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COMPLEX EVALUATION OF AIR QUALITY IN REZEKNE

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Abstract. *Paper presents results of air ionization level measurements made in past 3 years in Rezekne city. The concentrations of positive and negative air ions with mobility factor $k \geq 0{,}4$ $cm^2/V{\cdot}s$ were obtained by portative air-ion counter "Sapfir-3M" (Russia) in 8 parts of the city thrice per day. The approximate interconnections among ionization and chemical and mechanical pollution of air were analyzed. The complex evaluation of long – term air pollution impact on different parts of city is carried out using methods of lichenoindication and air ion research.*

Keywords*: air pollution, air ions, lihenoindication, urban ecology*.

Introduction

The city environment is characterized by elevated atmospheric pollution relevant to high traffic intensity, concentration of industrial objects and thermal energy production. The highest pollution level is usually observed in city centers and industrial [1]. Microclimatic features of city, such as relief and character of city buildings, are very important for pollution dispersion. For example, during the winter season in Rezekne city, which is situated on a lowering in relief, in anticyclonic conditions the arctic smog can be observed.

Emission data from stationary pollution sources were obtained according to methodical regulations approved by The Ministry of Environmental Protection and Regional Development, whereas the evaluation of traffic pollution needs data about weekly, daily and hourly traffic intensity. [2]

In observing the air quality of city environment, several methods can be used, for example: 1) analyzing data from stationary pollution sources; 2) measuring traffic flow intensity in city streets; 3) using bioindication of air quality; 4) summarizing data from air quality monitoring stations; 5) obtaining information about the state of human health, 6) measuring concentrations of light air ions in different city regions.

Since the end of the 20th century, the environmental pollution in Rezekne created by stationary pollution sources has significantly decreased: from 2669 tons of emissions in 1998 to 1317 tons in 2005. In 2009, only 219 tons of polluting substances have been detected mostly NO_x and CO. [3] It can be explained by the decline of industrial production (factories create only 13 per cents of stationary source emissions) and by the replacement of fuel oil by natural gas and wood chips in heat supply enterprises. Unfortunately, there are no emission calculations from low power heating systems, such as private houses, therefore the actual air pollution level created by stationary sources in Rezekne city is definitely higher and the dispersion of it is much weaker.

Until 2007, the intensity of traffic flows in city streets was increasing constantly but currently it tends to become stable or even decrease. Moreover, since 2005 the technical state of vehicles has significantly improved.

Hence, it can be declared that in the first decade of the 21th century the air quality in Rezekne city has ameliorated. It should be mentioned that the proportion of motorcars in Rezekne is approximately 83 – 85 per cents, whereas the number of bicycles is less than 1per cent of listed vehicles. Therefore it can be assumed that it is still possible to improve the air quality of the city in the future.

The long-term influence of pollution is presented quite precisely by lichenoindication data because the lichens are universally recognized to be very sensitive bioindicators that demonstrate the territorial differentiation of air pollution. The lichenoindication of air quality in Rezekne city is taking place since 2001.

A new method that is rarely used in observing the air quality in cities is the measuring of light air ion concentration. It is known that air ions have an effect on human health and well-being and interact with aerosol particles and chemical gasiform air pollution that is adsorbed on these particles. There are many studies in literature affirming that environmental air ion concentration levels and balance can affect a wide range of biological organisms, including humans. Elevated negative air ion levels are reported to have beneficial effects on humans, for example enhanced feeling of relaxation, reduced fatigue, stress, irritability, depression and tenseness level. Increased positive ion levels are reported to have no effect, or deleterious effects. [4, 5, 6] To ensure human health and well-being, the minimal concentration of negative and positive ions is necessary 400ions/ cm^3 [7].

The ion polarity is characterized by unipolarity factor K, which is the relation of concentration of positive and negative ions in $1cm^3$ of the air.

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

The article presents an integrated evaluation of air quality, basing on lichenoindication, traffic flows and light air ion concentration data.

Materials and methods

Lichenoindication

Lichenoindication is a bioindication using the lichens. The extinction of lichen and the decrease in its biodiversity indicate an elevated air pollution level, therefore the lichens are one of the most popular bioindicators. Lichens are highly diverse, that is why the identification of species is not always simple. The lichens are commonly divided into three main groups – crustose, foliose and fruticose lichens. The species of lichens respond differently to air pollution. Sensitive species disappear in conditions of even low pollution level while more resistant species survive in relatively high pollution. Usually, fruticose lichens disappear first, they are followed by foliose lichens and finally by crustose lichens. There is some regularity – the wider is the diversity of lichens and the more trunk surface is covered with lichens; the clearer is air in the given territory. The broad-leaved trees, such as maples, limes, ashes and elms, are more appropriate for the studies of lichens, whereas conifers are not appropriate for it. For lichen studies only grown-up trees are useful, because the covering of lichens on saplings has not developed yet.

Rezekne city map was divided into squares. The length of one edge was 500m. In each square, the flora of lichens on ten deciduous trees was inspected. The lichens were studied at the altitude of 1.3 – 1.5 m on the side the most covered with lichens. A transparent 20 x 20 cm polythene square, divided into 100 small quadrants, was put to the trunk of the tree. This method facilitates the defining of percentage of lichen covering on the trunk.

The air quality observations made in relation to the lichen covering on tree trunks are shown in the left lower corner of figure 2. Air pollution level is estimated to be low in places where all the three lichen groups are present, average in the places where two lichen groups are present and high in the places where only one lichen group (mostly crustose lichens) is present.

Traffic flow intensity measuring

The measurements of traffic flow intensity were taken on weekdays, on the biggest street junctions of Rezekne city, counting the transport units crossing the given junction in a period of one hour. The measurements were taken three times a day: 8.00 - 9.00, 13.00 - 14.00 and

17.00 - 18.00. The counting of transport units was performed mostly on the junctions situated on the main arterial roads of Rezekne city – Atbrivosanas aleja and Darzu street, as well as on Latgales street that is partially used for transit traffic in direction of Dagda and Ludza. The traffic flow measurements for the period 2007 – 2010 are summarized in the map of complex air quality evaluation (Figure 2).

Air ion measuring

To evaluate air ion level and dynamics of its changes, measurements of light air ions concentration in different places of Rezekne city were made. The bipolar air ions counter "Saphire-3м" 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 air with mobility factor $k \geq 0{,}4$ $cm^2V^{-1}s^{-1}$. Minimum resolution of the counter is 10 ions/ cm^3. Air flow rate through the aspirating camera while measuring the air ion concentration is (230 ± 23) l/min.

Each time in every measuring point 10 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 in the aspirating camera.

The air ion concentration measurements taken in different seasons in the period 2009 – 2010 are summarized and analyzed. The aim is to study the interaction between pollution and air ions and to clarify how the anthropogenic pollution influences the concentration of positive and negative air ions.

A wide network covering the whole city, including industrial zones, residential neighborhoods, recreational areas, main streets and junctions was estabilished (see figure 1).

Breaf characterization of measurement points.

1st test point – Rezekne Meat processing factory vicinity. It has not been considered to be particularly contaminated, but there is often a specific odor in this area. A railway and an important road junction are located nearby.

2nd test point – parking at the pharmacy "Lana". Located nearly the only monitoring station in Rezekne, situated in the city centre along the main street.

3rd test point – parking next to the intersection of Atbrivosanas and Latgale streets – the busiest intersection in Rezekne. Traffic intensity is high, in the mornings and evenings traffic jams tend to occur. The central bus station is located in this part of city.

4th test point - private residential area opposite Miera street. Quiet territory with low traffic intensity. A large cemetery resembling a park is located nearby.

5th test point is located on the territory of the Hospital of tuberculosis and resembles a quiet park with mixed tree plantations.

6th test point - neighborhood of the railway station Rezekne II. Considered to be one of the most polluted areas in Rezekne (not only air, but also soil and water). There is an active movement of passengers and goods. Stacijas street, one of the major city streets, is located along the station.

7th test point - parking at the Rezekne Secondary School #5. Represents the concentration of air pollution in the residential area of the Northern part of the city.

8th test point - parking at the factory of electrical tools "REBIR". Represents the industrial zone of the Northern part of the city.

Results and discussion

Lichenoindication does not provide data about short-term changes of air pollution that can be very inconsistent in time. Nevertheless, this method provides information about long-term influence of air pollution in one particular part of the city.

It can be seen that the biggest lichen covering on tree trunks and the lowest air pollution level is observed in the Southern part of the city with many trees and green zones where the

cottage-type buildings prevail and where there are no trunk roads. The covering of lichens on tree trunks overcomes 60 per cents.

The big lichen covering located in the Northern part of the city is mainly observed in the territory of storehouses and allotments. The high percentage of lichen covering in some other squares of the city, for example near the river, is related to the absence of air pollution sources, with the exception of allotments in the Western part of the city where the railway is relatively close. It can be presumed that the pollution created by this railway is dispersed by western winds above the city territory. Generally, the city territory is dominated by average air pollution related to the motor transport, the small boiler houses and probably to the relatively equable pollution dispersion from big boiler houses. High or very high air pollution level was observed mainly along the railways, near the railway stations and in the industrial city zones situated mostly in the Northern part of the city. In this part, the covering of lichens on tree trunks usually does not overcome 20 per cents and all the species of lichen are resistant to pollution.

All the three lichen groups (crustose, foliose and fruticose lichens) are simultaneously present only in some squares of the Southern part of the city and slightly along the river coasts. The tree trunk covering with crutose and foliose lichens is typical for all the city territory. In some squares along the railways, only crutose lichens are present. Along the city streets the population of foliose lichens is also poor. It is possible that the precision of obtained results in some city squares was influenced by the lack of trees suitable for lichenoindication.

According to the data from Road Traffic Safety Directorate (CSDD), in 1998-2010 the number of registered motorcars in Rezekne has increased by 28 per cents, whereas the number of lorries has decreased by 25 per cents and the number of buses has fallen more than twice [8]. The figure2 shows the averaged traffic flow intensity from the most important junctions of Rezekne. The comparable data of years 2007 and 2010 are shown in table 1.

Table 1.

Traffic intensity in the streets of Rezekne

Street junction	**The average number of vehicles per 1 hour** (on working day)		
	Year 2007	**Year 2010**	**Designation in the map**
Atbrivosanas street – Latgales street	1074	1139	A
Atbrivosanas street – Lubanas street	942	1042	B
Atbrivosanas street – Maskavas street	908	896	C
Latgales street – Darzu street	473	457	D
Latgales street – Ludzas street	496	501	E
Kr. Barona street – Liepu street	213	192	F
Ludzas street – Raznas street	552	530	G
Rigas street – Vilakas street	382	366	H

The calculations of transport units reflect the load of given streets. Rezekne has some particularities defining its traffic flow. There are two bridges over Rezekne river used for the motor transport. So the main traffic flow is on Atbrivosanas, Darzu and Latgales streets.

Air ion concentration during the whole measurement period and almost in all the test points showed large fluctuations. Concentration of positive and negative ions can vary from zero to hundreds of ions per cm^3 even among 10 measurements taken consecutively. Air ion concentration is greatly influenced by meteorological factors, such as wind speed and direction, temperature, and changes of relative humidity. The flow of air masses creates turbulence mixing the different layers of atmosphere and contributing to the pollution migration between them. Despite the high instability of air ion concentration during individual measurements, in long-term the average values are very important to provide more accurate information about air energetic saturation level that characterizes the air of the particular test point.

It is known that the air pollution in city is rising during the day. The pollution level starts to increase rapidly at approximately 8:00 and reaches the culmination at approximately 17:00 to decrease again in the nighttime due to the natural air purification. This cycle depends to a great extent on the traffic intensity. It is proved by data obtained in the monitoring station on Brivibas street in Riga. The concentration of carbon dioxide and benzene is in close correlation with changes in the quantity of cars on the street in twenty-four hours time. The concentration of sulphur dioxide is less related to the motor transport than to the industrial sector – the activity of boiler houses of different size and type. Therefore the level of this kind of pollution is relatively constant day and night. [9] It can be assumed that these regularities of air pollution changes exist not only in Riga but also in the other largest cities (it should be remarked that Rezekne is the 7th largest city in Latvia).

Unlike the mentioned air pollution, the concentration of light air ions has a tendency to decrease during the day. It permits to assume that air ions are important for the processes of air purification. The charge of air ions, interacting with the pollutant molecules, stimulates their mutual attraction and formation of bigger aggregates, and accelerates their sedimentation from air environment (see figure 1). First of all, it relates to the mechanical pollution components - various solid-state and liquid aerosols. The high adsorption capacities of gasiform substances on the aerosols reduce the amount of pollutant gases in atmosphere. Air ions can promote different chemical reactions in the atmosphere also. Especially strong decrease of ions during the day characterizes the measure points located near pollution sources crated by traffic. Besides, the rapidest decrease usually concerns the concentration of negative ions. It can be explained by the different structure of positive and negative ions. Negative ions are smaller but with higher mobility, consequently they can intervene in the process of air purification more rapidly and actively. It is important to mention, that in the points distant from pollution emission sources (e.g. Tuberculosis hospital), the decrease of ion concentration level during the day is not strong or does not even manifest itself.

The highest values of unipolarity coefficient K are observed near the railway station “Rezekne II”, on the junction of Latgales Street and near the Meat processing factory. In these measure points the pollution created by traffic and partially the industrial pollution dominate. The lowest values of coefficient K are observed on the Miera Street and near the Hospital of tuberculosis where the pollution sources are minimal. Intermediate values of K can be observed in the city center and in the Northern part of the city (see the map.). It is probable that in these city parts the characteristic air pollution of intermediate level is manifesting itself as well.

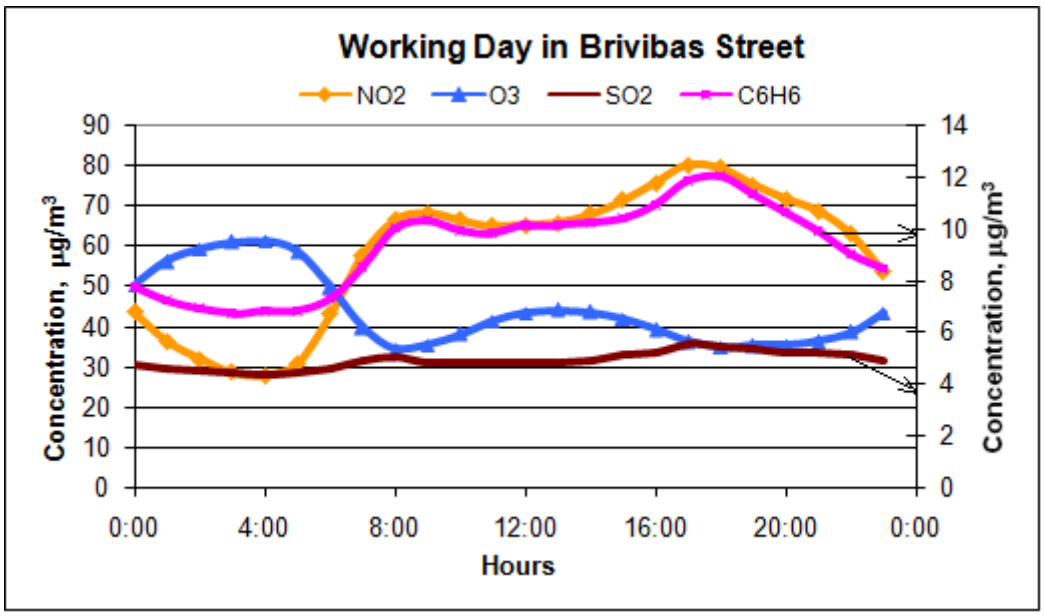

Fig. 1. **Dynamic of atmospheric pollution concentration** [10]

Speaking about complex evaluation of air quality, there are some aspects to be mentioned. Lichenoindication, ion measuring and counting of transport units correspond with each other relatively well. The maximal coverage of lichens on tree trunks and the minimal value of K is observed in the points with minor traffic flow (see junctions F, G and points 4 and 5 in figure 2). The average level of air ionization is not high in these points as well. It can be explained by the lack of anthropogenic ionization sources. It is known that the automobile exhaust gases also produce positive and negative air ions in almost similar proportions [11]. In these measure points the natural ionization level is preserved and its ion production and depletion rate is typical for parks and forests. The level of air ion concentration is not high but these ions are more "salubrious" because the negative ions prevail over the positive ones.

A low level of lichen coverage is located in the environs of railway. The vicinity of railway station "Rezekne II" encompasses the junction with the third the most intensive traffic flow, the lowest level of lichen coverage and the highest value of coefficient K. All these conditions indicate that there is a relatively high level of air pollution in this area (see squares D6, F6, E6, junction B and measure point 6 in figure 2). Intermediate lichen coverage is usually observed along the streets, whereas the lowest level of lichen coverage is located along the railway. It allows presuming that air quality is more influenced by railway than by motor transport in the city.

The traffic flow is the most intensive in the junction A (see figure 2). On average, this junction is traversed by 1124 motor cars per hour. Besides, the lowest total concentration of air ions is observed in the measure point that is located near this junction. Nevertheless, the value of coefficient K 0,95 is considered to be average and should not be regarded as unfavourable for human health because the amount of positive and negative ions in 1 cm^3 is almost balanced. It can inferred that a great part of air ions recombine taking part in the self-purification of air where the negative ions act a little bit more actively than the positive ones. Basing on the lichenoindication, the level of air pollution in this area is intermediate and does not reach the level of air pollution observed near the railway station or along the railways.

In the Northern part of the city there are two measure points 7 and 8 that should be mentioned. The point 7 is located near Rezekne Secondary school $N^{\#}5$ and it represents the residential area. It is significant that basing on lichenoindication, the level of air pollution in this area is low and there is the highest total concentration of air ions (see table 2), what is beneficial effect for human health. The park that is situated in the South, as well as the relief protect this

point from the influence of railway pollution, whereas the building defends it from the pollution created by motor transport. The measure point 8 is located in the industrial zone and it is more subjected to the motor car pollution from the junction C. This point is characterized by one of the lowest ion concentration levels and the lichenoindication data reveal that the level of air pollution in this area is high.

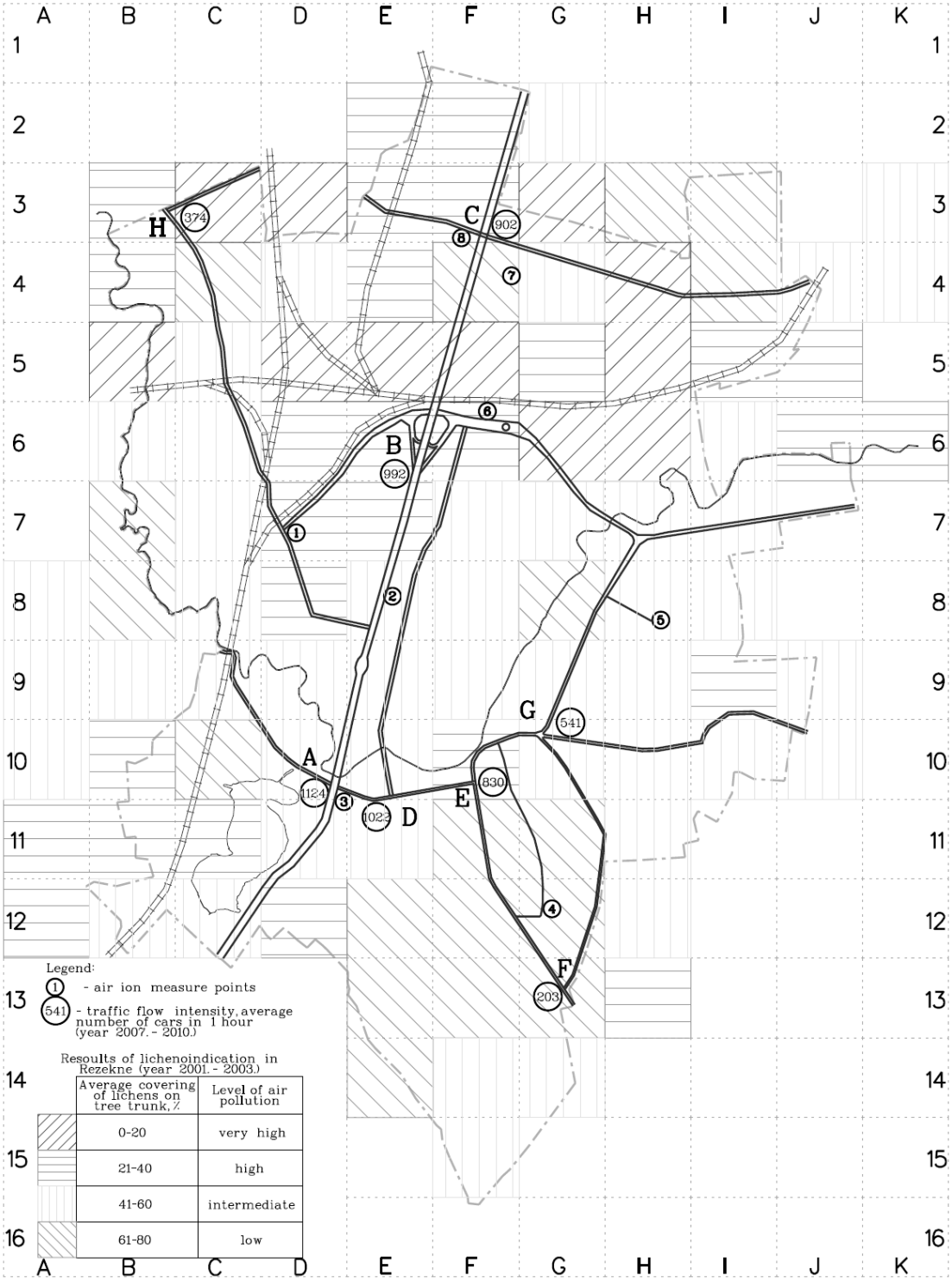

Fig. 2. **The map of complex air quality evaluation in Rezekne**

Table 2.

Summary of air ion concentrations and unipolarity factor K (2009 – 2010)

Measure points	Negative	Pozitive	Total	K
1. Meat proc.plant	279	264	543	0,95
2. Pharmacy "LANA"	259	210	469	0,81
3. Latgale Street	227	216	443	0,95
4. Miera Street	288	214	502	0,74
5. Tuberculosis hosp.	269	195	464	0,72
6. Rezekne II	219	238	457	1,09
7. Sec. School #5	333	274	607	0,82
8. REBIR	259	212	471	0,82

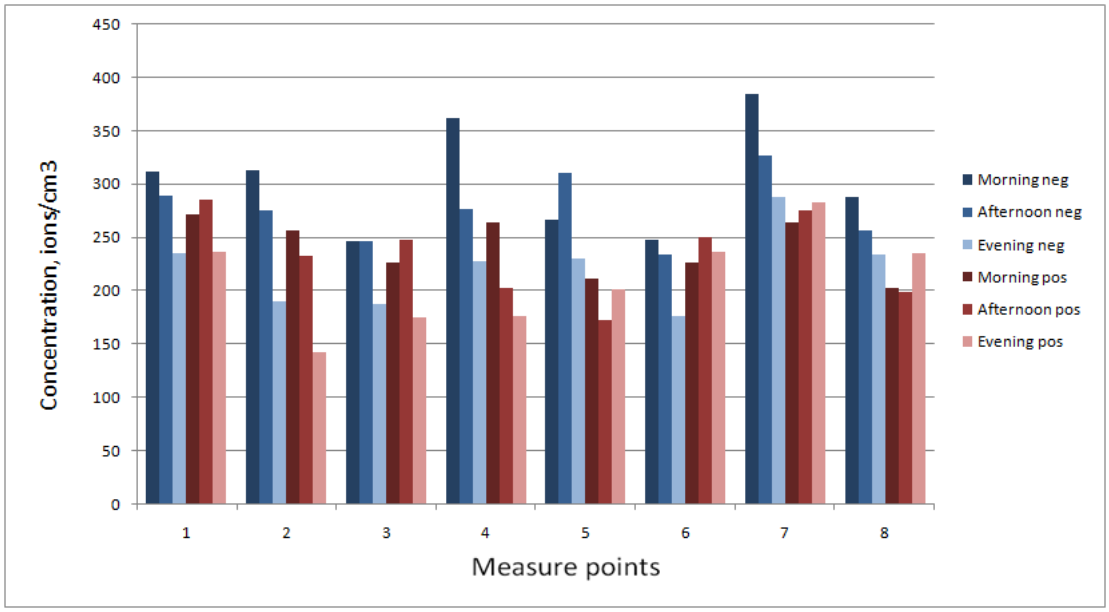

Fig. 3. **Average air ion concentrations in different daytime (2009 – 2010)**

Conclusions

1. Data obtained by lichenoindication, ion measuring and counting of transport units correspond with each other and all these elements can be used to obtain a common picture of air quality in the city and to interpret its changes.
2. The quality of city air is more influenced by railway than by motor transport. According to lichenoindication, the highest level of air pollution was observed along the railway, whereas the railway station Rezekne II is the only measure point were positive ions prevail over negative ones in long-term and where the total ionization level is one of the lowest in the city. Therefore the environs of railway and railway station can be considered to be unfavourable for human health.
3. The level of air pollution influences the total concentration of air ions and the unipolarity coefficient K. The highest is the level of pollution, the lowest is the total concentration of air ions and the highest is the value of K.
4. Air ions promote the processes of air natural purification.

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