Environmental Engineering and Management Journal

February 2019, Vol.18, No. 2, 447-454
http://www.eemj.icpm.tuiasi.ro/; http://www.eemj.eu

"Gheorghe Asachi" Technical University of Iasi, Romania

CHARGED AIRBORNE PARTICLES AS INDICATORS OF ATMOSPHERIC POLLUTION AND THEIR RELATION WITH LOCAL POPULATION HEALTH IN THREE ROMANIAN CITIES

Liliana Sachelarie[1], Mihaela Păpușa Vasiliu[1], Laura Ecaterina Dârțu[1*], Oana Maria Darabă[1], Maria Pușa Farcaș[2]

[1]Apollonia University of Iași, Muzicii Street, no. 2, 700399, Iași, România
[2]University of Oradea, Universității Street, no. 1, 410087, Oradea, România

Abstract

Electrically charged particles of air pollutants show the degree of atmospheric pollution they being consistent with some chemical indicators of air pollution. This study analyses these indicators of atmospheric pollution (EIAP) present in various zones around the cities of Iasi, Bacau and Piatra Neamt and correlate them with the incidence of some diseases amongst the population. The results show that certain values of electrical indicators of atmospheric pollution point to a higher incidence of diseases, especially to respiratory and cardiovascular diseases. Higher concentrations of electrically charged particles relate to higher degree of atmospheric air pollution and to higher incidence of disease in local population.

Keywords: air ionization, electrical indicators, environmental pollution

Received: March, 2015; Revised final: October, 2015; Accepted: October, 2015; Published in final edited form: February, 2019

1. Introduction

Air is essential for life. Air quality was and continues to be the main concern to all citizens, governments and international organizations who manage the conservation of our planet's health; the main reason for this ongoing concern is the fact that a clean atmosphere means a healthy environment, favorable for the development of life itself, from people to plants (Möller et al., 2008; Rusu et al., 2015). The role of atmospheric electricity in the vital activity of a healthy or a sick organism was studied by some researchers who highlighted the action and the effects of air ions such as Kuster and Barthel in 1951, Bisa in 1955, Rheinstein in 1960 and others.

Since 1980 the studies regarding air ions are dominated by American, Russian and Dutch researchers (Cramer, 1996; Kaune, 1983; Livanova, 1995; Reilly and Stevenson, 1993; Warner and Marchat, 1993). Using Ebert capacitors (which employs the principle of cylindrical condenser discharge, equipped with two-wire Leybold device) a group of Romanian researchers carried out a series of long-term experiments which were used to evaluate the influence of atmospheric phenomenon on the air ionization (Deleanu, 1983). Studies carried out in various Romanian spa resorts highlighted the curative and prophylactic effect of the air ions therapy.

The control of air quality requires a process of quantitative, qualitative, and repetitive observations and measurements of the concentration of one or more constituents. The data provided by the monitoring networks allows the calculation of air quality indicators, the identification of polluted areas, the comparison with the standards imposed by law and the implementation of rapid measures to eliminate and prevent pollution (Oprea et al., 2017; Rojanschi et al., 2002).

[*]Author to whom all correspondence should be addressed: e-mail: laura_ekaa@yahoo.com; Phone: +40742766813

In terms of health and preservation of environmental factors, the quantification of air pollution phenomena is a major challenge (Aionesei and Andriesan, 1986a; Manolache et al., 2017).The pollution sources which produce the greatest effect on air quality are the main branches of the economy: industry (electrical and thermal energy, construction industry, light industry and even the food industry), agriculture, transport and others. Pollutant dispersion into the atmosphere varies and depends on the source of pollution and the type of pollutant (Didă and Zoran, 2013). The neutral molecules of atmospheric air become ionized under the action of ionizing radiations contained in cosmic rays, which are composed of alpha, beta, gamma and ultra-violet radiation (Kelly and Fussell, 2011).

Gaseous ions carry charges equal to the integer number of elementary charges. Unlike electrolyte ions which are molecular ions, gaseous ions (air ions - atmospheric ions) resulting from the ionization of gases are atomic ions (McDonald et al., 1967). The air ions can be classified by the charge sign as positive air ions and negative air ions. Quantitative variations of air ions influence the oxidation capacity of the air penetrating the lungs and cells having repercussions for energy reserves in the tissues (number of ATP molecules) underlying the synthesis of cellular processes (Sierra-Vargas and Teran, 2012).

Air contains various numbers of air ions that form a spectrum; each category of these ions is defined by charge and mobility (in an electric field the speed of an ion is "1V/cm"); their mobility is inversely proportional to the pressure (Sabau, 2008). Air ions are involved in the metabolism of serotonin, neurohormone with implications for all body functions. Variation of air ions can shift the hydro mineral balance towards acid or base zone influencing the function of intracellular enzymatic equipment and the hydrolysis-synthesis processes. Negative air ions stimulate the immune system. Air ions are involved in the processes which ensure the nonspecific resistance of organisms to different diseases (Bencko, 1994; Ostro, 1993). The ionization degree of air gives us information concerning the state of atmospheric contamination. Morbidity or changes in the population differently contaminated are analyzed as a function of the indicators of air basin zoning (Coffin and Stokinger, 1977).

The *unipolarity coefficient (q)* can be used as an indicator of the air ionization degree, which is higher if the air is polluted, and the *polluting ionic coefficient (k)* which decreases from the source to periphery. The air from industrial and urban congestion is of lower quality and does not allow tissues to build up the necessary deposits of ATP-type macroergic molecules and as a result the integration and control systems of the body are constantly required to compensate for this deficiency (Deleanu, 1984).The respiratory system, having a direct and intimate connection with the environment, is strongly affected by atmospheric ionization (Bates, 1993). Therefore, positive or negative air ions are used in the treatment of various diseases with very good results. The effect of ions on the organism was studied and analyzed on a large scale by scientists (Jakab et al., 1995).

The aim of this study was to investigate the concentration of electrically charged particles in the air of threeRomaniancities and to determinetheireffect on the health of the population living in the investigated areas.

2. Materials and method

2.1. Sampling areas, procedures and climatic conditions

Our experiments were carried out in selected zones of three cities with different environmental and climate characteristics: Iaşi, Bacău and Piatra Neamţ, with a view to investigate the electrical indicators of atmospheric pollution (EIAP) and to correlate them with the incidence of respiratory and cardiovascular diseases.

The city of Iaşi is located in the north-east of Romania, at an altitude of 95 m above the mean sea level, has a generally mild climate, average relative humidity of 70%, average annual temperature of 9° C and the dominant air currents are in the east and south-east direction. Bacau is located in the central region of the Moldova province, at an altitude of 165 m above the mean sea level, with a mild climate, moderate cold winters and the dominant air currents are in the east and north-east direction. Piatra Neamt is located in the north-east of Romania, at an altitude of 345 m above the mean sea level and with a mild climate, being situated in a valley surrounded by mountains which provide protection. All three cities included in the study are industrial centers with heavy industry, light, manufacturing and quarrying.

The sampling sites were chosen at a distance greater than 3000m from the air currents circulating above the industrial areas. At Bacau and Piatra Neamt the measurements were taken in a central city area, and at Iasi in a suburb. The sampling and recording period of the electrical indicators of pollution (the nucleo-ionic pollution coefficient P) took place in different months of 2014.

Table 1. Sampling period in each city

City	*Period I*	*Period II*	*Period III*
Iasi	February	April	July
Bacau	January	June	September
Piatra Neamt	March	May	September

For electrically charged particles of pollution, we used the nucleo-ionic pollution coefficient (P) which is defined by the ratio of average concentration of the condensation nuclei per cm^3ofair (this concentration increases in the polluted environment) and sum of the positive and negative air ions concentrations from the same area. The formula is represented by Eq. (1):

$$P = \frac{NdC}{(n^+)+(n^-)} \quad (1)$$

where: P – nucleo-ionic pollution coefficient; NdC– average concentration of the condensation nuclei per cm^3 of air; $(n^+)+(n^-)$ – sum of the positive and negative air ions concentrations.

2.2. Instrumentation

Our measurements were carried out using a meter whose function was based on the principle of plan capacitor with aspiration. The device was developed within Polytechnic Institute. This device is made of two parts: the aspiration capacitor and the measurement block. The air sample is passed through the space between the capacitor's reinforcements which are exposed to a potential difference in order to allow the ions to circulate in an electric field and create an ionic flux. This generated flux is directly proportional to the number of ions that arrive in the capacitor (the flow in cm^3/h).

Air ions could be identified by the following properties: positive or negative charge, chemical under-layer (gases from air, humidity, small drops of solid particles), the number of charges (small ions have only one elementary charge, the larger ones may have more elementary charges), electrical mobility and life-time (from few seconds to several hours). In an impure or very wet atmosphere small ion settle and form larger ions. The quantity and the air humidity of the aggregation in the atmosphere are influenced by air temperature. Air humidity influences the air quality of the study zone and the health of the population. The moisture from the atmosphere, together with other weather variables (air temperature, wind) may constitute a major risk factor for the human body (Mathay et al., 1996).

The measurement of the degree of atmospheric impurity and its distribution within the zones under investigation is influenced by the absolute concentration of small ions (these are less numerous immediately near the pollution sources and their number increases as the distance from these sources increases), by the pollution coefficient (K-the ratio between the sum of large ion pairs and the sum of small ion pairs of both charges, the result of which decreases from the source to periphery) and by the coefficient of small ions with unipolarity (q-the ratio between the concentration of small positive ions and the negative ions, which increases with increasing air pollution).

The air ionization is also influenced by other factors, such as: air humidity (when these increases, the ion concentration decreases), water vaporization and condensation (producing an excess of positive ions with unfavorable effects), atmospheric pressure (inversely proportional), air movement (modifies the concentration of air ions), air temperature (direct ratio), solar radiation (air ions appear in all redox reactions) (Popa, 2005).

The excess of negative air ions is favorable to the increase of human resistance and unfavorable to the development of pathogens. Atmospheric electricity in the form of air ions and the air-electrical field is an energy form that influences human health. The ions from the atmosphere, in which atmospheric oxygen is included, affect cell processes, especially the energetic metabolism (Holgate, 2010).

We determined the number of small positive / negative air ions, the number of large ions and condensation nuclei and then we calculated the ratios between them and indices recommended in the literature. Previous experimental measurements made in our country indicated natural concentrations of air ions between 600-2200 pairs/cm^3**,** however in spa resort regions the values were higher (Deleanu et al., 1969). For the measurements we used an air ion meter (target collector method) which consisted of a probe (original collector) and an ion counter. In terms of mobility and size, air ions could be classified as small and large. The mobility of small air ions is high while that of the large air ions is extremely low.

The air ions collected on the probe surface generated a current proportional to their number and the flux in cm^3/h. Their deposit on the probe is determined by the action of: the electrical field of the charge, the ionic air volume, the exterior electrical fields, the inertia forces in case of heavy air ions and the probe intrinsic field (Aionesei and Andriesan 1986b). If the probe is working on a low potential, then air ions can be captured by both polarities, performing a summation and an indication of excess polarity. This is the reason why measurements made by this method are more precise. This counter has a higher sensitivity if high ohm value resistors are used.

At the sampling point in Iasi, we observed a decrease in the values of small positive ion concentrations, the tendency being clearly to decrease. At the sampling point in Bacau the values of small positive ion concentrations increased during the measurement period, the tendency being to increase. At the sampling point in Piatra Neamt we observed a constant value of 700 small positive ions/cm^3, the tendency being static.

3. Results and discussion

In the investigated cities we found that the number of small positive ions ranged between 550-797 ioni/cm^3 (Fig. 1). The highest concentrations of small positive air ions were recorded within the measurements conducted at the sampling points of Bacau and Piatra Neamt, places where we found a high level of pollution; this indicates that the number of small positive ions increases with an increasing degree of air pollution. These large concentrations of positive ions recorded in Bacau and Piatra Neamt indicate a high degree of pollution.

Also, a large variation was recorded in the number of small negative ions measured in the investigated areas. Small negative ions evolve depending on the degree of atmospheric air pollution with values which increase in areas with low pollution and decrease when the degree of atmospheric air pollution increases (Enache et al., 2005) (Fig. 2).

Air ions may act upon the human body in two ways: by entering the lungs together with the inhaled air or by acting directly upon the skin (Abdulaev et al., 1993). At the sampling point in Iasi, we observed an increase of the values of small negative ion concentrations during the measurements, the tendency being moderately upward. At the sampling point in Bacau the values of small negative ion concentrations remained constant, in close limits but presenting a moderate tendency to increase. At the sampling point Piatra Neamt, these values were around 350 small negative ions/cm^3, having a moderately decreasing tendency. Small negative ions are influenced by the degree of air pollution: their number is higher as the air is cleaner and decreases when the air pollution increases. The results showed large variations in the numbers of condensation nuclei recorded in the investigated areas. The highest number of condensation nuclei was recorded in Bacau and Piatra Neamt areas, whilst at the Iasi sampling point, during the measurements, adecrease of these values was observed (Fig. 3). At the sampling point in Bacau, during the measurement period, we observed a significant increase of the values of condensation nuclei/cm^3.

At Piatra Neamt, however, the number of condensation nuclei/cm^3 showed a modest decrease. Fig. 3 shows clearly that the number of condensation nuclei within the cities increases with the increasing degree of pollution and is directly proportional to them. In the areas where we conducted our measurements, we observed wide variations in the number of large ions, both positive and negative. Fig. 4 shows the quarterly average values of large positive and negative ions in each area.

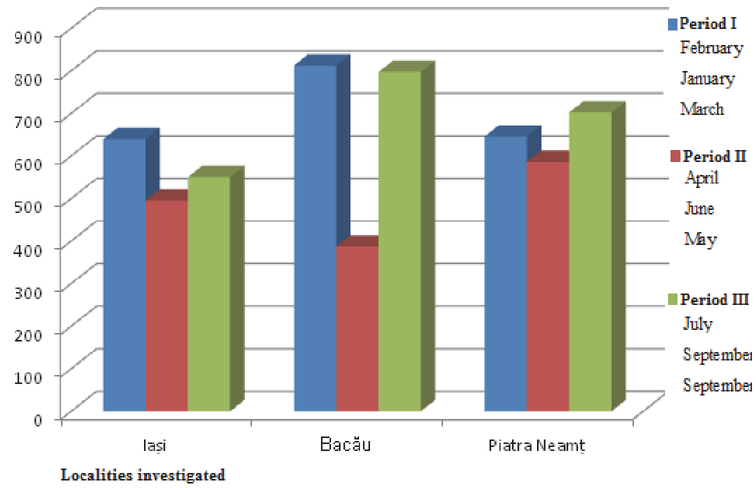

Fig. 1. The average values of small positive air ion concentrations (number of ions/cm^3) recorded in the areas studied during the three periods

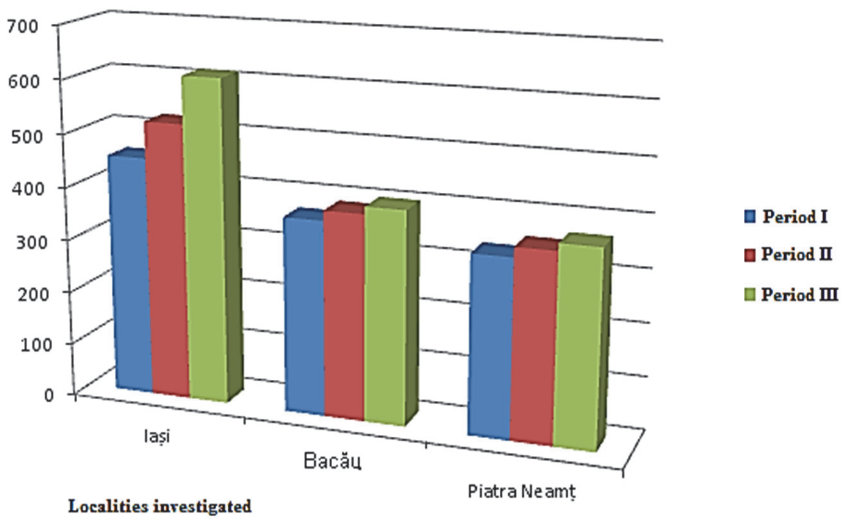

Fig. 2. The average values of small negative air ion concentrations (number of ions/cm^3) recorded in the areas studied during the three periods

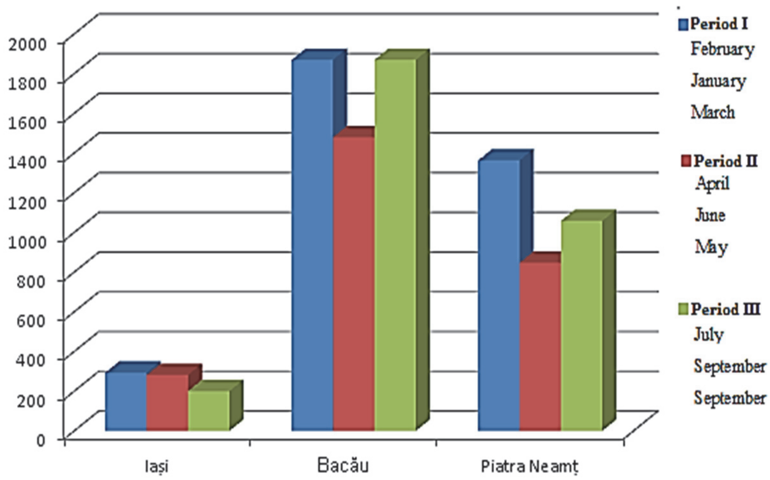

Fig. 3. The average values of the number of condensation nuclei (number x $10^2/cm^3$) recorded in the areas studied during the three periods

The highest level of large positive and negative ions were registered at the sampling points in Piatra Neamt and Bacau, presenting a clear increasing trend. The ratio of nuclei-ions of pollution P, varied within wide limits in all areas studied (Fig. 5). The P ratio defines the degree of air pollution in an area. Deleanu and al. (1969) consider that at values smaller than 10 the area may be considered clean, between 11-45 the area may be considered slightly polluted, between 46-110 areas are polluted, and over 111 areas are very intensely polluted.

At the sampling point Piatra Neamt we observed a smaller decrease of the P ratio, presenting a clear decreasing tendency, this means that the area could be included in the category of slightly polluted areas. Using this criteria, the studied areas could be classified as follows:

- Iasi is a polluted area;
- Bacau is a very polluted area;
- Piatra Neamt changed from a very intensely to a moderately polluted area.

These changes are mainly due to the dramatic decrease of manufacturing industry, but they were also influenced by the increasing number of vehicles, as a result of which the NO_2 pollution increased.

Road traffic is responsible for 70% of air pollution, 90% of carbon monoxide pollution and 60% of nitrogen oxide pollution, as well as lead emissions (which are three times greater than those caused by industrial activity). The degree of air pollution is usually defined by the ionic pollution parameters and their values are in perfect accord with some of the chemical parameters of air pollution, because ionic parameters are highly influenced by the humidity level present in the air. The level of humidity affects the number of small negative ions which decrease in number at high humidity levels.

Under our experimental conditions employed in the areas studied, the ratio between the sum of large ions and the sum of concentrations of small positive and negative air ions was the most credible result and indicated the lowest level of variability due to environmental conditions. This ratio is just as important as the chemical parameters for the measurement of the degree of air pollution in an area. During our study of the selected areas, we observed that with increasing air purity the number of small ions increased and, in areas statistically classified as polluted this number decreased with an increasing pollution level.

Using statistics provided by the medical services and the data for the electrical indicators of pollution a correlation was found regarding some aspects of public health issues especially those related to respiratory and ophthalmic diseases (Jakab et al., 1995; Mitchell and King, 1994). The results of air pollution analyses highlighted the high-risk zones present in the studied areas. In these areas we can assume that the incidence of respiratory diseases as well as ophthalmic diseases is higher than in areas with low levels of pollution (Juniper et al. 2000; Sava and Sinitchi, 1998). Thus, Bacau registered the highest incidence of acute forms of bronchitis and Piatra Neamt the lowest. The specific incidence of respiratory disease is presented in Fig.6.

The human respiratory system is highly influenced by air ions because it is directly and intimately related to the atmospheric environment. When negative ions are detected in air, healthy people show a decrease of respiratory frequency as a consequence of the increased permeability of the respiratory system. Higher concentration of ions of both charges, 5000-6000 per cm^3, also induces a respiratory stimulation. The negatively ionized oxygen is utilised better by the respiratory system, as indicated by a decrease of the catalysis (the oxy-reducing enzyme present in the lungs). Air ionization protects the mucus of respiratory channels against some aggressive toxic particles, depending on the particle's charges (those with negative charge). Higher concentration of positive air ions gives the sensation of dryness to the respiratory system, the entire body feels fatigued, it produces headaches and reduces the working capacity of the body.

Therefore, air ionization has a significant effect on the human body. The pulmonary pathway represents the gate through which air ions enter and act upon the organism, allowing the electrically charged particles to go through the alveoli and to transfer their charge to cells and blood colloids. This transfer is an induction phenomenon to alveoli level which determines the electrical charge of blood elements, the charge in alveoli being $1,5x10^4$, this giving in the adjacent capillary axis a potential of 42,5. In artificial conditions, when the ionization level increases, a normal subject could inhale up to $5x10^8$ ions, this means up to $3x10^9$ eV (Kruger and Reed, 1972). When large quantities of positive ions are ingested, the defense of the immune system of a human respiratory system decreases (Boe et al., 2000).

The exposure to negative air ions does not affect the volume of air inhaled, but the exposure to positive ions does, making breathing more difficult. As already remarked, the highest incidence of forms of acute bronchitis were recorded in Bacau and the lowest in Piatra Neamt (Fig. 6). In these areas the frequency of respiratory diseases, both conjunctive and chronic, is significantly higher than in the areas with lower air pollution levels.

Ophthalmic afflictions were more frequent in Bacau, however in Piatra Neamt, we recorded an increasing tendency to ophthalmic afflictions during the measurement period. We also observed that ophthalmic diseases have a higher frequency in younger people (Fig.7). During measurements in Bacau, the specific incidence of ophthalmic illnesses showed a tendency to increase. In the investigated areas we found an increased number of small ions present in the unpolluted air and in the areas designated statistically as polluted, the number of small ions decreased in proportion to the degree of pollution.

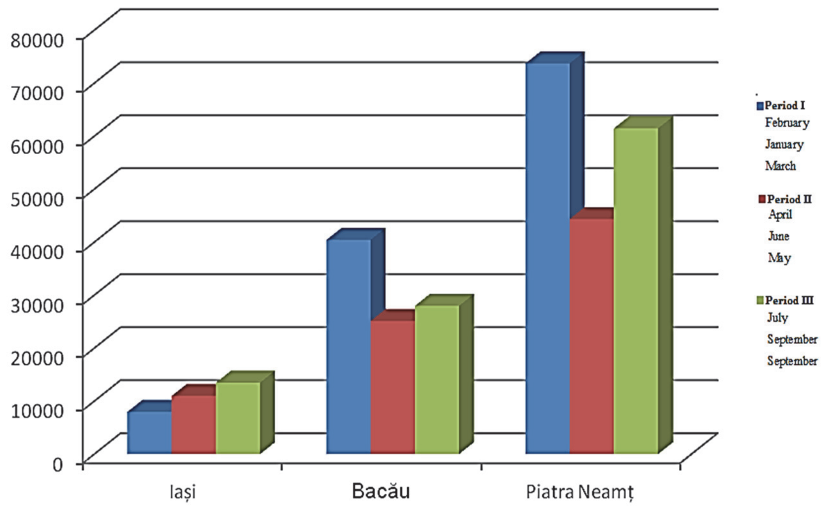

Fig. 4. The average values of large negative and positive air ion concentrations (number of ions/cm^3) recorded in the areas studied during the three periods

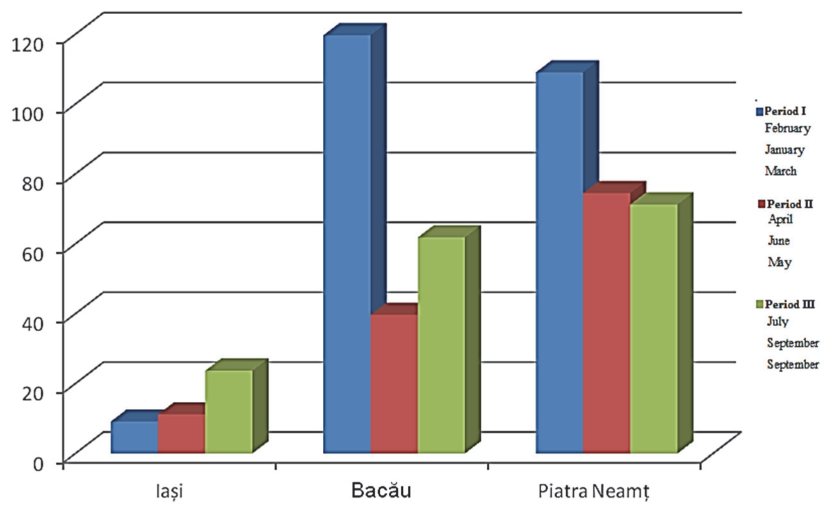

Fig. 5. The average quarterly values of P ratio in the studied areas

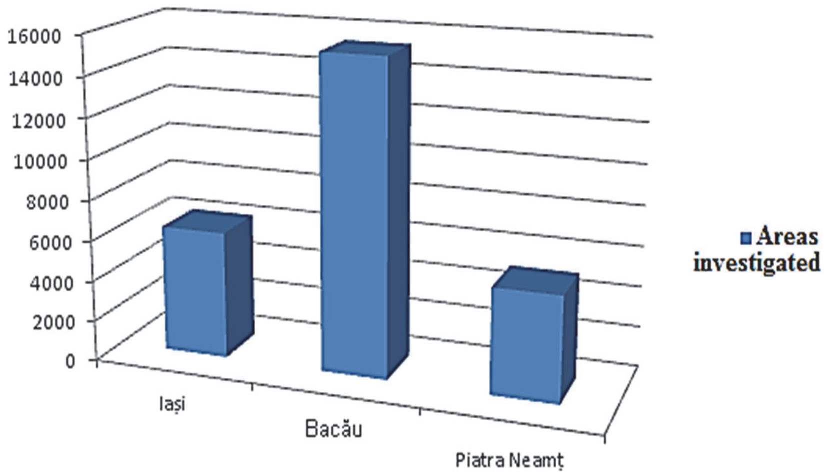

Fig. 6. The specific incidence of respiratory diseases in the investigated areas

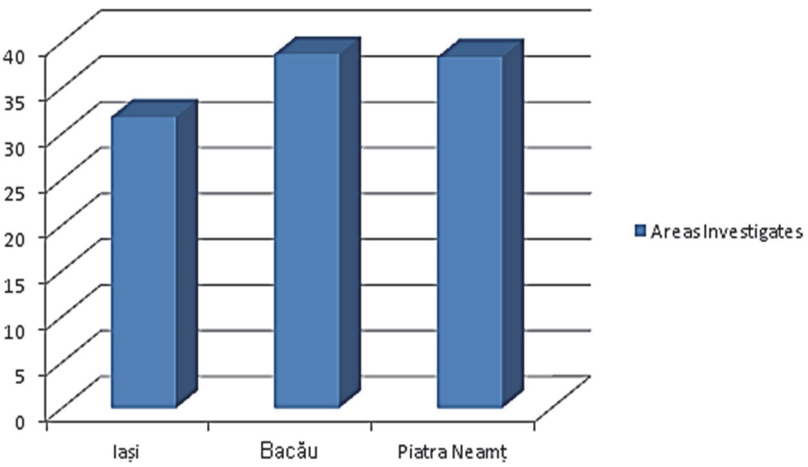

Fig. 7. The specific incidence of ophthalmic illnesses in the studied areas

The results obtained from the investigated areas have established a connection between the degree of pollution, the electrical indicators of environmental pollution and the incidence of respiratory disease. The results revealed a higher degree of air pollution in the sampled areas of Bacau and Piatra Neamt and lower in Iasi. The degree of pollution is strongly reflected by the increase of small positive air ions and by the concentration of condensation nuclei.

It should be emphasized that a small negative air ion concentration is inversely proportional to an air quality reduction, indicating that an increase in the concentration of small negative ions in air corresponds to unpolluted air, while a decrease corresponds to reduction in air quality. The results demonstrated that the pollution degree is inversely proportional to the number of small ions from the atmosphere. When air pollution increases, the number of small positive ions increases also. In terms of the health of the local population we referred especially to respiratory and ophthalmic diseases these having a higher incidence in areas where air has a higher degree of pollution, a result which was not surprising.

The degree of pollution is strictly reflected by the increase of small air ions (positive and negative), the sum of large ions and the value of the P ratio (inversely proportional to the decline of air quality). The values of air quality parameters determined could be sufficient to characterize the air in the locations investigated.

4. Conclusions

Our investigation attempted to establish a correlation between pollution, the degree of ionization of the atmosphere and the incidence of respiratory diseases.

The results obtained demonstrated a higher degree of air pollution in the sampled areas in Bacau and Piatra Neamt and lower in Iasi. The pollution degree was reflected by the increase of small positive air ions and of the concentration of condensation nuclei. The results clearly revealed the hypothesis of an association of respiratory diseases with air pollution, which, in turn, can be correlated to the values of electrical indicators of atmospheric pollution with different contributions depending on the duration and exposure intensity.

References

Abdulaev A.A., Gadzhiev K.M., Eiubova A.A., (1993), The efficacy of speleotherapy in salt mines in children with bronchial asthma based on the data from immediate and late observations, *Vopr Kurortol Fizioter Lech Fiz Kult*, **5**, 25-28.

Aionesei M., Andriesan C., (1986a), *Some Problems with the Aero Ions Dosing*, National Symposium of Air Ionization, vol II, Botosani, Romania, 306-317.

Aionesei M., Andrișan C., (1986b), *Verification of Aeroions Emission Regime*, National Symp. of Air Ionization, vol.II, Botosani, Romania, 266-267.

Bates D.V., (1993), Detection of chronic respiratory bronchiolitis in oxidant-exposed populations: analogy to tobacco smoke exposure, *Environmental Health Perspectives*, **101**, 217-218.

Bencko V., (1994), Health risk of indoor air pollutants: A Central European perspective, *Indoor and Built Environment*, **3**, 213-223.

Boe J., Dennis J.H., O'Driscoll B.R., (2000), European respiratory society nebulizer guidelines: clinical aspects, *European Respiratory Review*, **10**, 495-496.

Coffin D.L., Stokinger H.E., (1977), *Biological effects of air pollutants*, In: *Air Pollution*, Vol. II, Stern C.A. (Ed.), Academic Press, New York, 231-360.

Deleanu M., Strauss H., Elges E., Toader A, (1969), Experimental research on the influence of air ions on the human body, *Hygiene*, **12**, 717-726.

Deleanu M., (1983), *Air Ionization*, In: *Encyclopedia of Ocupational Health and Safety*, International Labour Office, vol. I, Geneva, 94-95.

Deleanu M., (1984), *Measurement of Air Ionization in the Different Environmental Conditions*, First National Symposium of Air Ionization, Botoșani, Romania.

Didă M.R., Zoran M., (2013), *Climate Change and Extreme Heat Events in Urban Areas in Relation with Health*, Proc. 13th International Balkan Workshop on Applied Physics, Constanţa, Romania.

Enache L., Filipescu C., Simionca Iu. (Ghe.), Botea S., Hoteteu M., Kiss Ja., Petec Calin Ghe., Rogojan R., (2005), *Natural and Artificial Air Ionization in Underground Spaces – an Environmental Factor with Therapeutic Potential*, Proc. of the 14th International Congress of Speleology, 21-28 August 2005, Kalamos, Greece, 426-429.

Holgate S.T., (2010), A brief history of asthma and its mechanisms to modern concepts of disease pathogenesis, *Allergy, Asthma and Immunology Research*, **2**, 165-171.

Jakab G.J, Spannhake E.W., Canning B.J., Kleeberger S.R., Gilmour M.I., (1995), The effects of ozone on immune function, *Environmental Health Perspectives*, **103**, 77-89.

Juniper E.F., O'Byrne P.M., Ferrie P.J., King D.R., Roberts J.N., (2000), Measuring asthma control. Clinic questionnaire or daily diary?, *American Journal of Respiratory and Critical Care Medicine*, **162**, 1330-1334.

Kelly F.J., Fussell J.C., (2011), Air pollution and airway disease, *Clinical & Experimental Allergy*, **41**, 1059-1071.

Kruger A.P., Reed E.J., (1972), Effect of the air environment on influenza in the mouse, *International Journal of Biometeorology*, **16**, 209-232.

Manolache G., Voinea S., Skliros D., Stefan S., (2017), Comparative study of urban and rural atmospheric aerosols in and near Bucharest, Romania, *Environmental Engineering and Management Journal,* **16**, 2381-2389.

Mathay M.A., Folkesson H.G., Verkman A.S., (1996), Salt and water transport across alveolar and distal airway epithelia in the adult lung, *American Journal of Physiology*, **270**, 487-503.

McDonald R.D., Bachman C.H., Lorenz P.J., (1967), Some psychomotor and physiological tests on human exposed to air ions, *Aerospace Medicine*, **38**, 145-148.

Mitchell B.W., King D.J., (1994), Effect of negative air ionization on airborne transmission of Newcastle disease virus, *Avian Diseases*, **38**, 725-732.

Möller W., Felten K., Sommerer K., Scheuch G., Meyer G., Meyer P., Häussinger K., Kreyling W. G., (2008), Deposition, retention, and translocation of ultrafine particles from the central airways and lung periphery, *American Journal of Respiratory and Critical Care Medicine*, **177**, 426-32.

Oprea M., Dunea D., Liu H.Y., (2017), Development of a knowledge based system for analyzing particulate matter air pollution effects on human health, *Environmental Engineering and Management Journal,* **16**, 669-676.

Ostro B.D., (1993), Examining acute health outcomes due to ozone exposure and their subsequent relationship to chronic disease outcomes, *Environmental Health Perspectives*, **101**, 217-218.

Popa G., (2005), Environmental protection, sustainable development and globalization, *Academica*, **15**, 68-75

Rojanschi V., Bran F., Diaconu G., (2002), *Protection and Environmental Engineering* (in Romanian), Economic Press, Bucharest, Romania.

Rusu C., Preda C., Sireteanu A., Vulpoi C., (2015), Risk factors in autism spectrum disorders: the role of genetic, epigenetic, immune and environmental interactions, *Environmental Engineering and Management Journal,* **14**, 901-917.

Sabau N.C., (2008), *Pollution of Pedospheric Environment*, Oradea University Press, Oradea, Romania.

Sava D.I., Sinitchi G., (1998), Comparative study on the effectiveness of treatment with negative air ions to classical therapy of chronic bronchitis, *Allergy*, **53**, 154.

Sierra-Vargas M.P., Teran L.M., (2012), Air pollution: Impact and prevention, *Respirology*, **17**, 1031-1038.