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Research on air ionization in the tourist resorts of Solca, Cacica, Gura Humorului and in Cacica salt mine - north-eastern Romania

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Abstract: This study captures for 6 days in May and August 2022 (time interval 8:00 AM-8:00 PM) the atmospheric levels of positive and negative ions in the atmosphere of three balneoclimatic resorts in north-eastern Romania (Solca, Cacica and Gura Humorului), in correlation with the values of meteorological elements of those days. The concentration of aeroions was measured hourly, in 2+2 days, in a characteristic point of each resort and on September 15, 2022 in 3 points / levels of Cacica salt mine. With average values of aeroion levels above 1000 / cc (1054 / cc at Solca, 1069 / cc at Gura Humorului and 1468 / cc at Cacica) the atmosphere of these resorts can be therapeutically exploited by aeroionotherapy. In the Cacica salt mine the aeroelectric potential is very high, here the total aeroion load varied between 9,026.5 and 11,464.5 aeroions/cc. The unipolarity coefficient (k) had average values of 0.72 at Solca, 0.9 at Cacica and 0.97 at Gura Humorului, indicating in all three resorts a quality air with therapeutic properties. In the Cacica salt mine the average value of the unipolarity coefficient was 1.26, with slight variations from one room to another.

1. Introduction

The air near the earth's surface is characterised by a number of physical, chemical, biological and electrical (air ionisation) properties that influence human health to a greater or lesser extent. Studies undertaken in the last century (Winsor and Beckett, 1958; Krueger and Reed, 1976) highlighted the role of negative aeroions in inhibiting the growth of viruses and bacteria and showed both inhibitory and alleviating effects in the adjuvant therapy of disease. In the 21st century other studies (Pino and Ragione, 2013) have demonstrated the effect of negative ions in the treatment of respiratory, circulatory and digestive diseases. Also, in the 21st century, the first approaches to the study of air ionization of air as a tourist resource appeared (Jianwu and Jiayuan, 2002). The mechanism of aeroion production, the lifetime of aeroions, their role on human health, the influence of climatic elements in aeroion production have also become research directions in the field of air ionization (Teodoreanu et al., 1984; Enache, 2017; Enache and Bunescu, 2019). Many researches on the occurrence of aeroions have shown that they are generated by electrical effects in nature (lightning and ultraviolet radiation), ionization of water molecules caused by river flow (Lenard effect), natural radioactive elements in the surface, vegetation (Mihăilă, 2014; Enache, 2017). Temporal variations of natural air ionization show a number of regularities. Thus, an annual regime has been identified that shows high values of air ionization in the warm season and low

values in the cold season, the cause being represented by the exchange of gases - including radioactive ones - between the soil and the air layer. A diurnal regime has also been found with a maximum of ionization during the night and at dawn and a minimum at noon (in the case of low ions), with causality not yet conclusively explained (Deleanu et al., 1988).

Outdoor tourist activities can benefit from the more ionised atmosphere of certain places. Forests and parks are components of the environment of greater interest and attractiveness due, among other things, to their high levels of air ionization. In the resorts analysed, forests and parks have a significant share. The environments with trees also have the highest air ionization values, almost double that of neighbouring environments (Yan, 2010) depending on tree species, forest structure and age (Qing and Weihua, 2005; Hairong et al., 2005). The high values of air ionization are attributed to aromatic substances (phytoncides) with ionizing properties, emitted by tree leaves (Deleanu and Elges, 1967). Geology and petrography of orogen-platform contact, presence of hydrographic aerations, geographical nature of sites, play a significant role in the genesis of aeroions (Teodoreanu, 1984).

The objectives of the research in this study aim at: i) outlining the meteorological and micrometeorological features of the days on which aeroionometric determinations were carried out, in order to observe to what extent they influenced the level of air ionization, ii) determining the minimum, maximum, but especially average levels of negative and positive aeroions, but also of the average levels of k, which, depending on its values, indicate whether aeroionotherapy can be practiced as a climatotherapeutic procedure in the researched resorts, and iii) outlining the regime during the day (time interval 8:00 AM - 8:00 PM) of air ionization and k, in order to observe when the most favourable conditions are met to practice aeroionotherapy by tourists who come for relaxation, cure and treatment in the three resorts.

2. Materials and Methods

2.1. Study area

The Solca - Cacica - Gura Humorului group of resorts is located in the north-east of Romania, at the contact of the Eastern Carpathians with the Moldavian Plateau and belongs to a region with great tourist attractiveness, called Bucovina. The three tourist destinations are located in a depressional corridor bordered to the west by the mountain peaks of the Carpathians (altitudes over 700 m) and to the east by the Suceava Plateau (350 m altitude) (Figure 1).

The proximity of the mountains, the relief with the appearance of hills and depressions, the structural-lithological characteristics of this depressional corridor (orogen/platform) and the transitional vegetation cover (mixture of conifers and deciduous trees) (Geografia Romaniei, 1992) determine a series of topo-bio- climatic conditions favouring outdoor tourist activities.

In the study area, the presence of mineral springs exploited for therapeutic purposes is well known: 6 at Solca (chlorinated, sodic), 5 at Cacica (chlorinated, sodic and sulphurous) and 4 at Gura Humorului (carbonated) (Bistricean, 2020). The hydrographic network is rich and belongs to the Suceava hydrographic basins, with tributaries Solca, Soloneț and Moldova with tributaries Humor and Bucovăț.

Above 500-600 m, the beech-conifer understory develops. At lower altitudes (below 500 m) the beech understory is specific with beech and beech forests mixed with sessile oak, hornbeam, sycamore, maple and other species (Geography of Romania, 1992).

At the level of the three UATs where the three resorts are located, the share of forest vegetation is consistent: Solca with 73.05%, Cacica with 48.09% and Gura Humorului with 72.31% (Corine Land Cover 2018 dataset).

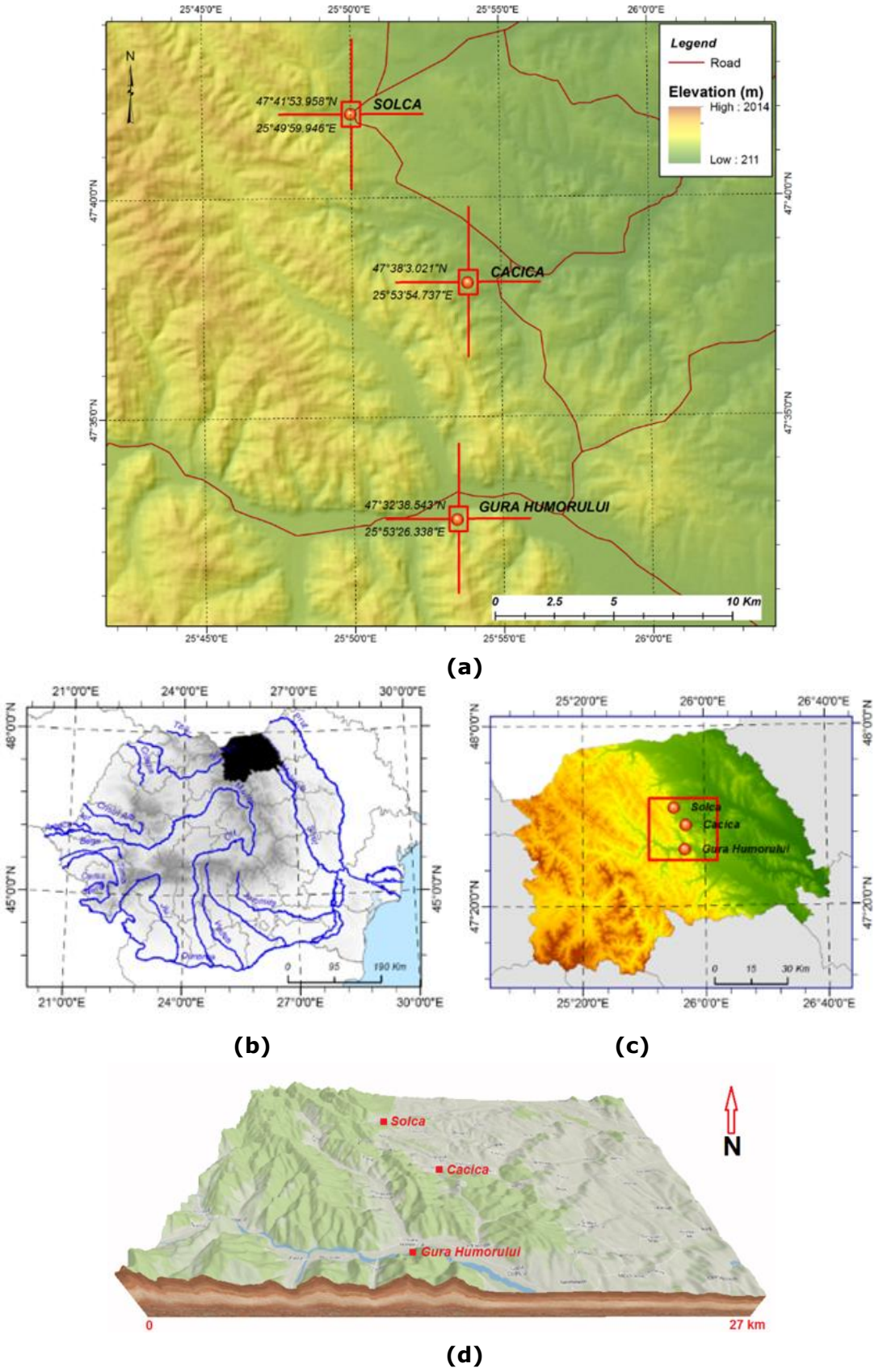


Figure 1. Geographical location of the places where aeroionometric measurements were made in the tourist resorts of Solca, Cacica and Gura Humorului (a), within Romania, Suceava County (b), at the contact between the Carpathians and the Suceava Plateau (c) three-dimensional block diagram showing details of the location of the three observation sites (d)

The tourist resort of local interest Solca is located on the valley of the homonymous river, at the foot of Obcinele Bucovinei, at an average altitude of 513 m. The locality has a special natural setting: hilly relief, rich vegetation with pastures, meadows, orchards and mixed (deciduous and coniferous), forests springs with mineral waters and bogs and a strong ozonized air. The resort has a bioclimate conducive to a wide range of spa procedures. The resort town of Solca (2405 inhabitants, 2021 according to NIS) officially has only 4 accommodation units with 79 beds (National Institute of Statistics -NIS, 2021).

Cacica is a tourist resort of local interest, being located at the foot of Obcinei Mari in the Solca-Cacica Depression, at an average altitude of 439 m. The locality had 3693 inhabitants in 2021 (NIS, 2021). The resort is known for its chlorinated-sodium, concentrated, slightly sulphurous, oligomineral waters, but above all for its salt mine, balneoclimatically used in the therapy of respiratory diseases with saline aerosols. The Cacica resort has 3 treatment centres where various therapeutic, prophylactic and recovery practices are carried out: Cacica Health Centre for the treatment of muscle disorders, genital disorders, osteoporosis, spondylosis, neuralgia, sprains, dislocations, metabolism and blood circulation. The tourist complex "Casa Nationalitatilor" through the "Virgil Săhleanu" treatment center, equipped with salt water swimming pool (hydromassage), sauna, fitness room, (cosmetic, medical-recovery and relaxation) massage and physiotherapy office. Cacica Spa and Leisure Complex offering relaxation, leisure and recreation services. The resort has a total of 17 accommodation units and 309 beds (NIS, 2021). The locality was visited by 10,285 tourists in 2021 (NIS, 2021).

The Cacica Salt Mine is located in the village of Cacica and has been on the tourist circuit since the second half of the 19th century. The galleries were dug by hand and run along several horizons. The main precincts of the salt mine are: The Roman-Catholic Chapel of St. Varvara (-27 m), the Orthodox Chapel (-35 m), the Salt Lake (-42 m), the Sports Hall (-79 m). The salt mine has a deposit consisting of two salt blades of 1600 - 2000 meters long, of 600 meters wide each and of up to 250 meters thick, summing-up 238 million tons of salt. The salt concentration is 84.71% (Munteanu, 2010).

From a microclimatic point of view, the salt mine is characterized by a moderately cool thermal regime: average annual values of temperature (10.2-10.4°C), relative humidity (that oscillates around 70-80 %), wind speed (<0.1 m/s). The effective-equivalent temperature is 9.5°TEE (Maiorescu et al., 2014). High-precision measurements conducted at hourly resolution between 1 July and 31 December 2018 at several levels in the salt mine indicated that the monthly average temperature fluctuated between 10.8°C and 8.8°C, while relative humidity had monthly average values that fluctuated between 65.4% and 82.9% (Mihăilă et al., 2019). The bioclimatic discomfort by cooling (calculated by THI) is not very pronounced, but it is permanent (Mihăilă et al., 2019). The stable atmosphere and the microclimatic uniformity give Cacica salt mine certain balneoclimatic qualities recommended both to tourists and patients (with respiratory diseases, bronchial asthma, etc.). In 2022, according to unofficial data (based on the number of access tickets sold) provided by the salt mine guides, who are SalRom employees, the salt mine was visited by 92,000 tourists.

Gura Humorului has been a tourist resort of national interest since 2005. The resort is located at 480 m altitude in the Humorului Depression at the confluence of the Humor and Moldova rivers. It has a natural and man-made environment favourable to tourist activities. Among the natural tourist attractions, we mention the Piatra Șoimului geological reserve, the Piatra Pinului nature reserve and the Arinis dendrological park with over 500 plant species, shrubs and trees from all continents that create a relaxing landscape. The anthropic tourist infrastructure includes: a swimming base with an indoor Olympic swimming pool and two outdoor swimming pools, six sports fields with night lighting, a skating rink that in summer turns into a roller and skateboard track, and a ski slope with a ski lift. The cultural heritage is also rich and varied: the Voroneț (1488) and Humor (1530) monasteries both included in the UNESCO heritage, the Museum of Popular Customs of Bucovina or the International Film Festival "Autumn in Voroneț".

With 13,278 inhabitants (2021 - according to NSI, 2021), Gura Humorului has 114 accommodation units, with 2405 beds. In 2021 the resort was visited by 67,157 visitors (NIS, 2021).

2.2. Methods and tools

Aeroionometric measurements were carried out with the PC Connectable Highly Accurate Air Ion Counter Tester COM-3200 PRO II (Figure 2) which complies with JIS (Japanese Industrial Standards) standards. The instrument additionally records air temperature (+/-1°C % accuracy) and air humidity (+/- 5%) (Figure 2). The data were downloaded to the computer and processed in Microsoft Excel.

(a) **(b)**

Figure 2. COM – 3200PRO II aeroion counter interface to aeroionometric measurements in the "Lake Hall", level II of the Cacica salt mine (a) aeroionometric measurements in the Lower Hall, level III in the Cacica salt mine on September 15, 2022 (b).

(a) **(b)**

Figure 3. CEM DT-171 DATA LOGGER thermo-hygrometer (a) and Windmaster 2 anemometer (b).

For precision measurements of air temperature and atmospheric humidity at the 1.5 m level we used the CEM DT-171 data logger (Figure 3a) and the Windmaster 2 anemometer (Figure 3b) to determine wind speed in Solca, Cacica and Gura Humorului resorts. The cloudiness in those three resorts was visually assessed and expressed in oktas of the celestial vault.

2.3. Data obtained

At each observation site in the three resorts we obtained 52 hourly values of the air ionisation parameters (52 minimum values for the determination interval, 52 mean values, 52 maximum values for both negative - n- and positive - n+ aeroions) to which the values of air temperature, humidity, cloudiness, average and maximum wind speed have been added.

From the Cacica salt mine we obtained two data samples (concerning the same air ionization parameters and the same meteorological elements) for each of the three representative levels in the salt mine (Sports Hall, Lake Hall, St Varvara Chapel).

2.4 Research methodology

In order to determine the aeroelectric properties of the air in the three resorts, we focused the observations on two months of the warm season, May and August, when the number of tourists visiting these resorts is higher. In all three resorts, we carried out hourly observations over four days, in the time interval 8:00 AM – 8:00 PM. In May observations were carried out successively on two weekends, one day each starting at Solca, continuing at Cacica and Gura Humorului on the first weekend and resuming in the same sequence on the following weekend (with the idea of capturing as many time sequences as possible, assuming that the weather is changeable from day to day). In August, under relatively stable weather conditions, the observations were organised in two consecutive days for each resort. For each hourly determination we proceeded as follows: at the 45th minute of the hour we switched on the instrument, calibrated the instrument for 2-3 minutes for the n- measurement, and then for 12-13 minutes determined the n- parameters; we then calibrated the instrument for the n+ measurement and determined their parameters for 12-13 minutes. In total, 48 to 52 minutes of determinations were made per hour at each resort, and 624 to 676 minutes of determinations for each category of ions (n- / n+) were made for each resort. In Cacica salt mine we chose to make the observations on a Thursday, when the salt mine is visited by fewer tourists. The observations lasted two hours in each of the three rooms. The determination sequences in each room were as follows: half an hour measuring the n- number, half an hour determining the n+ number with repeating the observations during the next hour.

3. Results

3.1. Meteorological and micrometeorological conditions. Influence of weather on air ionization

During the observations made at the three resorts the weather was generally fine, warm, calm, dry and sunny. The air temperature was lower in the morning and evening (13-14°C), warmer in the afternoon (26.9 - 31°C), with average temperatures ranging from 19.6°C in Gura Humorului to 23.7°C in Cacica. Air humidity ranged from 85 to 86.9% in the morning and evening and from 20 to 37% in the afternoon. The averages for this element were 50.5% in Solca, 57.1% in Cacica and 58.5% in Gura Humorului. The wind blew with average speeds of 0.6 m/s at Solca and Gura Humorului and 0.7 m/s at Cacica. The maximum speed reached 4.4 m/s at Cacica, 4.5 m/s at Solca and 5.1 m/s at Gura Humorului (Figure 4).

On the observation days, the cloudiness had average values of 2.5 oktas at Gura Humorului, 3.7 oktas at Solca and 4.2 oktas at Cacica. Intervals with the sky completely covered by clouds were rare, and those with the total absence of clouds in the sky more frequent.

In the salt mine, the air temperature was on average 12.7°C, and the air humidity was 84% with some small local variations. The air registered no detectable movement on the anemometer.

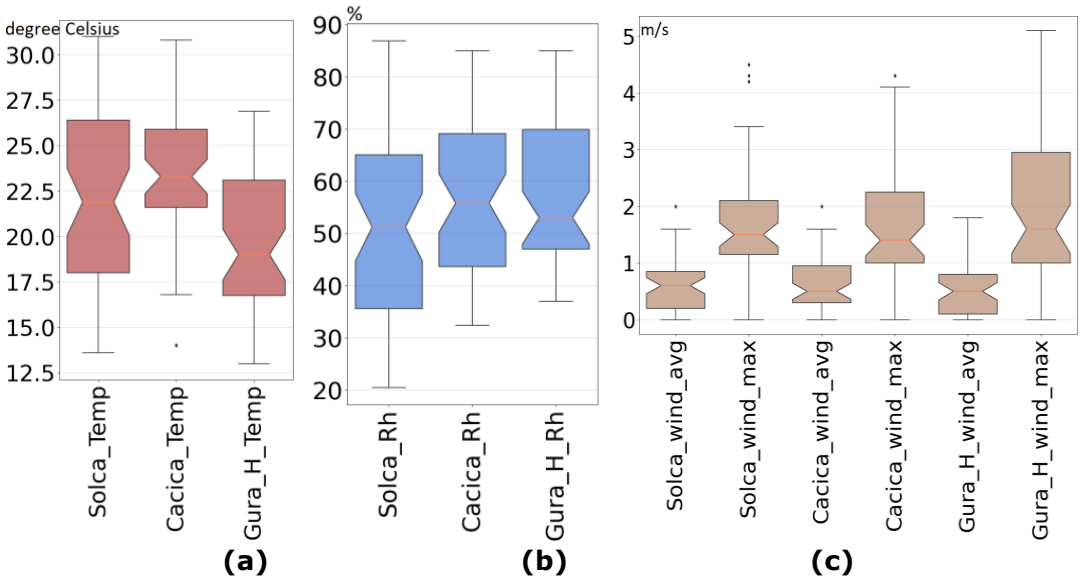


Figure 4. Box plot diagrams of air temperature (**a**), relative air humidity (**b**) and average and maximum wind speed (**c**) at Solca, Cacica and Gura Humorului during observations in May and August 2022.

The geographical location of the three resorts influences both the meteorological parameters and the degree of air ionization. From the analysis of the Pearson coefficients in Table 1, several aspects can be observed. The increase in air humidity or higher values of air humidity favoured in all observation points an increase in the levels both for n-, but especially for n+, and the decrease in the value of humidity generally led to the decrease of aeroion production and consequently to reducing their atmospheric levels.

Table 1. The values of the Pearson correlation coefficients established between the average levels of n- / n+ and the average values of air temperature - T, relative humidity - Rh, cloudiness - N and average - Aw / maximum - Mw of wind speed) during the observations in May and August 2020

negative ions	**Solca**	**Cacica**	**Gura Humorului**	**positive ions**	**Solca**	**Cacica**	**Gura Humorului**
ions-÷T	0.2	0.1	0.6	ions-÷T	-0.6	-0.2	-0.6
ions-÷Rh	0.4	0.6	-0.2	ions-÷Rh	0.7	0.6	0.5
ions-÷N	-0.4	-0.2	-0.3	ions-÷N	-0.03	-0.3	0.5
ions-÷Aw	-0.2	-0.4	-0.4	ions-÷Aw	-0.2	-0.2	0.02
ions-÷Mw	0.1	-0.5	0.1	ions-÷Mw	-0.2	-0.4	-0.2

Legend:	
-1 ÷ -0.5; 0,5 ÷ 1	statistically significant correlations
-0.4 ÷ -0.3; 0,3 ÷ 0.4	correlations with low statistical significance
-0,2÷ -0.1; 0,1 ÷ 0.2	correlations without statistical significance

If wind speed increases, it contributes to decreasing aeroion levels, and if the wind is weak, or in calm situations, aeroion production and levels are increasing.

If the air temperature is increasing, because of the increase in the duration of the Sun's brightness, it contributes to the increase in the production rate of n-, and if it is decreasing, it contributes to the reduction in the value of the negative air ionization parameters. The increase in temperature results in a reduction in the number of n+, and a reduction in the temperature values in an increase in their atmospheric concentration.

Decreasing cloud cover contributes to increasing n- production and decreasing n+ production, and increasing cloud cover has inverse aeroionometric effects.

However, the correlation coefficients between meteorological elements and n- / n+ levels have values with medium confidence due to the relatively short period for which they were calculated (Table 1). Extending the period would contribute to the consolidation of what was observed. Future studies will also focus on this objective.

The principal component analysis comprehensively completes the statistical relationships between the n- or n+ levels (also shown in Table 1), but transposed in a more comprehensive, suggestive and intuitive graphic format (Figures 5 and 6).

The wind, by positioning the axes corresponding to its parameters (average, maximum speeds) in relation to the n- / n+ axes, stands out in both groups of representations (Figures 5 a-c and 6 a-c) as a meteorological element that does not favour air ionization very much. Relative humidity with increasing or decreasing values imposes the same negative and positive air ionization, in different degrees of correlation, depending on the local topo-meteorological and geographical conditions, which is also observable from the analysis of the position and length of the axes of this element in Figures 5 and 6.

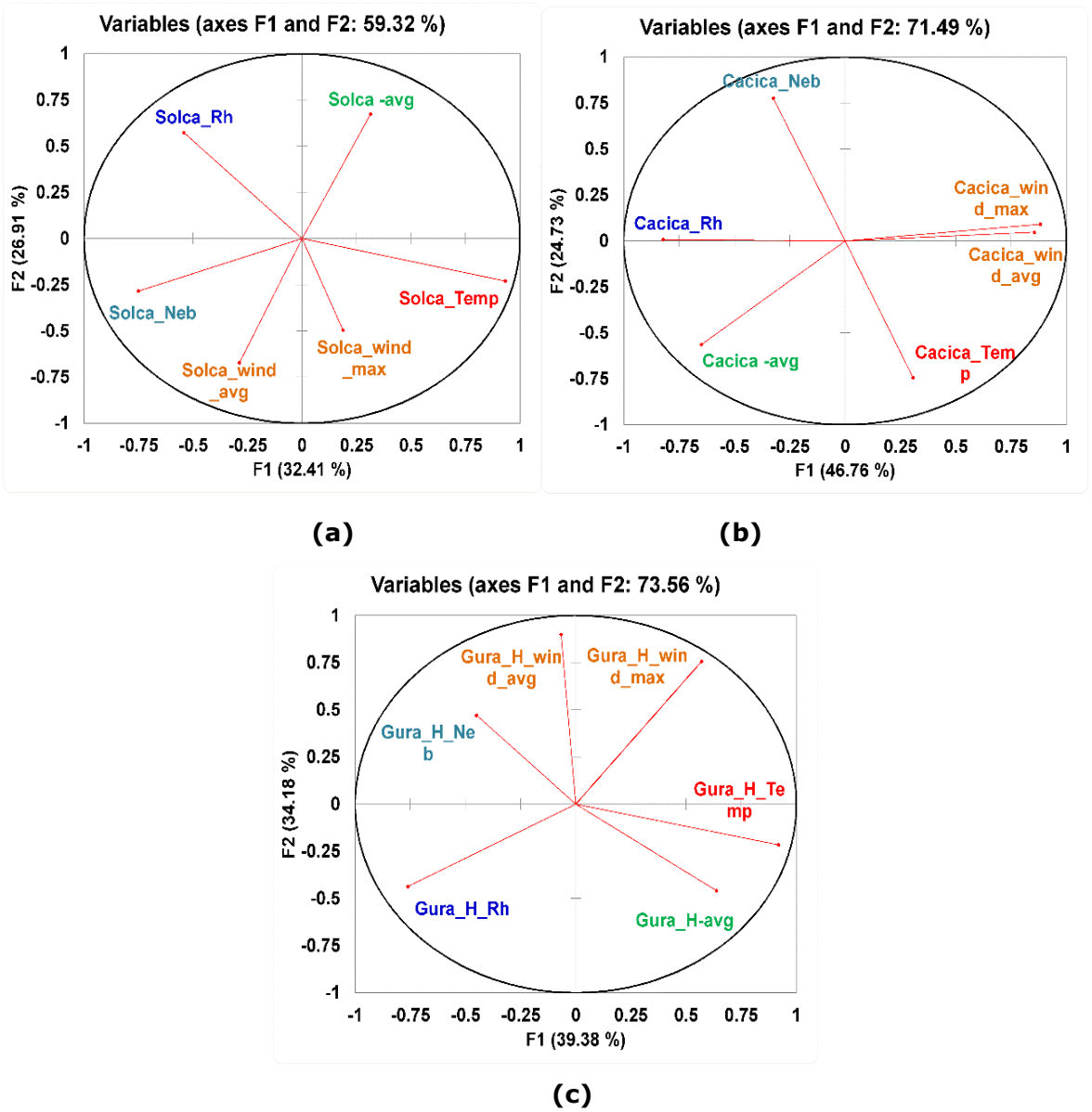


Figure 5. Correlation circles of the principal component analysis (PCA) of the n-level according to the values of the meteorological elements at Solca (a), Cacica (b) and Gura Humorului (c) based on the observations of May 20 and 28, respectively August 27-28 2022.

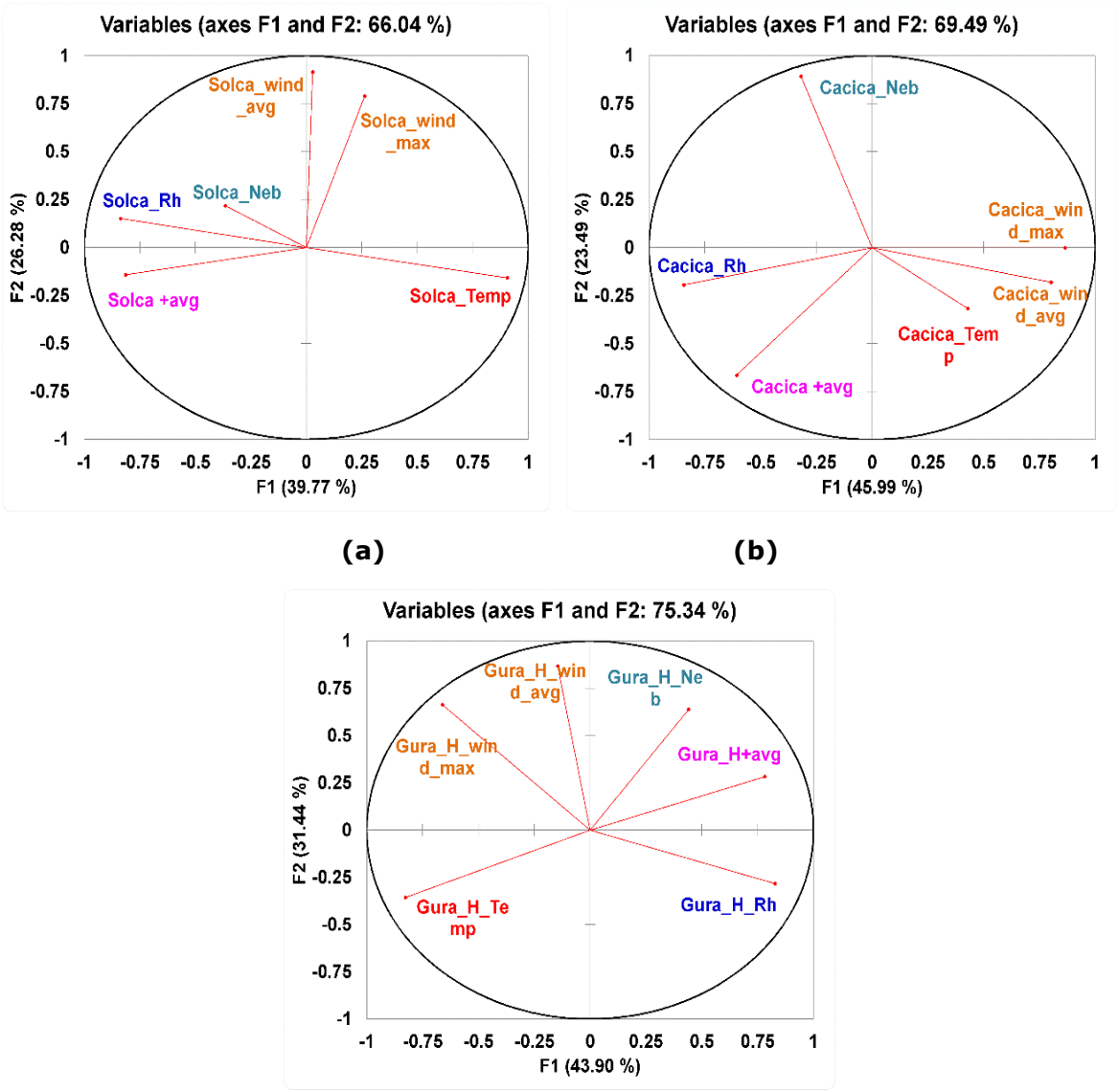


Figure 6. The correlation circles of the principal component analysis (PCA) of the n+ level according to the values of the meteorological elements at Solca (a), Cacica (b) and Gura Humorului (c) based on the observations of May 21 and 27, respectively August 23-24, 2022.

The temperature has positions and values directly proportional to those of negative air ionization and inversely to those of positive air ionization. Higher nebulosity limits the genesis of n-, but favours that of n+.

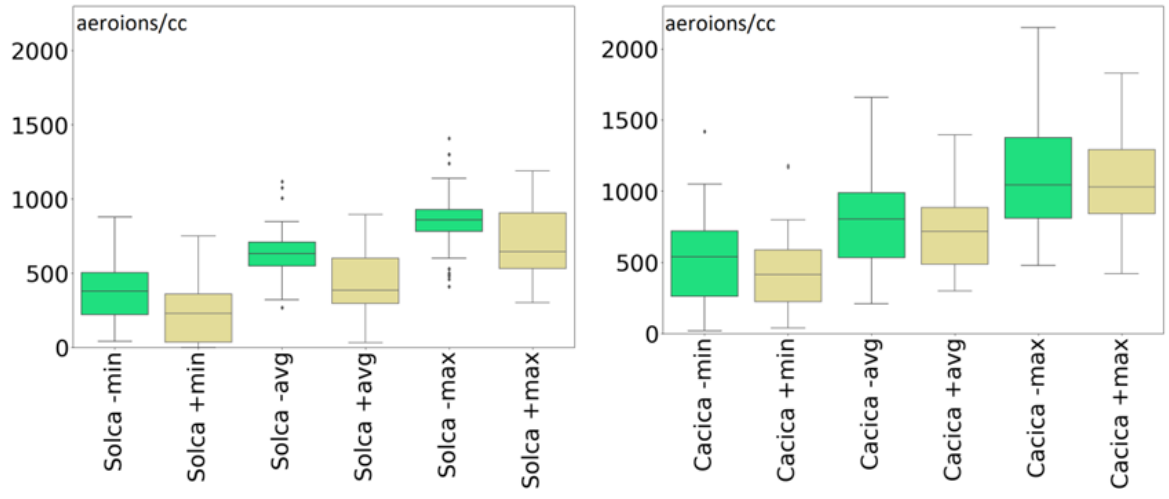
3.2. Aeroion concentration in the air of the researched resorts and the Cacica salt mine

The analysis of the extreme values of the atmospheric levels of aeroions in the atmosphere of the three resorts highlights a great temporal variability of this process. Analyzing the levels of n- (n+) we notice that they dropped during the observations in certain time sequences to 0 n-/ cc and rose in others up to 2150 n-/ cc at Cacica (between 0 n+/ cc and 1830 n+/ cc to Cacica) (Table 2). The analysis of the average levels of negative air ionization shows that they were between 540.2 n-/cc at Gura Humorului and 771 n-/cc at Cacica. The genesis of n+ resulted in their average levels between 440.0 n+/cc at Solca and 696.4 n+/cc at Cacica. In all 3 resorts, a higher share of n- compared to n+ is observed (Table 2).

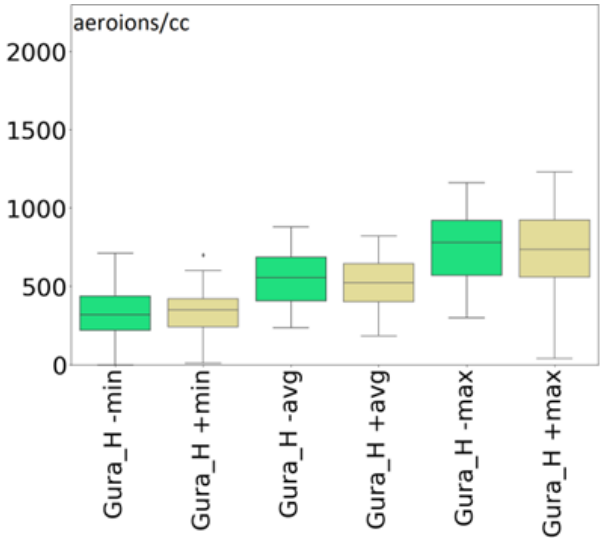
Table 2. Air ionization parameters in Solca, Cacica and Gura Humorului tourist resorts determined following observations made in May and August 2022.

Parameters	**SOLCA n_-**			**SOLCA n_+**		
	min	**avg**	**max**	**min**	**avg**	**max**
minimum with the lowest value	**0.0**			**0.0**		
averages of minimums	370.2			242.1		
average		**612.8**			**440.9**	
median		625.0			385.5	
average maxima			844.0			726.9
maximum with the highest value			**1410.0**			**1190.0**
Parameters	**CACICA n_-**			**CACICA n_+**		
	min	**avg**	**max**	**min**	**avg**	**max**
minimum with the lowest value	**20.0**			**40.0**		
averages of minimums	500.5			406.7		
average		**771.4**			**696.4**	
median		**787.0**			**687.0**	
average maxima			1093.3			1071.0
maximum with the highest value			**2150.0**			**1830.0**
Parameters	**GURA HUMORULUI n_-**			**GURA HUMORULUI n_+**		
	min	**avg**	**max**	**min**	**avg**	**max**
minimum with the lowest value	**0.0**			**10.0**		
averages of minimums	341.7			325.6		
average		**540.2**			**528.9**	
median		**552.0**			**537.5**	
average maxima			729.8			729.8
maximum with the highest value			**1160.0**			**1230.0**

The box plot diagrams display in a supple manner numerous statistical information regarding the variability but also the constancy over time of the levels of negative and positive air ionization in the three resorts (Figures 7 a – c). For the basic parameters analyzed (minimum, average and maximum), the higher levels of negative air ionization and lower levels of positive air ionization are clearly observed. It can be noted that in the resort of Cacica air ionization is a more intense and fluctuating atmospheric process. We can deduce that the air of the three resorts meets the qualities for practicing aeroionotherapy, and tourists can fully benefit from the predominantly negative atmospheric charge of aeroions.



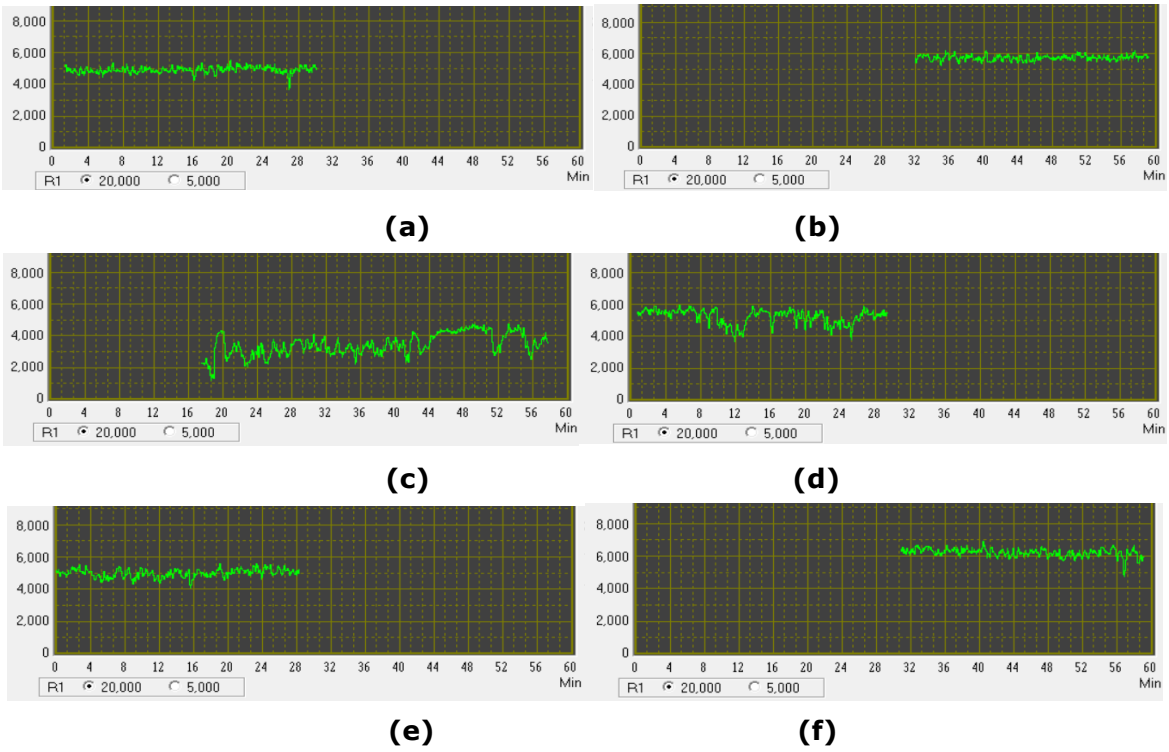
(a) **(b)**



(c)

Figure 7. Box plot type diagrams indicating air ionization parameters in the tourist resorts Solca (a)- [(20 and 28 May, respectively 27-28 August 2022)], Cacica (b)- [(21 and 27 May, respectively 23 -24 August 2022)] and Gura Humorului (c) - [(22 and 29 May, respectively 25-26 August 2022].

In the group of figures 8, the very low variability of the number of negative and positive aeroions can be observed at levels III and I of the salt mine and significantly higher at level II, which is a connection node of the access tunnels in the salt mine, but where the Bride's Lake, the Ballroom and the Salt Museum are located, interconnected with each other. At level II, more active air currents are formed that constantly and sensitively disturb the regime of air ionization (Figures 8 c and d).



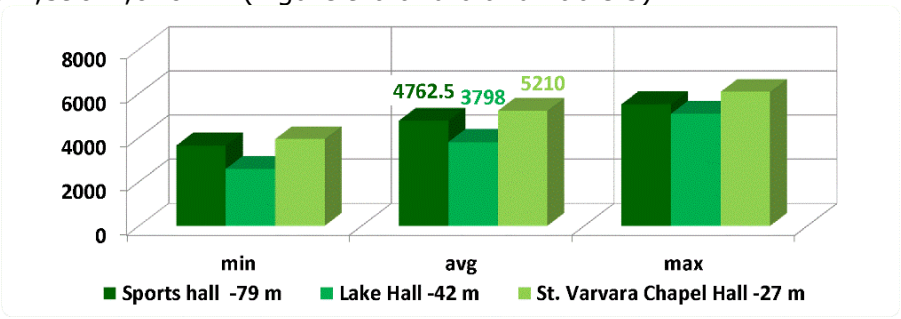
(a) **(b)**

(c) **(d)**

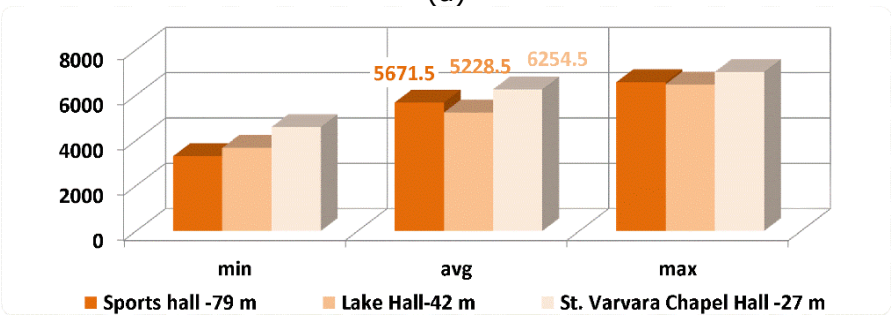
(e) **(f)**

Figure 8. Screenshots during the determinations of the number of negative / positive aeroions in the air of the Cacica salt mine in the Lower Hall (level III) (**a** n_-/**b** n_+), Hall of the Lake (level II) (c n_-/d n_+) and the Varvara Chapel hall (level I) (**e** n_-/**f** n_+) of the Cacica salt mine – September 15, 2022.

In the Cacica salt mine, the variability of ions was relatively small, but the average values of air ionization were very high: over 5,000 aeroions/cc in all 3 horizons where measurements were made. Thus, in the Sports Hall (-79 m) n- had values between 3,640 and 5,510 cc, and n+ a minimum of 3,300 and a maximum of 6,570 cc. In Lake Hall (-42 m) high values were also recorded: 2,580-5,080 n-/cc, respectively 3,670-6,470 n+/cc. The highest values were measured in St. Varvara Chapel Hall (-27 m): 3,930-6,070 n- and 4,590-7,020 n+ (Figure 9 a and b and Table 3).



(a)



(b)

Figure 9. The minimum, average and maximum number of n_- (**a**) and n_+ (**b**) (nr./cc) at the levels of -79 m, -42 m and -27 m in the Cacica salt mine on September 15, 2022.

Table 3. Air ionization parameters in the Cacica salt mine on September 15, 2022

Sports hall -79 m	**n-**			**n+**		
	min	avg	max	min	avg	max
10,00-10,30	4200	4623	5200			
10,31-11,00				5220	5722	6200
11,01-11,30	3640	4902	5510			
11,31-12,00				3300	5621	6570
Lake Hall -42 m	min	avg	max	min	avg	max
12,30-13,00	***2580***	3448	4770			
13,01-13,30				3670	5207	5940
13,31-14,00	2930	4148	5080			
14,01-14,30				4020	5250	6470
St. Varvara Chapel Hall-27m	min	avg	max	min	avg	max
15,01-15,30	3930	5000	5760			
15,31-16,00				4730	6210	6880
16,01-16,30	4470	5420	6070			
16,31-17,00				4590	6299	**7020**
Total	min	avg	max	min	avg	max
Sports hall -79 m	3640	4762.5	5510	3300	5671.5	6570
Lake Hall -42 m	***2580***	3798	5080	3670	5228.5	6470
St. Varvara Chapel Hall -27m	3930	5210	6070	4590	6254.5	**7020**

In the air of the resorts, k had average values between 0.7 at Solca and 0.98 at Gura Humorului (Figure 10 a).

K was 1.19 in Sports Hall, 1.38 in Lake Hall and 1.20 in St. Varvara Chapel Hall (Figure 10 b).

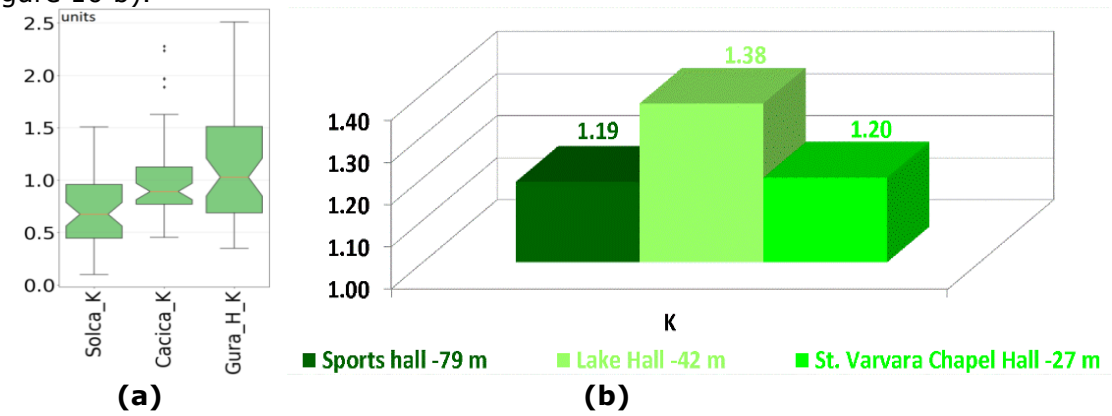


Figure10. Box plot diagrams of k in the Solca, Cacica and Gura Humorului tourist resorts resulting from measurements in May and August 2022 (**a**); k values at -79 m, -42 m and -27 m levels in the Cacica salt mine on September 15, 2022 (**b**).

3.3. The daytime regime of the air ionization process

The diurnal regime of atmospheric aeroion levels takes the form of the letter U in the case of n-, n+ as well as in the case of k. Relatively high values of total air ionization are observed, with more than 1,000 aeroions/cc throughout the day, with a maximum at 10.00 and 20.00. K on the other hand, reaches a maximum value in the morning (above 1.1 at 8.00 AM and 09.00 AM) and in the evening (8:00 PM), respectively, and drops to a minimum of 0.7 (at 13.00 and 14.00) (Figure 11 a-d).

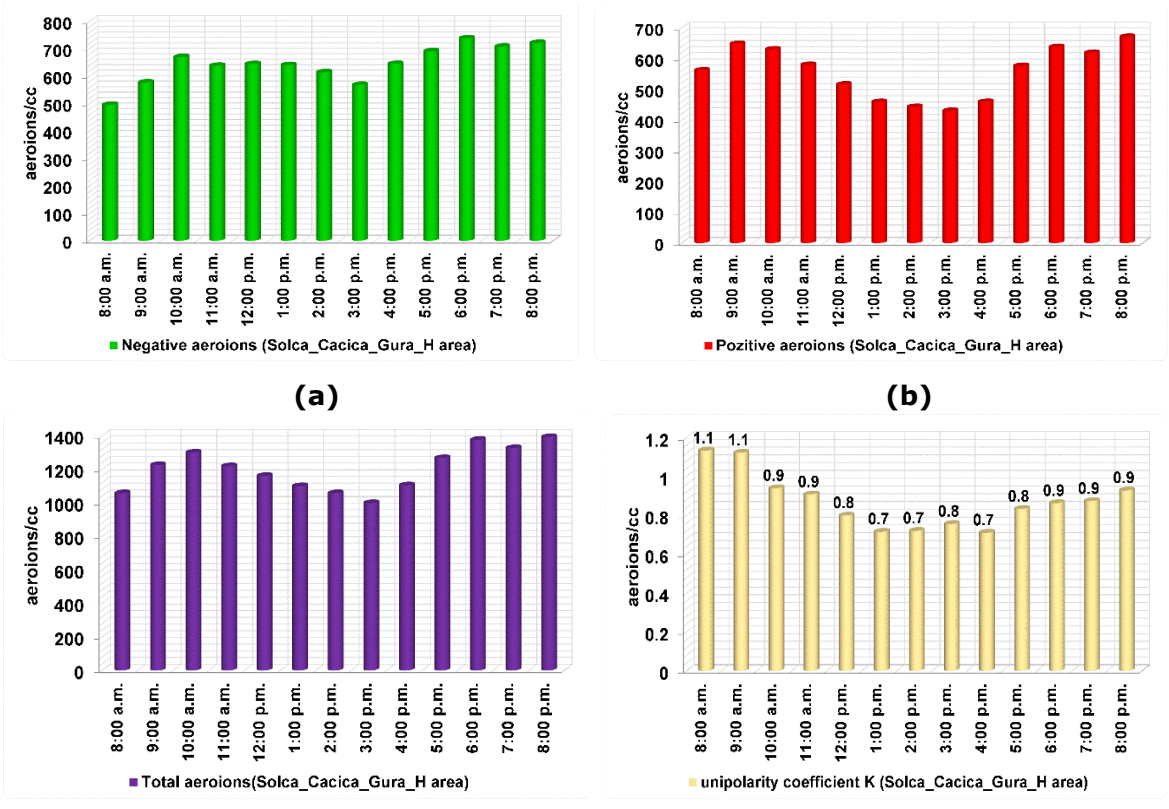


Figure11. The number of n_- (a), n_+ (b), of the total number (**c**) and of k (**d**) in the Solca, Cacica, Gura Humorului tourist area in the daytime interval 8.00 a.m. and 8.00 p.m. (May, August 2022)

4. Discussion

Air ionization on the territory of Romania has values between 650-2200 ions/cc. These differences are attributed to the geological constitution and the physical-geographical conditions of the location of the different resorts (Teodoreanu et al., 1984). Thus, in the mountain resorts, the air ionization values usually exceed 1,200 aeroions/cc and increase with altitude (Borșa with 1,212; Balvanyos-Turia with 1,435; Bușteni with 1,200-1,500; the 1,400 altitudes with 1,519 and the 2000 altitude with 1,917). The resorts in the hilly, submountain levels have close values of 1,000 aeroions/cc (Slănic Moldova with 920; Oglinzi 1,074 or Soveja 1,106). The plain and coastal plain floor has the lowest values of air ionization (Mamaia with 666; Eforie Nord with 903) (Enache, 2017, Enache and Bunescu, 2019). The aeroionometric determinations in the researched area are within those related to the hill floor.

For the salt mines, aeroionometric measurements were carried out over several years on various horizons (from -15 m in the Târgu Ocna salt mine to -110 m in the Turda salt mine), and the recorded values varied quite a lot: from a minimum of 320 aeroions /cc in Ocna Dej (-80 m) up to a maximum of 2,900 aeroions/cc in the Cacica salt mine (-58 m), with variable k (between 0.5 at Slănic Prahova and 1.48 at Târgu Ocna).

Table 4. The number of aeroions determined in the Cacica salt mine by various researchers

Cacica salt mine	n_+ (ions/cc)	n_- (ions/cc)	n total (ions/cc)	k	month / year	Source
	-	-	1.306	0,98	2008	Simionca, 2008
-38 m	1.490	1.420	2.910	1,05	IX, 2010	
-58 m	650	660	1.310	0,98	VI, 2009	Enache, 2017
-58 m	1.500	1.300	2.800	1,15	VIII,1999	
Sports hall -79 m	5.671,5	4.762,5	10.434	1,19		
Lake Hall -42 m	5.228,5	3.798	9.026,5	1,38	VII, 2022	Mihăilă et al., 2023
St. Varvara Chapel Hall -27 m	6.254.5	5.210	11.464,5	1,2		

A synthesis of the determinations made by Simionca (2008), Enache (2017) and Mihăilă et al. (2023) in the Cacica salt mine is presented in Table 4. The determinations in the Cacica salt mine in September 2022 captured levels of air ionization (Figures 8 a-f, 9 a - b, 10b, Table 3) which significantly exceed the previous ones (Table 4).

5. Conclusions

The days on which the aeroion measurements were carried out, from the months of May and August, were characterized by clear weather, average temperature values between 13-14°C in the morning and 26-31°C at noon. The humidity had high values in the morning and evening (85 - 86 %) and at noon it did not exceed 59 %. Cloudiness fell between 2.5 ocktas at Gura Humorului and 4.2 ocktas at Cacica. The wind did not exceed the average speed of 1 m/s during the determination period. Using the Pearson correlation coefficient and PCA analysis between the levels of air ionization and those of meteorological elements, we observed that air humidity directly proportionally and more significantly influenced these levels, and wind speed inversely proportionally influenced these levels, but to a lesser extent. The increase in air temperature contributed to the increase in the number of n- and to the reduction of the number of n+. From the value combinations of meteorological elements and other determining factors, a regime of air ionization results during the day with two maxima, in the morning and in the evening, when the determining factors of air ionization reach values more favourable to their genesis. With total average air ionization values of over 1000 aeroions/cc in all 3 resorts

(1,053 / cc at Solca, 1,068 / cc at Gura Humorului and 1,467 / cc at Cacica) and with subunit k, the atmosphere of the Solca-Cacica-Gura Humorului tourist region can be used therapeutically through aeroionotherapy, at least in the warm season. The high levels of air ionization in the Cacica salt mine recommend it for aeroionotherapy. The daily regime of the air ionization level is characterized by a maximum in the morning and evening and a minimum in the afternoon hours. The unipolarity index (k) has the same profile. Under these conditions, we can say that the time interval for aeroionotherapy recommended for tourists who come for relaxation, cure and treatment in the three resorts is in the morning (between 8:00 AM-11:00 AM) and in the evening (between 5:00 PM-8:00 PM).

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