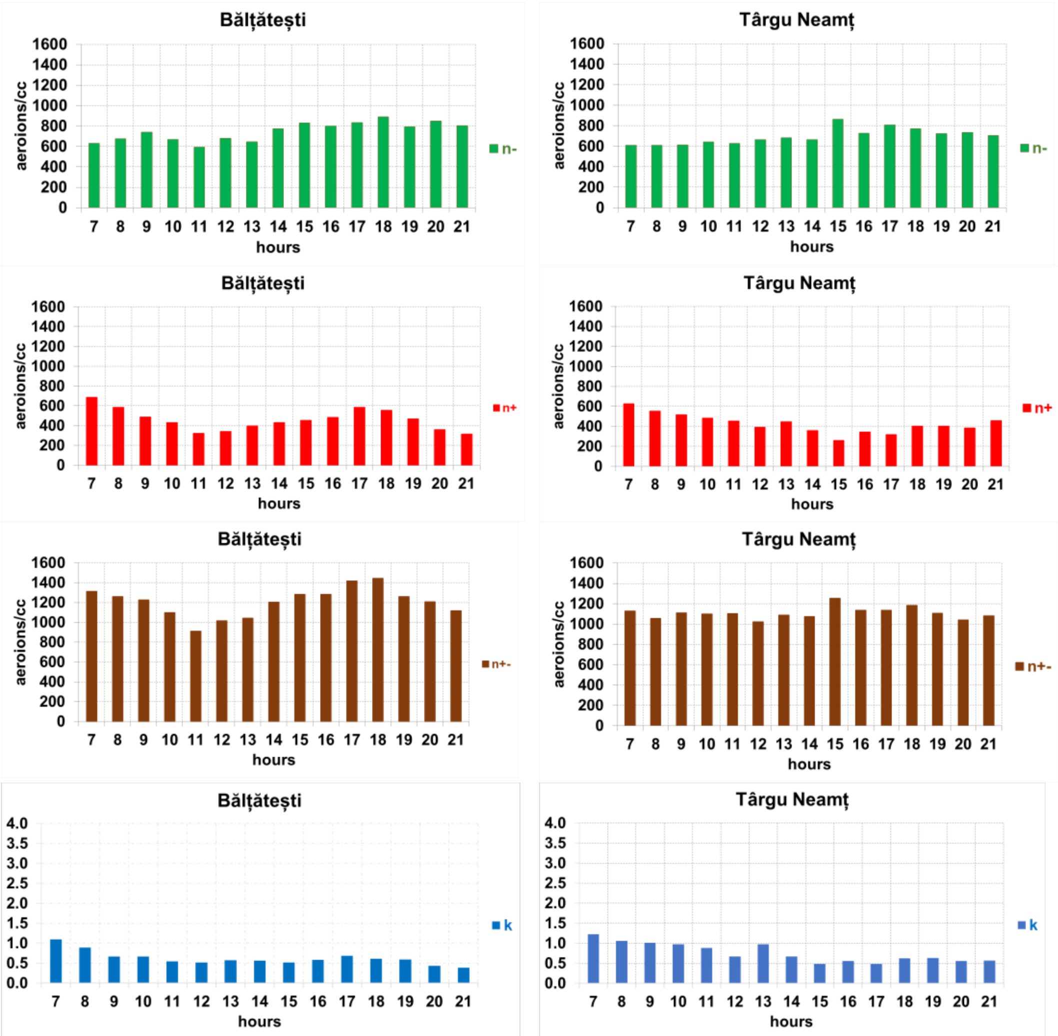

Fig. 11. The diurnal regime of the concentration of negative and positive air ions, the total number of air ions and the unipolarity coefficient k at Bălțătești and Tg. Ocna in the days of July 2022 when the monitoring was carried out.

Negative air ionization was maintained in the two resorts at values between 600 and 800 / 900 air ions cm^{-3}, throughout the observation hours. Positive air ionization ranged from 300 to 600 / 700 air ions cm^{-3}. We noted higher variability of air ionization at Bălțătești this month: average air ionization values ranged from 900 to over 1400 air ions cm^{-3}, compared to Târgu Neamț: 900-1200 air ions cm^{-3}. At Bălțătești, the total air ionization regime during the day, in July, was very clear (a minimum during 11.00h and a maximum during 18.00h), but at Târgu Neamț we did not notice a clear diurnal air ionization regime for this month.

The unipolarity coefficient, k, was subunit in the two resorts, in most of the observation hours, indicating a clean, sanogenous, aeroionized, predominantly negative air, suitable for balneotherapy but also for a wide range of outdoor tourist activities (**Fig. 11**).

3.2.4. Extreme values of air ion levels. Their analysis with reference to average levels

The extreme values of air ionization reached high values in both resorts (in April in Bălțătești, and in July in Târgu Neamț - **Tables 1** and **2**).

At Bălțătești negative air ionization reached a maximum of 1720 air ions cm^{-3} in April, and at Târgu Neamț 1800 air ions cm^{-3} in July. At Bălțătești, this value was reached against the background of an intensification of the wind speed (5 m/s) from the western sector, which favoured the advection of air rich in air ions from the surrounding wooded areas. In Târgu Neamț, the maximum level of negative air ionization can be attributed to the high temperature (26°C) and low humidity (55%), conditions favourable for the production and dispersion of air ions.

Table 1.

Parameters of air aeroionization in the tourist resort of Bălțătești, determined from observations made in January, April, July and October 2022.

Bălțătești	January		April		July		October	
	n-	n+	n-	n+	n-	n+	n-	n+
Minimum with the lowest value	0	0	0	0	20	0	0	0
Averages of minimums	60	115	136,7	134	589,8	315	96	70
Average	210	323	260	335	746	459,8	351,2	398,4
Median	228	253	296	244	773,3	454	388	421
Average maxima	434	536	550	562	889	685	480	619
Maximum with the highest value	1050	1050	**1720**	*2020*	1540	1100	860	1002

Table 2.

Air ionization parameters in the tourist resort of Târgu Neamț, determined from observations made in January, April, July and October 2022.

Târgu Neamț	January		April		July		October	
	n-	n+	n-	n+	n-	n+	n-	n+
Minimum with the lowest value	0	0	0	0	0	0	0	0
Averages of minimums	70,1	95,5	123,7	140,4	283,5	115,6	138	203
Average	290	169	360	416	678	470	483	557
Median	281	217	349,2	343,2	683	403	548,3	518
Average maxima	433,1	559,4	744	695,8	912,5	644,1	616,9	716
Maximum with the highest value	1300	1030	1090	1360	**1800**	*2100*	1200	1200

Positive air ionization reached a maximum of 2020 air ions cm^{-3} at Bălțătești, and 2100 air ions cm^{-3} at Târgu Neamț. At Bălțătești, the maximum value was recorded on the same day and at the same time as the maximum negative air ionisation. For Târgu Neamț, the peak of positive air ionization occurred on the same day as the peak of negative air ionization, but a few hours later, in the evening, in a context characterized by high temperatures (23°C) and wind speed exceeding 4 m/s. The minimum values were below 0 air ion (n- and n+) in both stations in almost all the months we monitored.

The Bălțătești resort is located 92 m higher than Tg. Neamț and it would have been expected that the air ionization levels would be higher in Bălțătești. However, it appears that in the higher levels of air ionization from Tg. Neamț the presence of the hydrographic axis of the Ozana river which favors an easy and constant gravitational drainage of air volumes coming from the west, from the Stânișoarei peaks to the east-southeast, along the axis of the valley, somewhat less cloudiness, combined with a longer duration of the Sun's brilliance, make the process of air ion production to be somewhat more intense at Tg, Neamț. This occurs despite the fact that the socio-economic activities (consumers of especially negative air ions, through the generated atmospheric pollutants) from Tg. Neamț are more intense than in Bălțătești.

4. DISCUSSION

4.1. Influences of meteorological factors on air ionisation

Regarding the relationship between air ionisation and air temperature, our study showed that an increase in air temperature usually leads to an intensification of the air ionisation process. Thus, the highest air ionisation values were recorded in the warmest month (July). These correlations are also highlighted in other researches (Crețeanu and Frimescu, 1961, 1963), which indicate an intensification of the number of small ions with increasing temperature. Also, Wang et al. (2004) find a positive correlation of air ionization with air temperature in the range 5-40˚C at 35% humidity, but did not observe a significant influence of humidity. Wang finds that with increasing temperature, the kinetic energy of molecules or atoms increases, and the ability of oxygen to be ionized increases. Hui et al. (2020) observes different correlations between seasons: positive in spring and negative in summer and autumn. On divergent positions are Tingting et al. (2014) and Pengfei et al. (2015), who identify an inverse correlation between air ionization and air temperature.

We found that relative humidity with high values induces a decrease in the air ionization process. Humid air does not favour the dispersion of air ions in the atmosphere, leading to a lower concentration of negative or positive ions. The negative correlation between air ionisation and humidity has been shown by earlier studies (Geekel, Simpson cited by Schweidler and Kohlrausch, 1923), which observed a decrease in air ion concentrations with increasing air humidity. Deleanu (1986) also identifies an inverse dependence of ionization on humidity, but a moderate one, and Enache (2017) concludes that under high humidity conditions, the number of negative air ions decreases, but the number of positive air ions increases.

We note that cloudiness can affect the distribution and dispersion of ions in the atmosphere. In general, a clear sky day allows for better air ionisation, as high solar radiation helps to boost the air ionisation process. In contrast, on days with dense clouds or haze, air ionisation was lower. Similar results have been obtained in other studies (Wu et al., 2006; Ji, 2007; Tang et al., 2011; Li et al., 2011; Mao et al., 2014).

Wind can influence the distribution of ions in air. Strong wind can disperse ions and promote pulsating air ionization, depending on its structure. Lack of wind or weak wind can lead to the accumulation and concentration of ions in a confined space. In our study, at Bălțătești, the maximum values of air ion concentrations coincided with the highest wind speeds (5 ms^{-1}). The positive correlation between air ionization and wind has been confirmed by other research (Wang et. al., 1991; Ye et al., 2000; Qi et al., 2011; Si et al., 2014). Wind origin is also important in the process of air ionization: wind blowing from forest or natural environments (meadows, waters) generates increasing air ionization (Wu, 1996; Enache, 2017).

4.2. Practicability of aeroionetherapy in the researched resorts

The significantly high values of total air ionization in July in Bălțătești and Târgu Neamț resorts (over 1000 air ions cm^{-3}), correlated with subunit values of the unipolarity coefficient k, favour the practicability of aeroionotherapy in these resorts, in association with other climatotherapeutic procedures (air cure, ground cure, air bath, heliotherapy, hydrothermotherapy etc.) (Laza, 2000; Amiranashvili et. al., 2013).

According to other studies (Lazzerini, 2018, cited by Shu-Ye et al., 2018), the concentration exceeding 1000 negative air ions cm^{-3} was considered as threshold value for stimulating the human immune system. The effects of aeroionetherapy, demonstrated by extensive studies, have highlighted its role on the cardiovascular and respiratory system (Iwama et. al., 2002; Ryushi et. al., 1998; Ju et al., 1997; Wiszniewski, 2014). This reconfirms the climatotherapeutic potential of the local atmosphere, providing a valuable opportunity for those who wish to benefit from the positive role of air ionization in the process of prophylaxis, restoration of physical and intellectual capacity or healing of some diseases (Deng, 2019).

4.3. Diurnal regime of air ionisation

The maximum air ionisation values are recorded in the first part of the day, between sunrise and midday. This may be due to several factors, such as the increasing solar radiation during this period and the photosynthesis process of plants, which contributes to the release of negative ions into the atmosphere. The lowest values of air ionisation are observed in the midday (January and April) and evening (July and October). The U-shaped pattern with high air ionization values in the early morning and evening hours, has also been observed in other studies (Wu, 2001; Wang, 2003; Xu, 2004; Zhao, 2007; Hui et al., 2020).

4.4. Comparisons with other studies

Data from the most recent study on air ionization in the region at the Carpathian - Suceava Plateau contact carried out for the resorts of Solca, Cacica and Gura Humorului in July 2022 (Mihăilă, 2023) show a number of differences, but also similarities with the average values of air ionization in the resorts of Bălțătești and Târgu Neamț.

The average values of total air ionization are higher at Bălțătești and Târgu Neamț (1121.2 air ions cm^{-3} and 1205.8 air ions cm^{-3}, respectively), than at Solca and Gura Humorului (1052 air ions cm^{-3} and 1068.2 air ions cm^{-3}, respectively), but lower than at Cacica (1467.4 air ions cm^{-3}).

Negative air ionization is similar in Bălțătești and Cacica (746 air ions cm^{-3}, respectively 771 air ions cm^{-3}), with lower values in Târgu Neamț (695.4 air ions cm^{-3}), Solca and Gura Humorului (612 air ions cm^{-3}, respectively 540.2 air ions cm^{-3}).

Positive air ionization has comparable values at Târgu Neamț, Bălțătești, Solca and Gura Humorului (values between 425 and 528 air ions cm^{-3}) and higher values at Cacica (696 air ions cm^{-3}). Enache (2016) mentions average air ionization values of 1050 air ions cm^{-3} and a unipolarity coefficient of 0.88 at Bălțătești, and at Soveja, another subcarpathian resort, 1200 air ions cm^{-3}, respectively a k of 0.9. total air ionization.

Other studies carried out in the relatively recent past in balneoclimatic resorts in Romania have shown quantitative and qualitative differences between balneoclimatic floors: at Sinaia total values of 800 air ions cm^{-3} were recorded (Frimescu, 1964), at Sovata they exceeded 1100 air ions cm^{-3}, at Vatra Dornei the concentration of air ions varied between 951 and 1615 (Pascu and Ștefănescu, 1969), at Băile Herculane the total ionization exceeded 1000-2000 air ions cm^{-3} (Brînză, 1974), and on the Black Sea coast, the values of air ionization varied between 980 ions cm-3 at Sf. Gheorghe, and 1180 ions cm^{-3} at Sulina (Enache, 1978). Typically, in regions located at average altitudes of about 1000 m, a uniformity of data is observed, with values between 900 and 1300 air ions cm^{-3} (Enache, 2017).

4.5. Limitations and future research directions

This study is based on asynchronous measurements carried out at Bălțătești and Târgu Neamț over a limited period of time, consisting of three consecutive days in January, April, July and October 2022. The study was not synchronous in the two resorts, due to the limitation induced by the existence of only one air ion counter used in the monitoring. In our analysis, we analyzed the local air ionization process in correlation and under the influence of four meteorological elements: temperature, relative humidity, cloudiness and wind.

In order to get a more comprehensive view and to show the annual and diurnal course of air ionization, it is necessary in the future to extend the measurement period, including the addition of additional days and months of the year (i.e. hours of the day) to analyze this process. The impact of air pollution on air ion concentrations, and the influence of air ionisation, its prophylactic and therapeutic effects, in the surveyed resorts, on tourists could also be investigated through questionnaires / surveys focused on this issue.

There are studies and reports in this regard showing that smoke and dust caused by human activity increase the likelihood that positive and negative ions annihilate each other, which reduces the concentration of negative ions (Deng, 2019), that the level of negative air ions depends on the degree of air pollution (Amiranashvili, 2013), and that negative air ions can reduce the number of respirable and inhalable dust particles (Tanaka, 1996; Lazzerini, 2018). The high efficiency of negative air ions in removing PM_{10} and $PM_{2.5}$ has been confirmed in others research (Daniels, 2002; Lee et al., 2004; Grinshpun et al., 2005).

By combining air ionization and air quality data, we will obtain a more detailed picture of the valence of the local air environment, whose peculiarities result from the interactions between determining factors (Shu-Ye, 2018). This approach would provide a solid basis for identifying air quality protection and improvement measures to optimize the therapeutic benefits of air ion therapy (Lazzerini, 2018; Hui, 2020).

5. CONCLUSIONS

Measurements carried out in Bălțătești and Târgu Neamț resorts during January, April, July and October 2022, focused on environmental and weather conditions as factors determining the air ionization process. Measurements of air ion levels in the 4 months aimed to determine the major features of the annual regime of air ionization, and the hourly measurements aimed to outline the features of the daytime regime of this process.

Weather conditions during the observation period had an impact on the air ionisation process. Thus, the influence of the meteorological factors taken into account (temperature, humidity, cloudiness and wind speed), on air ionization was 66.3% at Bălțătești and 63.4% at Târgu Neamț. Air temperature was the element with the most pronounced impact on air ionisation. The highest values of air ionization were reached in the context of high thermal values, the Pearson coefficient indicating a positive correlation (0.5) between the process of air ionization and temperature. Wind speed was another meteorological element with a direct, positive influence on air ionisation. The maximum air ionisation values recorded overlapped with periods of wind intensification (wind speeds above 4-5 ms^{-1}), while humidity and cloudiness were negatively correlated with air ionisation with little impact on air ionisation.

Over a year, summer is the season with the highest degree of air ionisation. Average air ion levels in the atmosphere rose in July to 1100 - 1200 air ions cm^{-3} at Târgu Neamț and Bălțătești. These values highlight the most favourable time of the year for air ionisation therapy. In extenso, in the warm season of the year, the maximum values of air ionization generated negative air ion levels reaching 1720 air ions cm^{-3} at Bălțătești, 1800 air ions cm^{-3} at Târgu Neamț, and positive air ion levels reaching 1720 air ions cm^{-3} at Bălțătești and 1800 air ions cm^{-3} at Târgu Neamț. Annually, k values are lowest, even subunit, on days in the warm season months (especially summer), increasing on cold season days (especially winter).

The daytime air ionization regime averaged over the 4 months of observations, shows that the periods with the lowest total air ionization values at Bălțătești and Tg. Neamț correspond to the afternoon, to evening hours. In the morning, the air ionization values are also lower. The diurnal maxima of air ionization are positioned during the day, but precise temporal positioning with relevant statistical assurance would require longer periods of observations on the order of months and even years, not days. In this way, some random, disturbing meteorological events would be removed from the influence on the diurnal regime of some minor, local, long-term influencing factors, but which, in the short term, can impose abrupt increases or significant decreases, thus a certain air ionisation regime, difficult to sustain with plausible, stable explanations. When observations at two or more stations are asynchronous, the analysis becomes more complicated and the results are even more difficult to reconcile. During the daytime, k values were lowest (with some exceptions) in the midday and afternoon hours, and highest in the morning and evening. The 4-month averaged daytime regime of k at Bălțătești and Tg. Neamț revealed hours with predominantly subunit k. The daytime regime in July revealed an even longer range with sub-unit values (8.00-21.00h in Bălțătești and 9.00-21.00h in Târgu Neamț) of the k-index.

The geographic location in the Neamț Depression of the Moldavian Subcarpathians, in an optimal bioclimate, with mixed vegetation and active air ionization processes make the tourist resorts of Bălțătești and Târgu Neamț, attractive climatic-touristic destinations with high potential for practicing aeroionetherapy. These resorts can meet the requirements of tourists all year round. The warm season is favourable for all tourist activities. In summer there are no restrictions for tourism. The most favourable month for aeroionetherapy is July when air ionisation values exceed 1000 air ions cm^{-3} in both resorts. In Târgu Neamț, also October records high air ion levels (1040 air ions cm^{-3}). The recommended times of the day for aeroionetherapy are morning and afternoon in both resorts. The results obtained in this study encourage the effective use of aeroionetherapy for prophylactic and therapeutic purposes in Bălțătești and Târgu Neamț resorts.

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