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Atmospheric light air ion concentrations and related meteorologic factors in Rezekne city, Latvia

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Abstract

The well-minded impact of light negative air ions on human organism is still under discussion. The measurements of air ions are not widespread in Latvia yet. The paper presents new results of air pollution evaluation in Rezekne city. Measurements of positive and negative air ion concentrations in Rezekne city were taken during the spring, summer and autumn 2009 and during the winter 2010. Measurements were taken by portative air ions counter "Sapfir-3M" in eight different points of Rezekne city thrice a day. The concentrations of positive and negative air ions with mobility factor $k \geq 0.4$ $cm^2 V^{-1} s^{-1}$ were measured. Temperature, relative humidity, wind velocity, direction, etc., were also taken into account. The approximate interconnection between ionization and chemical and mechanical air pollution in relation with meteorological conditions was analyzed. The highest level of air ion concentration was observed in mornings, whereas in afternoons this concentration level decreased due to the growth of anthropogenic air pollution in the city, as light air ions, because of their charge, promoted the coagulation and the settlement of pollution particles. This regularity is typical for summer, whereas in spring, autumn and winter it is not characteristic. The unipolarity factor was usually less than 1 in mornings, but usually larger than 1 in afternoons especially in the most polluted city areas where minor concentration of air ions was detected. The ionization level is an original indicator of energetic saturation and aerosol pollution of atmospheric air.

Key words

Air ions, Air quality, Air pollution, Air ionization

Introduction

Air quality is one of the most important factors to guarantee the quality of human life. At the same time, the atmosphere is exposed to the impact of pollution. Continuous movement of air masses in local and global area refers to the spread of pollution over wide territories and to the changes of pollution concentration in time and space. Consequently, the measuring of air pollution, its perfection and regularity are the most important components of every monitoring system.

Nowadays, there are many discussions about the chemical and mechanical air pollution. Such parameters as the concentration of CO_2, SO_2, NO_x, O_3, benzene, toluene, dust particles etc. are often monitored. In fact, the concept of air quality cannot be formulated only as the presence of various substances in the air. The air is environment where different kinds of energetic fields are also present, and the source of which may be located out of the analyzed air volume.

Air ionization is a process when positive and negative air ions form in atmosphere due to the impact of natural or artificial anthropogenic effects. The term "air ion" signifies all airborne particles that are electrically charged and serve as a basis of air conductivity. Hence "air ions" comprise a large variety of charged particles of different chemical composition, mass and size, from molecular clusters up to large aerosol particles (Dolezalek *et al.* 1985, Tammet, 1998).

Air ions differ by their mobility, which is a function of their mass. According to their mobility the air ions are classified into small or cluster ions if the mobility $K > 0.5$ $cm^2V^{-1}s^{-1}$, intermediate ions, and large ions if the mobility $K < 0.03$ $cm^2V^{-1}s^{-1}$ (Tammet, 1998). During their lifetime cluster ions undergo series of transformations by ion-molecule reactions, continuously changing their chemical identity. The cluster ions are removed from atmosphere either by random attachment to the aerosol particles, resulting in formation of "aerosol ions", by ion-ion recombination or other loss mechanisms. In other classification cluster ions are called "light ions" and aerosol ions are called "heavy ions".

As natural sources of ionization mostly can be radioactivity of the earth's crust, cosmic radiation, the friction of water droplets (hydroaeroionization), friction of air mass's movement, magnetic storms, open flame, hot surfaces, etc.

The problem of environmental air ion importance involves two subjects: Air ions as an environmental factor and air ions as an environmental indicator. Air ions are important in the electrical processes, in the formation of aerosol particles in the atmosphere, etc. Air ions are involved in the formation of secondary aerosol particles by ion induced nucleation and they are responsible for the establishment of charge distribution on initially neutral aerosol particles. The mobility spectrum of natural air ions is known to respond to many processes of local and regional scale: air pollution, environmental radioactivity, boundary layer turbulence and meteorology (Horrak, 2001).

The measurements of atmospheric electrical conductivity as an indicator of air particulate pollution can be dated back to the beginning of the 20^{th} century. Due to ambiguous interpretation of atmospheric conductivity, many scientists have been looking for other electrical methods and factors based on the measuring of depletion rate of small ions by aerosol particles to determine particulate pollution of air (Flagan, 1998, Hoppel, 1970). The concepts of "electrical factor of air pureness" (Tverskoi, 1949; Smirnov, 1983) and "aerosol electrical density" (Tammet, 1991) were introduced. The mobility spectrum of large ions, if it is in balance with aerosol particle size spectra, is a proper measure of atmospheric aerosol pollution. The small ion mobility spectrometry is widely used to detect some gaseous trace species in air (Carr, 1984; Eiceman and Karpas, 1994). The major environmental and industrial applications of ion mobility spectrometry include monitoring of toxic chemicals, stack gases, and chemicals that are considered to be hazardous for man and environment (e.g. military gases, explosives, drugs). Even small concentrations of such trace gases like pyridine strongly and uniquely affect the mobility spectra of positive air ions (Parts and Luts, 2004). The mean mobility of small ions also showed response to air pollution (Hoppel, 1970; Parts and Salm, 1992).

Motor vehicles emit light ions of both signs in roughly equal numbers, increased sharply with engine speed (Jayaratne *et al.,* 2010). A significant source of aerosol particle and air ion emissions in cities is exactly diesel engines. The number of emitted ions and particles can be strongly dependent on presence and type of exhaust after-treatment system (Lähde *et al.*, 2009).

Ionic factor of pollution $\left(\frac{N^{\pm}}{n^{\pm}}\right)$ was suggested by Russian professor M.G.Shandala in early 70's to evaluate anthropogenic air pollution over industrial zones and big cities. This factor is relationship between heavy and light air ion concentrations of both polarities. Within the metallurgical plant value of the factor has reached 71; 0.5 km away - 55, but 3 km away just 36 (Shandala, 1974).

"Air ion mobility spectrum at a rural area" refers to measurements of ion spectrum and wind direction taken in Tahkuse observatory in 1993 - 1994. The air coming from the sector from the West to the North-northwest is characterized with higher concentrations of small air ions (0.5-3.14 $cm^2V^{-1}s^{-1}$) and few large heavy ions (mobility k 0.00041 - 0.0042 $cm^2V^{-1}s^{-1}$, diameter 22-79 nm). This sector is expected to be relatively clean compared with others (Horrak, 2001).

The studies of air ion impact on humans started in 1930s. Since then, there have been many studies with contradictory results. The widespread belief of the direct biological effects of air ions on live organisms deserved critical comments (Dolezalek *et al.,* 1985). The physical and chemical side-effects associated with ion generation by natural or artificial ionization are probably the main cause of observed biological relevance. The large air ions just like aerosol particles in ambient air can affect human health due to their depositing in the respiratory tract (McClellan and Miller, 1997).

In many trials significant influence of physiological side-effects is denied, and impact of air ions on human health, well being and mental abilities is highlighted (Fornof and Gilbert, 1988). The impact of air ions on human health and the environment in whole depends on the degree of ionization and on ion polarity. Ion polarity is characterized by unipolarity factor K, which is the relation of concentration of positive ions and concentration of negative ions in $1cm^3$ of the air.

$$K = \frac{n^+}{n^-}$$

The research in medicine shows that it is necessary to ensure the presence of both negative and positive ions to ensure a good quality of human life. Unlike positive ions, increased negative air ion levels are reported to have beneficial effect. The negative charged oxygen ions can be assimilated more easily in organism and thus play very important role in metabolism. The physiological impact of the positive and negative air ions is described in the Table 1.

The object of the study is the level of air ionization in the Rezekne city and its changes over time and space. Different sources of atmospheric pollution can affect the ionization level of the ambient air in different city parts. It is supposed that air ions, due to their charge, can promote the coagulation and settlement of pollution particles. This is the first step to find out possible correlations between air ion concentration and air quality in the city.

Table - 1: A comparison of impact of the positive and negative air ions on human health

Negative air ions	Positive air ions
- Reduction of the level of serotonin in blood	- Increasing of the level of serotonin in blood
- Raising the level of glucocorticoid in adrenal glands	- Promotion of mineralizing of corticoids in adrenal glands
- Stimulating of thyroid- Stimulation of ovary	- Failed activity of thyroid- Impairment of ovary
- Activation of testis	- Decreasing of alertness and concentration
- Promotion of deep and persistent sleep	- Causing sleep disturbance
- Reduction of aggression and anxiety	- Increased aggression and irritability
- Memory improvement	- A memory weakening
- Regulation of arterial blood pressure	- Over-sensitivity to pain
- Increasing of tolerance to pain	
- Improvement of brain function	

Materials and Methods

Rezekne is the 7th biggest city in Latvia, historical and geographical centre of Latgale region, located in the eastern part of the country bordering with Russia, Lithuania and Byelorussia. The lowest point in Rezekne is 130 m asl, whereas the highest point reaches approximately 187 m asl. Rezekne is situated in Atlantic continental humidity temperature zone and it results in rather cool summers and mild winters. 70% of city territory is built up, 13% is green area but 15% is industrial zone. In 2009, the population was 35 526, the density of population – 1973.7 people km^{-2}.

To evaluate the air ion level and the dynamics of its changes, measurements of light air ions concentration in different places of Rezekne city were made. Bipolar air ions counter "Saphire-3M" was used. Air ion counter is intended to provide separate and simultaneous measurements of negative and positive air ion concentration in 1 cm^3 of the air with mobility factor $k \geq 0.4$ cm^{2}V^{-1}s^{-1}. Minimum resolution of the counter is 10 ions cm^{-3}. While measuring the air ion concentration, air flow rate through the aspirating camera is (230 ± 23) l min^{-1}. The volume of aspirating camera is (13 ± 1) pF. The device operates as follows. The air under test is pumped through the aspirating camera by the help of the blower. In the camera, the electrostatic field made by the camera's positive and negative power supply affects the ions. As a result, the ions deviate to the direction of the collector and settle there for a charge storage time. After charging, the electric charge runs down via the key on the input resistance of the amplifier. The amplified impulse is measured and indicated.

Each time and in every measure point ten measurements of positive and negative ions were taken using 16 sec averaging mode. The ion counter was placed perpendicularly to the wind flow in order to avoid measurement inaccuracies caused by sudden wind blasts into aspirating camera. Air temperature, relative humidity, atmospheric pressure, wind speed and direction and nebulosity were determined also. The measurment was performed during four seasons: spring, summer, autumn and winter.

1. The first measuring of air ion concentration was performed in spring - from March 16, 2009 to April 2, 2009 (with some exceptions due to technical reasons) twice a day: in mornings and afternoons. Concentration of positive and negative air ions was established in eight test points: in the morning from 7:00 to 10:00 and in the afternoon from 16:30 to 18:00. The main test points were selected around Atbrivosanas aleja, the main street of Rezekne, where the strongest impact of transport pollution was expected. In addition, the following areas were selected: vicinity of Meat processing factory, Latgale branch of National Blood Center, and Secondary School No. 5 where the impact of transport pollution on air ions could not be the key factor. In some test points, intensive measurements were made during working hours with one hour intervals: Hansa Bakery on 02/04/2009, monument "Vienoti Latvijai" on 26/03/2009, National Blood Center on 17/03/2009.

2. In summer, measurements were performed three times a day (7:00 to 10:00, 12:00 to 14:00, and from 16:30 to 18:00) during the period from July 27, 2009 to August 11, 2009, with the exception of August 1 and August 2 due to technical reasons.

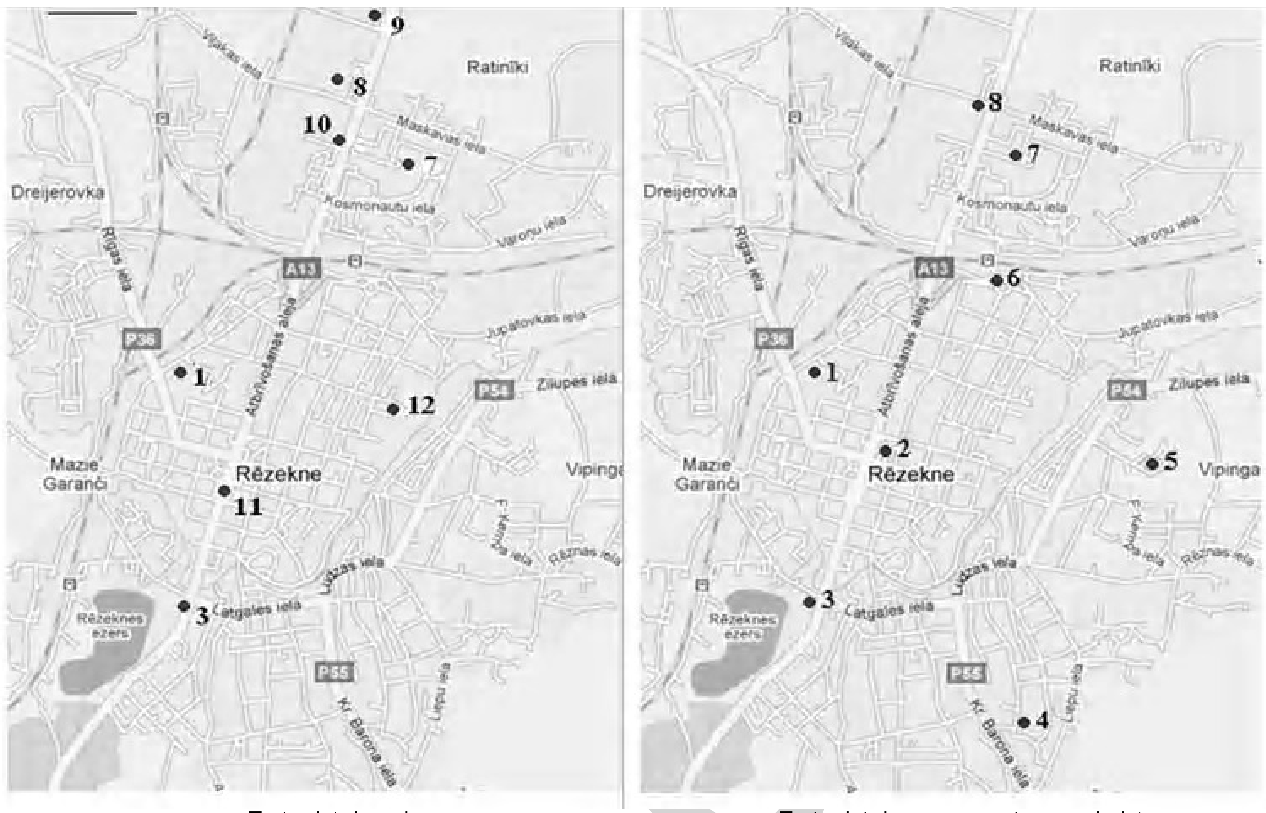
3. In autumn 2009, measurements were performed in eight test points on November 4, 9, 10, 11 and 17. The procedure of taking measurements was the same.

4. In winter 2010, measurements were taken in eight test points thrice a day on January 30 and 31, February 11 and 26 and on March 5 and 6.

The spring test points are mainly located close to the main street and do not give a complete picture of air ionization conditions in the city. Therefore to perform summer, autumn and winter measurements, a wider network was established covering the whole city, including industrial zones, residential neighborhoods, recreational areas, main streets and junctions. (Fig.1 , Table 2) The summer and autumn measurement network is taken as the basis for further studies.

Results and Discussion

During the whole measurement period and almost in all the test points the air ion concentration showed large fluctuations. Concentration of positive and negative ions varied from zero to hundreds of ions cm^{-3} even within ten sequential measurements.



Test points in spring Test points in summer, autumn and winter

Fig. 1: Grid of test points

Concentration of air ions was greatly influenced by meteorological factors such as wind speed and direction, temperature and changes of relative humidity. The flow of air masses created turbulence, mixing the different layers of the atmosphere and contributing to pollution migration between them. Despite the high instability of air ion concentration in individual measurements, in long-term the average values are important to provide more accurate information about energetic saturation level that characterizes the air of particular test point.

The ionization rate of atmospheric air in Rezekne corresponded to the intermediate level. Based on the literature analysis, the characteristic air ionization rate for urban territories is 100 - 500 ions cm^{-3}. The obtained results in Rezekne are compatible with similar researches in other countries, e.g. in cities of Australia, where mean positive and negative light ion concentrations at the five city road sites were 309 and 294 cm^{-3}, respectively (Jayaratne *et al.,* 2010).

Measurements in spring: The spring was quite wet and cold. In observation period relatively strong (up to 6m s^{-1}) wind of changeable direction was stated. From 8:00 to 9:00 in mornings, the air temperature was usually from 0 ºC to - 4 ºC and only two days it fell to - 9 ºC and one day reached 3.6 ºC. At lunch time (11:00-12:00), the air temperature varied in the range of 0.5 to 4 ºC and only three times it was lower than 0 ºC. In evenings from 17:00 to 18:00, the air temperature was in the range from 0.6 to 6.7 ºC and only three times it was lower than 0 ºC.

The peaks of concentration of air ions of both polarities were usually observed in mornings. In evening it tended to decrease. During the springtime, the prevalence of positive ions over negative ones was observed in the most of test points. The majority of observations showed that unipolarity factor reached the maximum value in mornings and decreased in evenings (Table 3).

Intensive measurements during working days in spring showed a cyclic increase and decrease of air ion concentration reaching the maximum values in mornings and late evenings, and the minimum values around middays. Near the National Blood Center the sharpest fluctuations were observed. The minimum value (10 for negative and 20 for positive) was recorded at 12:00, but peaks were observed at 11:00 and 13:00. In other two test points such a dramatic tendency was not recorded, but sharp diurnal variations were characteristic. In all three observations, the concentration of light air ions tended to grow from 10.00 to 11.00. The total ionization rate near the National Blood Center was lower (up to 200 ions cm^{-3}) than near the monument „Vienoti Latvijai" and near Hansa Bakery (located in the city center) where it was higher than 600 ions cm^{-3}. To ensure better interpretation of obtained data about the variations of air ions concentration and to understand the processes, it is necessary to measure more detailed ion spectrum, including heavy ions.

Measurements in summer: The summer was quite wet and warm. During the observation period relatively strong wind of changeable direction (predominant southwest and west) was stated. Air temperature in mornings was usually from 14 to 18 ºC. At lunch time air temperature varied in the range of 19 to 23 ºC but in the evening it varied from 19 to 27ºC.

The peaks of air ion concentration were usually observed in mornings, whereas in afternoons and evenings it tended to decrease. Unipolarity factor had a tendency to increase in evening, because during the day the air pollution increased mainly due to the growth of traffic flows on the main streets of the city. Supposedly, light air ions, especially negative ones, settled on pollutant aerosol particles and contributed to their loss via charge transfer processes. Charged particles of pollutants were better subjected to the coagulation in bigger aggregates and eventual sedimentation in gravity field. This regularity was observed in all the test points, with the exception of Miera Street and park at the Hospital of Tuberculosis, where no significant air pollution sources were located. A contrary trend was observed near the pharmacy "Lana" probably due to variable wind direction and the fact that the test point was located almost in courtyard, not directly at the junction with intensive car traffic (Fig. 2).

Table - 2: Characteristic of test points during summer, autumn and winter period

No.	Test point	Short description	Seasons of measurement
1	**Rezekne meat processing factory**	The vicinity so far has not been considered to be particularly contaminated, but there is often specific odor in this area. Nearby are located railway, and an important road junction.	Winter, spring, summer, autumn
2	**Pharmacy "Lana"**	Car parking at the pharmacy "Lana" was chosen as nearly the only monitoring station in Rezekne is located. It lies along the main street.	Spring, summer, autumn
3	**Latgale Street**	Intersection of Atbrivosanas and Latgale Streets is the busiest intersection in Rezekne. Traffic intensity is high, in the mornings and evenings traffic jams tend to occur. There is the central bus station at this part of the town.	Winter, spring, summer, autumn
4	**Miera Street**	Private residential area opposite the Miera Street is quiet with low traffic. Beside a large cemetery resembling the park is located.	Spring, summer, autumn
5	**Tuberculosis hospital**	The territory resembles to quiet park with mixed tree plantations.	Spring, summer, autumn
6	**Rezekne II**	Neighborhood of Rezekne railway station II is considered to be one of the most polluted areas in Rezekne (not just air, but also soil and water). There is active movement of passengers and goods transport. Along the station one of the major city streets Stacijas Street is located.	Spring, summer, autumn
7	**Secondary School #5**	Parking at the Rezekne Secondary School #5 represents a concentration of air pollution in the residential area of Northern part of the city.	Winter, spring, summer, autumn
8	**REBIR**	Parking at the factory of electrical tools "REBIR" represents industrial zone of the Northern part of the city.	Winter, spring, summer, autumn
9	**Hansa Bakery**	Located in the Northern part of the city close to the main street.	Winter
10	**Rûpnîcas street**	The junction of Atbrivosanas and Rupnicas Streets on territory of former Canned milk plant, now partially abandoned industrial territory.	Winter
11	**Vienoti Latvijai**	The monument "Vienoti Latvijai" is a symbolic city center and is located opposite Rezekne City Council. There are medium levels of traffic intensity.	Winter
12	**NBC LB**	National Blood Center Latgale branch is located in a very quiet and peaceful area near a river. There is practically no traffic in the immediate vicinity.	Winter

Table - 3: Average values of spring measurements

Test point	**Morning test average**			**Evening test average**			**Average per testing period**		
	Concentration, ions cm^{-3}			**Concentration, ions cm^{-3}**			**Concentration, ions cm^{-3}**		
	Negative	**Positive**	**K**	**Negative**	**Positive**	**K**	**Negative**	**Positive**	**K**
Secondary School #5	382	189	0.19	229	250	1.09	306	220	0.72
Rûpnîcas street	314	306	0.97	98	89	0.90	206	198	0.96
REBIR	159	333	2.09	152	139	0.91	156	236	1.52
NBC LB	181	245	1.35	235	215	0.91	208	230	1.11
Monument "Vienoti Latvijai"	156	206	1.32	295	206	0.70	226	206	0.91
Latgales street	112	264	2.36	157	112	0.71	135	188	1.40
Meat processing factory	178	401	2.25	249	367	1.47	214	384	1.80
Hanza Bakery	111	403	3.62	169	258	1.83	140	331	2.36

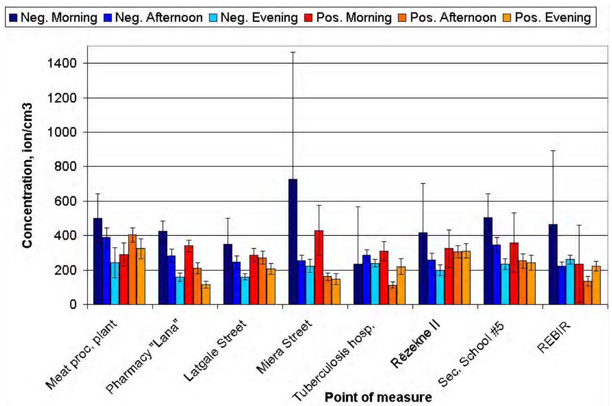


Fig. 2: Average values of summer measurements

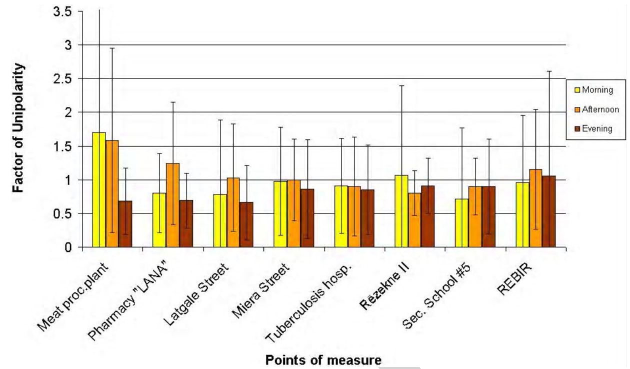


Fig. 5: Changes of unipolarity factor in autumn measurements

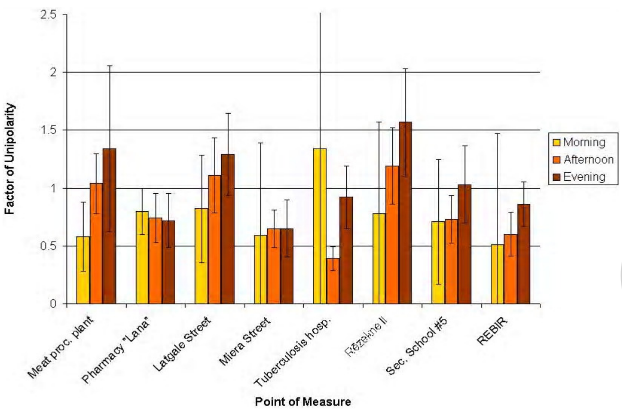


Fig. 3: Changes of unipolarity factor in summer measurements

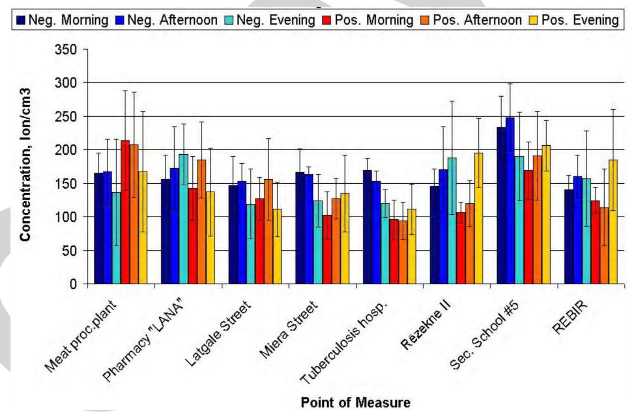


Fig. 6: Average values of winter measurements

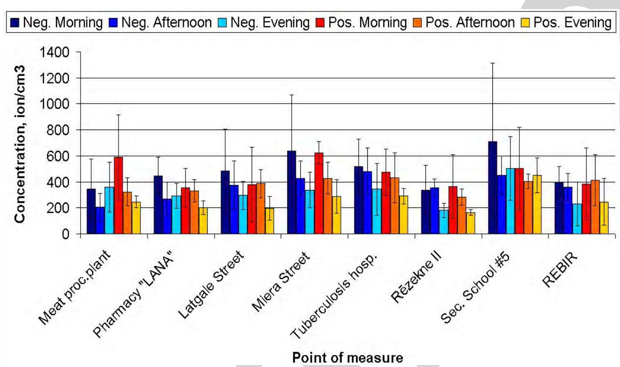


Fig. 4: Average values of autumn measurements

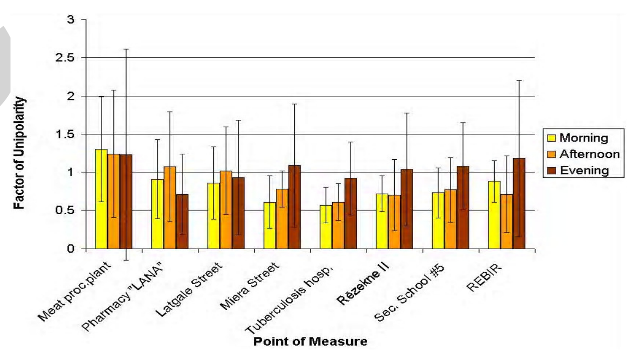


Fig. 7: Changes of unipolarity factor in winter measurements

In summer period, the factor of unipolarity was less than 1 in the most of test points, and it was beneficial for human health because the negative ions dominated over the positive ones. The factor of unipolarity was slightly more than 1 only near the railway station "Rezekne II" and at the intersection of Latgale street and Atbrivosanas street. These points were characterized by the highest level of air pollution in the city. The third largest value of unipolarity coefficient 0.9 was observed in the vicinity of Meat processing factory, probably due to the factory pollution - vapors, odors, aerosols distributed in the atmosphere during the meat processing. The lowest factor of unipolarity 0.61 was calculated on Miera street, which is considered to be a favorable district (Fig. 3).

The calculations of standard deviation and relative error showed that most fluctuations of ion concentrations were present in morning time. It referred particularly to the negative air ions. Ion concentrations measured in afternoons and evenings were relatively homogeneous without typical bursts.

Measurements in autumn: In autumn, relatively strong wind of changeable direction (predominant west) was stated. Air temperature in mornings was usually from - 3.5 to 3.5ºC. At lunch time air temperature varied from 3 ºC to 4ºC whereas in evening it was in the range of -5 to 4º C.

The peak of concentration of air ions was usually observed in mornings, but in afternoons and evenings the concentration tended to decrease. In this case the influence of certain time of the day was not determined. The peak of unipolarity factor was observed near the meat processing factory and near the station “Rezekne II” (in mornings), but near the pharmacy “Lana”, on Miera street and Latgale street the value of unipolarity factor reached the maximum in afternoons, whereas near the factory “REBIR” its value was maximal both in afternoons and in evenings. In autumn, in the most of test points the prevalence of negative ions over positive ones was stated (Fig. 4 and 5).

The calculations of standard deviation and relative error showed the tendency that was equal to the summer measurements: the fluctuations of ion concentrations were usually stated in morning time, they were less evident in afternoon and evening (“Rebir” is an exception). In general, it was observed that the deviations from the mean value were a little bit higher than in summer.

Measurements in winter: In winter period, the wind of changeable direction and middle velocity was stated, predominately 0-2 m s^{-1} with the exception of several blasts reaching 4-5 m s^{-1}. Air temperature in the mornings of measuring days was usually from - 11 to 3ºC. At lunch time, the air temperature varied in the range of - 4 to 3.5ºC. Air temperature in evenings was in the range of 8 to 2ºC. The lowest temperatures were caused by the north, northeast wind, whereas the west or southwest wind brought higher temperatures and thaws. When the air temperature was under - 15 ºC the measurements of ion concentration were not taken due to the technical specification of apparatus.

In this case it was not possible to establish a common regularity of ion concentration changes in relation with daytime. The dynamics of ion concentration were individual in each test point. Probably, the air pollution was not the main factor determining ion concentrations in winter conditions. On the other hand, the air pollution itself had not a typical daily variation due to the big central heating plants working in relatively stable regime during all the winter period. Some other factors, such as meteorological conditions, temperature inversion, etc., were probably more important in the formation of ion concentration. At the same time, was not discovered that specific meteorological conditions (e.g., snowstorm or thaw) had a specific influence on the level of air ionization. Measurements in winter were relatively stable. Unlike the results obtained during the summer and autumn measurements, in winter period there were no extremely high deviations from arithmetical mean (Fig. 6 and 7).

The analysis of dispersion according to Fischer’s parameter shows whether the data obtained during the morning, afternoon and evening measurements belong to the same distribution or not. In the case of spring and winter measurements, there was no significant difference between general group of obtained data and the groups of morning, afternoon and evening data. They belonged to the same distribution. In the case of summer measurements, each group differed significantly from the general group and it means that the distribution of air ion concentration really depended on the daytime. In the case of autumn measurements, a significant difference from general group was found only in afternoon data of negative ions and in evening data of positive ions.

- The ionization rate of atmospheric air in Rezekne corresponds to the intemediate level (basing on the literature analysis, the air ionization rate for urban territories is 100 - 500 ions cm^{-3}). The measurements carried out in different seasons show that the concentration of the negative air ions is ranging from 135 ions cm^{-3} on Latgale street during the spring to 554 ions cm^{-3} near Rezekne Secondary School Nº5 in the autumn. The concentration of positive ions varies from 188 ions cm^{-3} on Latgale Street during the spring to 453 ions cm^{-3} near Rezekne Secondary School No. 5 in the autumn. In some test points and during separate hours of the day, the concentration of negative air ions tends to exceed 1000 ions cm^{-3} (e.g. on Miera street), but it is not a sufficient indicator to consider any part of the city to be a resort area.

- In general, the level of air ion concentration depends on the temperature of the air. The average daily values of ion concentration in spring and winter period are lower than during the summer and autumn period.

- The concentration of light air ions decreases when the total air pollution in the city accumulates and increases. The maximal concentrations of ions and minimal values of unipolarity factor K are observed in mornings when the air is relatively clean, whereas the minimal concentrations of ions and maximal concentrations of K are observed mostly in evenings when the daily pollution has been accumulated in the urban air. This regularity characterizes summer but it is not typical for other seasons.

- During all the measuring period, the average value of unipolarity factor K is higher than 1 near Rezekne Meat processing factory, on Latgale Street, and near the factory “Rebir”. Near the railway station “Rezekne II”, the average value of K is close to 1. It confirms the predominance of the positive ions over the negative ones in areas with relatively high air pollution. It is probable that in the process of pollution neutralization the negative ions are “consumed” at first.

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