Some results of study of variations of light ions concentration and their connections with the ionizing radiation and sub-micron aerosol content in air under the conditions of Tbilisi city

Avtandil Amiranashvili

Mikheil Nodia Institute of Geophysics of Ivane Javakhishvili Tbilisi State University
Tbilisi, Georgia, avto_amiranashvili@hotmail.com

ABSTRACT: Results of analysis of variations of sum light ions concentration (N, cm^{-3}) and their connections with radon (Rn), galactic cosmic rays intensity (Q) and content of sub-micron aerosols by diameter ≥ 0.1 micron (S) in surface boundary layer of Tbilisi city are given.

Measurements of radon, ions and aerosols were conducted 4 times a day at height 3 floor of the building of the cloud chamber of Institute of Geophysics (8 meters above the level of soil, 41.754º N, 44.927º E, the height - 450 m above sea level), into 9, 12, 15 and 17-18 hour. The neutron component of galactic cosmic rays was measured by neutron monitor continuously (Cosmic Rays Station of Institute of Geophysics). The data about daily mean values of the investigated parameters for 2010 year without taking into account weather conditions (356 days, from 9 to 17-18 h) are analyzed.

Thus, the values of N in the investigated period changed: year - from 269 to 2516 (average – 917), warm period (April-September) - from 516 to 1817 (average – 1004), cold period (October – March) - from 269 to 2516 (average – 830). The minimally necessary level of N for the favorable influence on the health (1000 cm^{-3} and more) are observed: year - not more than 35 % of the measurements cases, warm period – 46 %, cold period – 23%. Average values of N in the week-days and weekends respectively comprise: year – 899 and 967 (the difference is significant), warm season –998 and 1021 (the difference is no significant), cold season – 798 and 911 (the difference is significant). Analogous weekly effect for S is observed also.

The weak direct effect, almost absence of effect or strongly feedback effect of intensity of ionizing radiation (Rn, Q) with the light ions content in atmosphere are revealed. One of the reasons for this effect can be catalyzation of the processes of formation secondary aerosols in atmosphere according to the scheme of gas→ particle by the ionizing radiation, which occur more intensive than the ions formation. The corresponding examples of the connections of ionizing radiation with the ions content and sub-micron aerosol concentration are presented. For example, the coefficient of linear correlation R between the content of light ions and the characteristics of the air ionization has the following values: year – pair LgN – Rn, R= -0.63 (the level of significance α = 0.0001); pair LgN – Q, R= 0.13 (α = 0.01); warm season - pair LgN – Rn, R= -0.09 (α = 0.2); pair LgN – Q, R= -0.11 (α = 0.15); cold season – pair LgN – Rn, R= -0.65 (α = 0.0001); pair LgN– Q, R= 0.08 (α = 0.25). As is evident, the picture is fairly complicated, whereas under the normal conditions the concentration of light ions always directly depends on the intensity of the ionizing radiation. The connection of the N and S takes the reverse classical form.

The equations of the multiple linear regressions between the N, Rn, Q and S are given.

Key words: Light ions, radon, cosmic rays, sub-micron aerosol

INTRODUCTION

The light ions concentration in the atmosphere (or air electrical conductivity, proportional to the content of light ions) in many respects defines the ecological state of medium both itself and being the indicator of the purity of air in the aspect of aerosol pollution. The formation of light ions in the ground layer of the atmosphere occurs due to the alpha radiation of radon and short-lived products of its decay (40 %), gamma-radiation of soil (40 %) and cosmic rays (20 %). The disappearance of ions occurs due to their recombination and attachment to the aerosols. Usually the concentration of light ions always directly depends on the intensity of the ionizing radiation [Chalmers 1974]. Atmospheric aerosol is the mixture of the usual particles of the natural and anthropogenic origin (mineral aerosol, sea aerosol, the solid ejections of industrial enterprises and transport, etc.) and the so-called secondary aerosol. Secondary aerosol is formed in the presence of the chemical and photochemical reactions according to the scheme of gas→ particle. However, it turned out that radioactive and cosmic radiation contributes to the acceleration of the processes of the secondary aerosol formation [Muraleedharan, Subba Ramu and Vohra 1984; Harrison 2002; Smirnov and Savchenko 2005; Amiranashvili et al. 2004; Amiranashvili et al. 2005; Amiranashvili 2007; Amiranashvili et al. 2010; Amiranashvili, Bliadze and Chikhladze 2013].

The special features of the effect of the radio nuclide emission in the formation of secondary aerosols in the conditions of Tbilisi city (Tbilisi type of smog) are revealed. Intensification by the ionization of the aerosol pollution of the atmosphere under the conditions of Tbilisi is so strong which this leads also to worsening in the quality of air in the aspect of its ionic composition also. As a whole the Tbilisi type of smog is characterized by the impossible under the natural conditions feedback of the content of radon, gamma-radiation and cosmic radiation with the concentration of light ions in air, caused by the formation of secondary aerosols in the quantity, which in conjunction with the usual particles is capable of joining more ions to itself how them it is formed with the ionization. The Tbilisi type of smog can occur also in other strongly contaminated cities and environments [Amiranashvili, 2011a, 2011b, 2011c; Amiranashvili, Bliadze and V. Chikhladze 2012].

Therefore the task of the analysis of the balance of formation and disappearance of light ions in the environment, where the content of aerosols depends on the radon content and cosmic rays intensity was set. This work is the continuation of the foregoing studies. The results of the analysis of the connection of total light ions content in air with radon, neutron component of cosmic rays intensity and sub-micron aerosols in surface boundary layer of Tbilisi city for three periods of year are given below.

MATERIAL AND METHODS

The summary light ions concentration (N, cm^{-3}) was measured by Gerdien's type instrument. The radon content (Rn, Bq/m^3) was determined by the sampling method of air through the filter with the subsequent calculation of the alpha particles of the short-lived products of its decay. Content of a total quantity of sub-micron aerosols by diameter $\geq$ 0.1 mcm (S, cm^{-3}) was measured with the use of an instrument FAN, which works in the counting regime. The neutron component of cosmic rays was measured by neutron monitor (Cosmic Rays Station of Institute of Geophysics). Radon and light ions concentrations measurements were conducted 4 times a day at height 3 floor of the building of the cloud chamber of the Institute of Geophysics (8 meters above the level of soil, 41.754º N, 44.927º E, the height - 450 m above sea level), into 9, 12, 15 and 18 hour (in the winter time - 17 hours). The cosmic rays intensity (Q, imp/hour) was measured continuously [Amiranashvili, 2011a, 2011b, 2011c; Amiranashvili, Bliadze and Chikhladze 2012; Serdiukova and Kapitanov 1969].

Work gives the results of measurements for 2010 year. The analysis of data is carried out without taking into account weather conditions. The data about the daily mean values of the investigated parameters are analyzed (356 days, from 9 to 17-18 h).

The following designations will be used below (besides those pointed out above and well-known): C_v - coefficient of variation (%); α - the level of significance; R – coefficient of linear correlation; R^2 - coefficient of determination; 95% (+/-) - 95% - confidence interval of mean values; cold period: October – March; warm period: April-September. The dimensionality of the investigated parameters are omitted further to be more convenient.

RESULTS

The results in tables 1-4 are given.

Table 1 Statistical characteristics of daily mean values of radon content in air, galactic cosmic rays intensity, sub-micron aerosols and sum light ions concentrations in Tbilisi in 2010

Parameters	Year				Cold period				Warm period			
	Rn	Q	S	N	Rn	Q	S	N	Rn	Q	S	N
Min	0.7	7452	352	269	0.7	7452	352	269	1.2	8089	413	516
Max	13.0	10016	15729	2516	13.0	10016	12256	2516	6.9	9416	15729	1817
Mean	4.0	8676	2714	917	5.2	8579	2885	830	2.9	8772	2544	1004
Stdev	2.4	357	2086	333	2.8	429	1920	393	0.9	232	2230	231
C_v,%	58.8	4.1	76.9	36.3	54.5	5.0	66.6	47.4	31.6	2.6	87.7	23.0
Count	356				177				179			

In table 1 statistical characteristics of daily mean values of Rn, Q, S and N in Tbilisi in 2010 are presented. As follows from table 1 the values of investigated parameters in three periods of year change in the following ranges. Rn: year and cold period - from 0.7 to 13.0 (average values – 4.0 for year and

5.2 for cold period), warm period - from 1.2 to 6.9 (average value – 2.9); Q: year and cold period - from 7452 to 10016 (average values – 8676 for year and 8579 for cold period), warm period - from 8089 to 9416 (average value – 8772); S: year - from 352 to 15729 (average value – 2714), cold period - from 352 to 12256 (average value – 2885), warm period - from 413 to 15729 (average value – 2544); N: year and cold period - from 269 to 2516 (average values – 917 for year and 830 for cold period), warm period - from 516 to 1817 (average value – 1004). The minimally necessary level of the sum light ions content for the favorable influence on the health (1000 cm^{-3} and more) are observed: year - not more than 35 % of the measurements cases, cold period – 23%, warm period – 46 %.

Table 2 Weekly variations of daily mean values of sub-micron aerosols and sum light ions concentrations in Tbilisi in 2010

Parameters	Year		Cold period		Warm period	
	S	N	S	N	S	N
Week-days	2834	899	3048	798	2622	998
Weekends	2402	967	2461	911	2343	1021
Difference	432	-68	587	-113	279	-23
α	0.05	0.1	0.1	0.15	low significant	no significant

Table 3 Linear correlation between of daily mean values of logarithm of summary light ions, radon content in air, galactic cosmic rays intensity and logarithm of sub-micron aerosols concentrations in Tbilisi

Parameters	Year, R min = 0.10, α =0.05				Cold period, R min = 0.15, α= 0.05				Warm period, R min = 0.15, α=0.05			
	Lg N	Rn	Q	Lg S	Lg N	Rn	Q	Lg S	Lg N	Rn	Q	Lg S
Lg N	1	-0.63	0.13	-0.55	1	-0.65	0.08	-0.72	1	-0.09	-0.11	-0.31
Rn	-0.63	1	-0.13	0.49	-0.65	1	-0.02	0.62	-0.09	1	0.08	0.37
Q	0.13	-0.13	1	0.09	0.08	-0.02	1	0.04	-0.11	0.08	1	0.31
Lg S	-0.55	0.49	0.09	1	-0.72	0.62	0.04	1	-0.31	0.37	0.31	1

Average values of the sum ions and sub-micron aerosol concentrations in the week-days and weekends (table 2) respectively comprise. N: year – 899 and 967 (the difference is significant), cold season – 798 and 911 (the difference is significant), warm season –998 and 1021 (the difference is no significant); S: year – 2834 and 2402 (the difference is significant), cold season – 3048 and 2461 (the difference is significant), warm season –2622 and 2343 (low significant difference).

The weak direct effect, almost absence of effect or strongly feedback effect of intensity of ionizing radiation (Rn, Q) with the light ions content in atmosphere are revealed (table 3).

The coefficient of linear correlation R between the content of light ions and the characteristics of the air ionization has the following values: year – pair LgN – Rn, R= -0.63 (the level of significance α = 0.0001); pair LgN – Q, R= 0.13 (α = 0.01); warm season - pair LgN – Rn, R= -0.09 (α = 0.2); pair LgN – Q, R= -0.11 (α = 0.15); cold season – pair LgN – Rn, R= -0.65 (α = 0.0001); pair LgN– Q, R= 0.08 (α = 0.25). As is evident, the picture is fairly complicated, whereas under the normal conditions the concentration of light ions always directly depends on the intensity of the ionizing radiation. The connection of the N and S takes the reverse classical form (table 3). One of the reasons for this effect can be catalyzation of the processes of formation secondary aerosols in atmosphere according to the scheme of gas→ particle by the ionizing radiation, which occur more intensive than the ions formation.

Table 4 The values of coefficients of equations of the multiple linear regression of daily mean values of logarithm of summary light ions concentrations with radon content in air, galactic cosmic rays intensity and logarithm of sub-micron aerosols concentrations in Tbilisi

Coefficient	Year		Cold period		Warm period	
	Lg N = a·Rn+b·Q +c·Lg S + d					
	Value	95% (+/-)	Value	95% (+/-)	Value	95% (+/-)
a	-0.030666	0.005984	-0.022396	0.008245	0.002969	0.016155
b	0.000045	0.000035	0.000040	0.000043	-0.000008	0.000063
c	-0.181446	0.046313	-0.319389	0.075481	-0.102144	0.052270
d	3.268864	0.312837	3.724387	0.420465	3.386666	0.524170
R^2 multiple	0.49, α = 0.001		0.59, α = 0.001		0.10, α = 0.05	
Shares of Rn, Q and Lg Q in the limits of variation scope for variations of Lg N, %						
Share of Rn	12.8		9.5		0.6	
Share of Q	3.9		3.5		0.3	
Share of Lg S	10.2		17.1		5.4	

The values of coefficients of equations of the multiple linear regressions of daily mean values of Lg N with Rn, Q and Lg S in table 4 are given. As follows from this table for year and cold period variations of Lg N by variations of Rn and Lg S are mainly caused (year - share of Rn for Lg N = 12.8 %, share of Lg S for Lg N = 10.2 %; cold period - share of Rn for Lg N = 9.5 %, share of Lg S for Lg N = 17.1 %). In the warm period variations of Lg N practically do not depend on variations of Rn (share of Rn for Lg N = 0.6%) and weakly depend on variations of Lg S (share of Lg S for Lg N = 5.4 %). Share of Q for Lg N is considerably less than share of Rn and Lg S: year - 3.9 %, cold period - 3.5 %, warm period - 0.3 %.

DISCUSSION

In the strongly polluted cities and the localities the ionizing radiation (radon, cosmic rays, gamma radiation) instead of the well-known effect of an increase of the concentration of light ions (or air electrical conductivity) can lead to the inverse effect, their decrease. This phenomenon in Tbilisi was discovered (Tbilisi type of smog). Moreover, for radon - for all periods of year with weaker inverse correlation into the warm half-year. For the cosmic rays - weak direct connection during the year and in the cold period, and reverse - into the warm half-year.

As it was noted in the works [Amiranashvili, 2011a, 2011b, 2011c] the well-known balance equation relating the formation and disappearing of light ions N taking into account the influence of the ionizing radiation on the formation of secondary aerosols can take the form:

$$dN/dt = q - \alpha' N^2 - \beta SN - \beta' S(q)N$$

where: q is the intensity of ion formation, α΄- recombination coefficient, S - usual aerosol concentration, S(q) – secondary aerosol concentration as q function, β and β΄ - coefficient of the capture of light ions by usual and secondary aerosols respectively. Depending on the nature of the connection between q and N(q) under the conditions of the strongly contaminated atmosphere (similar to Tbilisi) negative correlation between q and N is completely possible.

However, appears the problem of the separate determination of the ranges of sizes and concentration of the secondary aerosol, formed under the action of the different kind ionizing radiation with different state of atmosphere (temperature, humidity, solar radiation, the forming secondary aerosols gases, etc.), which is necessary for evaluating the values of β΄ and S(q).

Further detailed field and laboratory investigations of this effect with the use of equipment for measuring the concentration of aerosols and ions over a wide range of the spectrum of their sizes and mobilities are also desirable. It is also interesting to explain, in what still cities is observed this phenomenon, how it is extended. The area of propagation of this type of smog around the city is also of interest.

Besides atmospheric industrial and environmental electricity and ecological aspects of the indicated phenomenon it is important to also estimate its climatic effects (influence on the solar radiation, visibility, cloudiness, precipitation, thunderstorm activity, etc.).

CONCLUSIONS

Some special features of variations of light ions concentration and their connections with the ionizing radiation and sub-micron aerosol content in air under the conditions of Tbilisi city are revealed. The weak direct effect, almost absence of effect or strongly feedback effect of intensity of ionizing radiation (radon, cosmic rays intensity) with the light ions content in atmosphere for three periods of year (year, cold and warm seasons) are revealed. One of the reasons for this effect can be catalyzation of the processes of formation secondary aerosols in atmosphere according to the scheme of gas→ particle by the ionizing radiation, which occur more intensive than the ions formation.

Weekly Variations of the light ions and sub-micron aerosol concentrations is study. The multiple linear regression analysis connection the light ions concentration with radon content, cosmic rays intensity and sub-micron aerosol content are carried out.

ACKNOWLEDGMENT

The designated project has been fulfilled by financial support of the Shota Rustaveli National Science Foundation (Grant N GNSF/ST08/5-437).

REFERENCES

Amiranashvili, A., 2011a: Negative Correlation Between of Light Ions Content and Radon Concentration: Particularity of Tbilisi City Air Pollution, or Norm for the Urbanized Locality?. *Proceedings*,. 14th Int. Conf. on Atmospheric Electricity, Rio de Janeiro, Brazil, August 07-12, 2011, http://www.icae2011.net.br/.

Amiranashvili, A., 2011b: The feedback effect of intensity of ionizing radiation with the light ions content in atmosphere. Paradox (the Tbilisi type of a smog), or usual phenomenon for the strongly pollution cities?. *Collected Papers New Series*. ISSN 2333-3347, Tbilisi, **3(82)**, 95-100.

Amiranashvili, A., 2011c: Tbilisi Type of Smog as Attribute of Feedback Effect Between the Air Ionization Intensity and Small Ions Concentration, *Proceedings*,. 7th Asia-Pacific Int. Conf. on Lightning, November 1-4, 2011, Chengdu, China, ISBN: 978-1-4577-1467-2, 496–499, http:// ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=6110175, http://www.apl2011.net/.

Amiranashvili, A.G., 2007d: On the Role of Cosmic and Radioactive Radiation on the Formation of the Secondary Aerosols in Atmosphere. *Abstracts*,. Int. Conference “Near-Earth Astronomy 2007” Terskol, Russia, 3-7 September 2007.

Amiranashvili, A.G., Amiranashvili, V.A., Gzirishvili, T.G., Kharchilava, J.F., and K.A. Tavartkiladze, 2005: Modern Climate Change in Georgia. Radiatively Active Small Atmospheric Admixtures. *Monograph*, *Transactions*,. M. Nodia Institute of Geophysics of Georgian Acad. of Sci. ISSN 1512-1135, **59**, 128 pp.

Amiranashvili, A.G., Amiranashvili, V.A., Kirkitadze, D.D., Chiabrishvili, N.G., and K.M. Chochishvili, 2004: To a Question About the Formation of Secondary Aerosols in the Atmosphere, *Proceedings*,. Mikheil Nodia Institute of Geophysics, ISSN 1512-1135, Tbilisi, **58**, 119 – 126, (in Russian).

Amiranashvili, A., Bliadze, T., and V. Chikhladze, 2012: Photochemical smog in Tbilisi, *Transactions*,. Mikheil Nodia Institute of Geophysics of Ivane Javakhishvili Tbilisi State University, ISSN 1512-1135, **63**, 160 pp., (in Georgian).

Amiranashvili, A., Bliadze, T., and V. Chikhladze, 2013: Air Pollution in Tbilisi in the Winter Fogs, *Abstracts*,. 6th Int. Conf. on Fog, Fog Collection and Dew, Yokohama, Japan, May 19-24, 2013.

Amiranashvili, A., Bliadze, T., Kirkitadze, D., Nikiforov, G., Nodia, A., Chankvetadze, A., and V. Chikhladze, 2010: Surface Radon as the Air Pollution Catalyst by Secondary Aerosols in Tbilisi, *Transactions*,. Mikheil Nodia Institute of Geophysics, ISSN 1512-1135, Tbilisi, **62**,197-206, (in Russian).

Chalmers, J.A., 1974: Atmospheric Electricity. Leningrad, Gidgometeoizdat, 421 pp., (in Russian).

Harrison, R.G., 2002: Radiolytic particle production in the atmosphere, *Atmos. Environ*, **36**, 159-160.

Muraleedharan, T.S., Subba Ramu, M.S., and K.G. Vohra, 1984: Experimental Studies of the Formation of Aitken Nuclei in the Atmosphere. *Proceedings*,. 11th Int. Conf. on Atmospheric Aerosols, Condensation and Ice Nuclei, Budapest, Hungary, 3-8 September.1984, **1**, 52-57.

Serdiukova, A.S. and Yu.T Kapitanov, 1969: Isotopes of Radon and the Short-Lived Products of Their Decay in Nature, M., Atomizdat, 312 pp. (in Russian).

Smirnov V.V. and A.V. Savchenko, 2005: Effect of Ionizing Radiation on the Formation of Nanoparticles in the Atmosphere. *Chemistry for Sustainable Development*, **5**, 649-654, (in Russian).