APPLICATIONS OF AIR ION MEASUREMENT IN ENVIRONMENTAL DIAGNOSTICS

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Introduction

Air ions: nature and classification.
Artificially generated and natural air ions in applications.

Air ions as environmental factor

Hypothesis of immediate biological activity.
Ion-induced nucleation.
Electrostatic deposition of pollutants.

Air ions as environmental indicator

Indication of particulate and radioactive pollution.
Cluster ion mobility spectrometry.
Size spectrometry of aerosol particles.

Remarks about measuring methods

Cluster ion spectrometry. Aerosol ion spectrometry.
Measuring of ionization rate and aerosol electric density.

The meaning of the term *ion*

is different in different fields of physics.

In a general physical context, the ion is an atom with unbalanced electric charge. An ion of mass 2 amu is called a light ion and an ion of mass 200 amu is called a heavy ion.

In the atmospheric physics, the *atmospheric ion* or *air ion* means **any** airborne particle that drifts relative to the surrounding air controlled by electric field.

Light or *small* or *fast* air ions are charged molecular clusters of mass typically a few hundreds of amu.

Heavy or *large* or *slow* air ions are charged macroscopic particles of mass about 10^8 amu.

Methods based on artificial ionization and natural ionization.

Artificial ionization is used in *Plasma Chromatography* (millisecond-aged cluster ion mobility spectrometry) to detect trace gases in environmental air.

Another application of artificial ionization in environmental diagnostics is the *Electrical Aerosol Analysis* based on artificially charged large air ion mobility spectrometry.

In the present talk, the attention is paid to the methods employing the measuring of **naturally created air ions**.
The amount and mobility distribution of these ions offer hidden information about air pollution. On the other hand, the natural air ions are active in some environmental processes and they should be considered as an immediate environmental factor.

Immediate biological activity of air ions???

Tchijevsky, A.L. Air ionization, its role in National Economy (in Russian), 758 pp., Moscow, 1960.

(References to 1488 papers about biological effect of air ions)

Dolezalek, H., R. Reiter, and P. Kröling Basic comments on the physics, occurrence in the atmosphere, and possible biological effects of air ions, Int. J. Biometeorol., vol. 29, pp. 207–242, 1985.

Charry, J.M.and R. Kavet (editors) Air Ions: Physical and Biological aspects, 214 pp., CRC Press, Boca Raton, 1987.

Martinac, I. On the Biological Effects of Small Air Ions and the use of Ionizers in Occupied Indoor Environments. Kungl. Teknisiska Högskolan, Report A4-141, 125 pp., Stockholm, 1993:

"So far, those facts do not suggest that humans are directly affected by small ions".

Ion-induced nucleation

Homogeneous condensation of water in the atmosphere is not possible. All cloud droplets are born on condensation nuclei. The amount of condensing water does not depend on nuclei. If the number of condensation nuclei decreases, the droplets will be bigger and the development of rain is activated. Small air ions in themselves are not active as cloud condensation nuclei but they can initiate the process of gas-to-particle conversion producing condensation nuclei. The corresponding process is called the *ion-induced nucleation* [Castleman, A.W. Clusters. Elucidating gas-to-particle conversion processes*. Environ. Sci. Technol.*, vol. 22, No. 11, p. 1265, 1988].The ion-induced nucleation in the atmospheric air essentially depends on the trace gases of extremely low concentration and theoretical estimation of the role of this phenomenon in environmental processes is hindered. The condensation nuclei born on small air ions are inherently charged and the balance of charged and uncharged fractions of nanometer particles is modified by ion-induced nucleation. Charged nanometer particles act as intermediate air ions. It follows the measuring of intermediate air ions has an application as a method of diagnostics of the ion-induced nucleation in atmospheric air.

Air ions as environmental indicator

The average value of the ionization rate q in a few lower meters of the atmosphere is about 10 $cm^{-3}s^{-1}$. An almost stable component of 2 $cm^{-3}s^{-1}$ is created by the cosmic rays, the variable rest is a characteristic of environmental radioactivity . The direct measuring of the ionization rate is troublesome. Easy to measure quantities are the air conductivity λ and polar concentrations of small air ions n_+ and n_- . A rough model of the equilibrium of small air ions is

$$q = \alpha n^2 + gn \ ,$$

where $n = (n_+ + n_-) / 2$ is the average concentration of small air ions, α is the coefficient of recombination and g is a characteristic of the content of the aerosol particles in the air. Thus, the small air ion concentration depends on two factors of environmental importance: q and g. In a typical situation, $gn \approx 30\alpha n^2$. Thus,

$$q \approx gn \quad \text{or} \quad n \approx q/g \ .$$

Relative variations of small air ion average mobility K are low and air electric conductivity $\lambda = eKn$ is closely related to n.

Dolezalek, H. World Data Centre for Atmospheric Electricity and Global Change Monitoring, *Europ. Sci. Notes Inform. Bull.* 92–02, pp. 1–37, 1992.

Allik, R. A. On the electrical factor of air pureness (in Russian), *Proc. NIU GUGMS USSR*, ser.1, no. 4, 47 pp., 1941.

Allik made the first thorough analysis of the electrical conductivity of the air as an indicator of air pollution. He split the conductivity into the product of a constant and two factors

$$\lambda = eK \times q \times (1/g),$$

and called the second factor the *electric factor of air pureness*. Correspondingly, the coefficient *g* could be called the factor of air impurity. Really, this term is too pretentious because the coefficient *g* is characterizing the particulate pollution only. It measures the capability of aerosol particles to adsorb small ions and a more adequate term is the *aerosol electric density*.

Cluster ion spectrometry

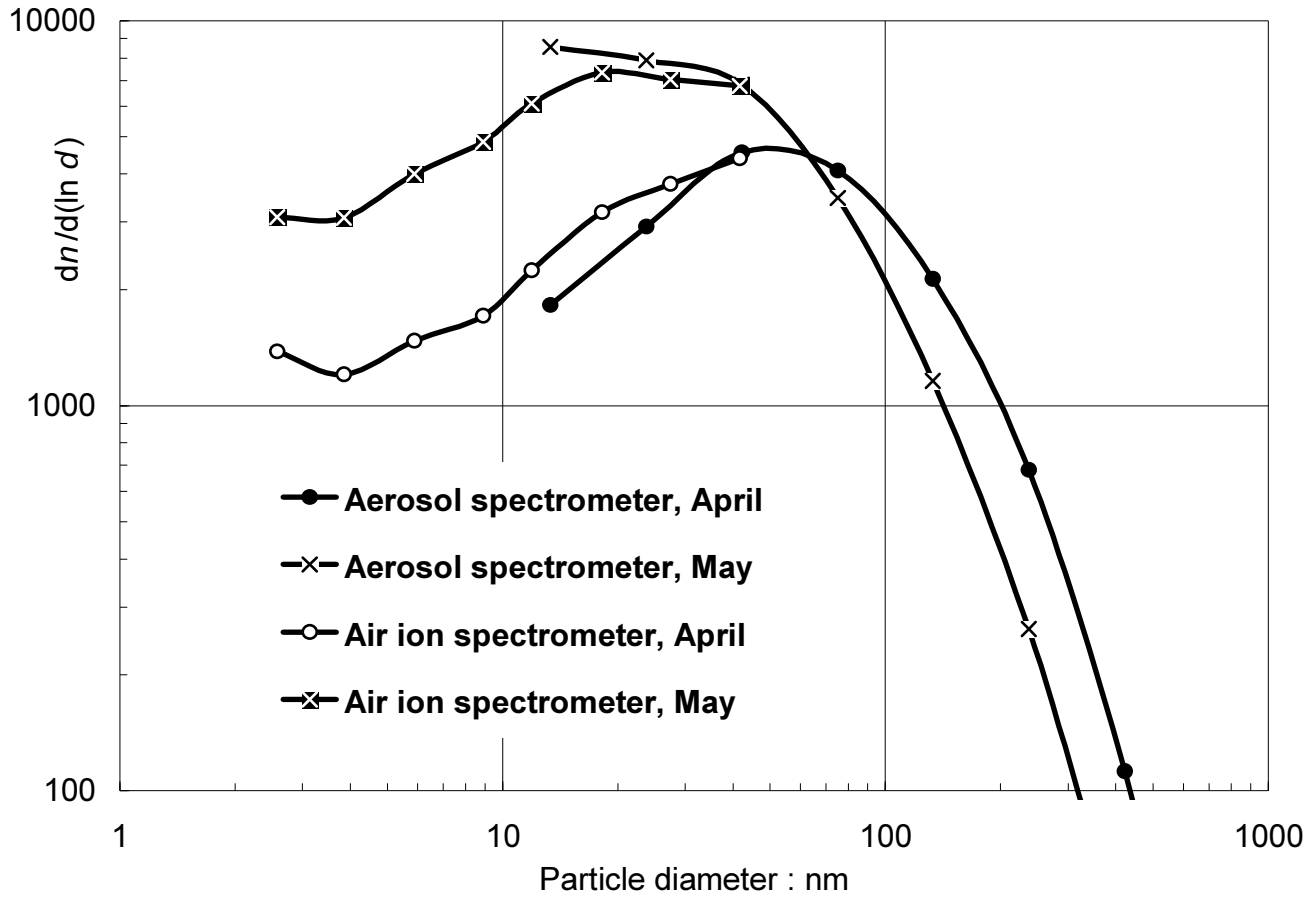
A small air ion encounters about 10^{10} neutral molecules per second. The lowest concentration of a trace gas of high proton or electron affinity detectable by the means of a mobility spectrometer depends on the age of air ions. If the age is 10 ms, typical for a drift tube mobility (TOF) spectrometer, the lowest relative concentration is estimated about 10^{-11}. The maximum age is reached in the naturally ionized atmospheric air where the average age of small ions is about 10^2 s. Thus, the mass and/or mobility spectrometry of natural air ions is promising enhanced sensitivity compared with the plasma chromatography. In practice, the relative concentration of 10^{-15} cannot be measured because of the instrumental noise and the problems of interpretation of the measured spectra.

Carr, T.W. Plasma Chromatography, 259 pp., Plenum Press, New York and London, 1984.

Eisele, F.L. Natural and transmission line produced positive ions. J. Geophys. Res. D, vol. 94, pp. 6309–6318, 1989.

Aerosol spectrometry

The measuring of the mobility spectra of large air ions created by artificial charging of aerosol particles is a common method of aerosol measurement. The artificial charging is efficient in the particle size range above 30 nm. In the nanometer size range, the methods based on natural bipolar charging are competitive. If the mobility spectrum of natural large air ions is measured, the nanometer aerosol particle size distribution can be calculated. The measuring of large air ions can be used as a method of diagnostics of atmospheric aerosol. Particle size spectra presented in Figure demonstrate how the air ion measurements are complementing the traditional atmospheric aerosol measurements.



Size distributions of atmospheric aerosol at Tahkuse Observatory, 1994, directly measured by an aerosol size spectrometer and calculated according to large air ion measurements.

Remarks about measuring methods

Mass-spectrometer, TOF chamber, aspiration condenser.

Perkins, M.D. and F.L. Eisele First mass spectrometric measurements of atmospheric ions at ground level. *J. Geophys. Res.*, vol.. 89, no. D6, pp. 9649–9657, 1984.

Eisele, F.L. First tandem mass spectrometric measurement of tropospheric ions. *J. Geophys. Res.*, vol.. 93, no. D1, pp. 716–724, 1988.

Tammet, H. *The Aspiration Method for the Determination of Atmospheric-Ion Spectra*, 200 pp. NSF and IPST, Washington and Jerusalem, 1970.

Multichannel aspiration spectrometer.

Mirme, A. Electric Aerosol Spectrometry, 130 pp., Ph.D. Thesis, University of Tartu, Tartu, 1994.

Ionization rate and aerosol electric density.

Tammet, H. Aerosol electrical density: interpretation and principles of measurement. *Report series in Aerosol Science*, no. 19, pp. 128–133, 1991.

Semenov, K.A, L.G. Sokolenko, and Ya.M. Svarts Simultaneous measuring of the aerosol electrical density and ionization rate. *Proc. Main Geophys. Obs*., St. Petersburg, issue 514, pp. 3–11, 1988.

Size distribution of airborne particles.

Hõrrak, U. J. Salm, E. Tamm, and H. Tammet Derivation of the size spectrum of aerosol particles from a mobility spectrum, Submitted to the 14th ICNAA, Helsinki, 1996.