Tbilisi Type of Smog as Attribute of Feedback Effect Between the Air Ionization Intensity and Small Ions Concentration

Avtandil Amiranashvili

Atmospheric Physics Department,
Mikheil Nodia Institute of Geophysics of Ivane Javakhishvili Tbilisi State University,
1, M. Aleksidze str., 0171, Tbilisi, Georgia
avtandilamiranashvili@gmail.com

***Abstract*—In Tbilisi according to the data of the complex stationary and mobile monitoring of small ions concentration, radon, gamma-radiation of soil and sub-micron aerosol concentration in 2009-2011 the feedback effect of intensity of ionizing radiation with the small ions content in atmosphere is 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.**

I. INTRODUCTION

The small ions concentration in the atmosphere 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 small 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. Under the normal conditions the concentration of small ions always directly depends on the intensity of the ionizing radiation [1].

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 [2-9].

Therefore the task of the analysis of the balance of formation and disappearance of small ions in the environment, where the content of aerosols depends on the radon content and gamma-radiation was set. The preliminary results of the analysis of the connection of total small ions content with air ionizing radiation in surface boundary layer of Tbilisi city (strongly pollution location) and ecologically clean locality in Western Georgia are given below.

II. METHOD AND DATA DESCRIPTION

The stationary and expeditionary investigations in the urban and ecologically clean locality for different regions of Georgia are carried out.

Stationary measurements of concentration of small ions (cm^{-3}) by Gerdien's type instrument was carried out. The radon content (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 [10]. Content of a total quantity of sub-micron aerosols by diameter ≥ 0.1 mcm (cm^{-3}) was measured with the use of an instrument FAN, which works in the counting regime. The indicated 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 data about the daily mean values of the investigated parameters are analyzed (511 days, from 9 to 17-18 h). Work gives the results of stationary measurements from June 2009 through February 2011.

Mobile studies of small ions concentration are conducted with the aid of the portable ions counter of the production of firm "AlphaLab, Inc.". Work represented the data about of small ions content in Tbilisi (20 points in different city locations, 40 measurements in 2010), and also in 111 points of Western Georgia at the heights from 100 to 500 m above sea level (city, rural locality, health resort zones, the coast of Black sea, etc., period from 2007 through 2009). All mobile measurements of small ions were accompanied by measurements of the gamma-radiation (nSv/hour).This measurements in Tbilisi city accompanied by measurements of radon and sub-micron aerosol also.

The analysis of data is carried out without taking into account weather conditions at wind speed not above 1.5 m/s. The following designations will be used below: C_v - coefficient of variation, %; R- coefficient of linear correlation; α - the level of significance.

The dimensionality of the investigated parameters are omitted further to be more convenient.

III. RESULTS

The results in table 1-3 and fig. 1-8 are given. In table 1 and fig. 1-3 the data about stationary monitoring of investigated parameters, and in table 2-3 and fig. 4-8 the data about mobile measurements are presented.

TABLE I
STATISTICAL CHARACTERISTICS OF SMALL IONS CONCENTRATION, RADON AND AEROSOL CONTENT IN TBILISI (STATIONARY MEASUREMENTS)

Parameter	Radon	Aerosol	Sum Ions
Max	13.1	9060	1935
Min	0.8	238	215
Range	12.3	8822	1720
Average	4.4	2235	815
St Dev	2.3	1655	244
C_v	52.5	74.0	29.9
	Correlation matrix (α=0.001)		
Radon	1	0.47	-0.45
Aerosol	0.47	1	-0.33
Sum Ions	-0.45	-0.33	1

TABLE II
STATISTICAL CHARACTERISTICS OF SMALL IONS CONCENTRATION, GAMMA-RADIATION, RADON AND AEROSOL CONTENT IN 20 LOCATION OF TBILISI (MOBILE MEASUREMENTS)

Parameter	Gamma-radiation	Radon	Aerosol	Sum Ions
Max	109	16.0	9000	1200
Min	53	1.4	750	200
Range	56	14.6	8250	1000
Average	81.9	6.3	3638	492
St Dev	10.9	3.0	1928	251
C_v	13.3	47.4	53.0	51.0
	Correlation matrix			
Gamma-radiation	1	0.37	0.24	-0.15
Radon	α=0.05	1	0.70	-0.51
Aerosol	α=0.1	α=0.0005	1	-0.48
Sum Ions	α=0.35	α=0.001	α=0.001	1

TABLE III
STATISTICAL CHARACTERISTICS OF SMALL IONS CONCENTRATION AND GAMMA-RADIATION IN 111 LOCATION OF WESTERN GEORGIA (MOBILE MEASUREMENTS)

Parameter	Max	Min	Range	Average	St Dev	C_v	R
Gamma-radiation	159	15	144	63	30	48	0.27 (α=0.01)
Sum Ions	3100	450	2650	1844	563	31	

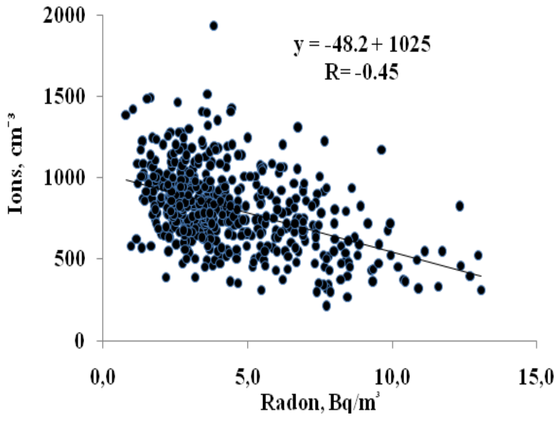

Fig. 1 Correlation between radon and small ions concentration in Tbilisi (stationary point of measurement)

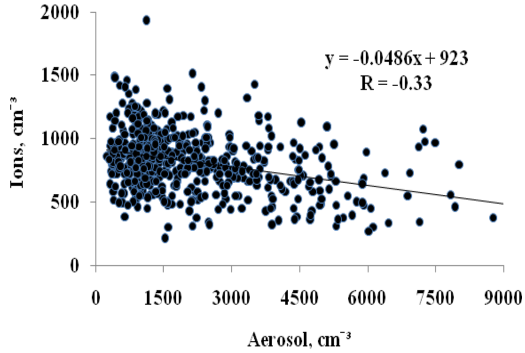

Fig. 2 Correlation between aerosol and small ions concentration in Tbilisi (stationary point of measurement)

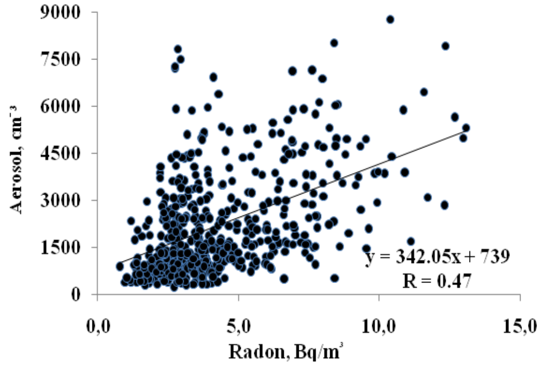

Fig. 3 Correlation between radon and aerosol concentration in Tbilisi (stationary point of measurement)

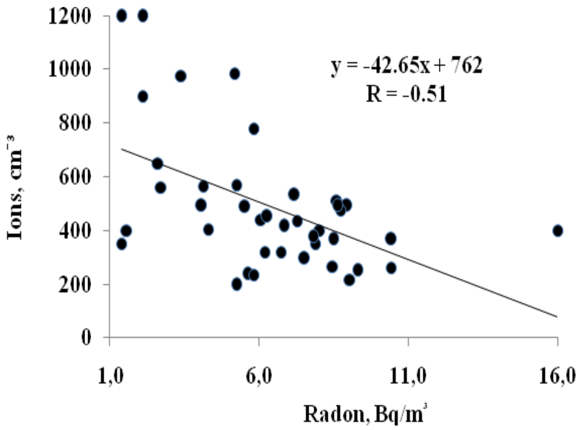

Fig. 4 Correlation between radon and small ions concentration in 20 locations of Tbilisi

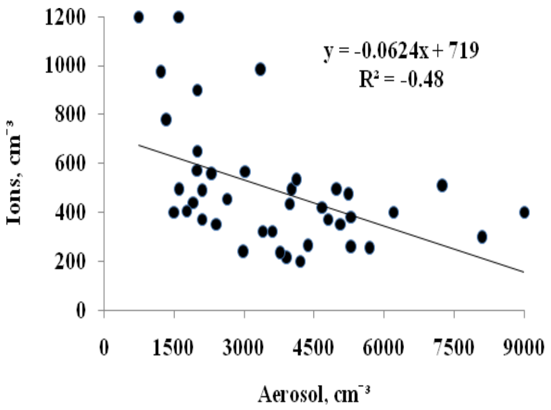

Fig. 5 Correlation between aerosol and small ions concentration in 20 locations of Tbilisi

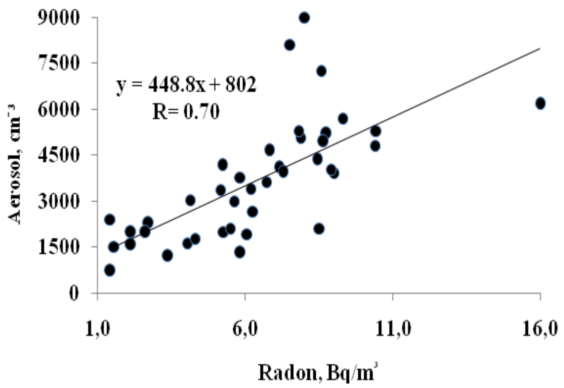

Fig. 6 Correlation between radon and aerosol concentration in 20 locations of Tbilisi

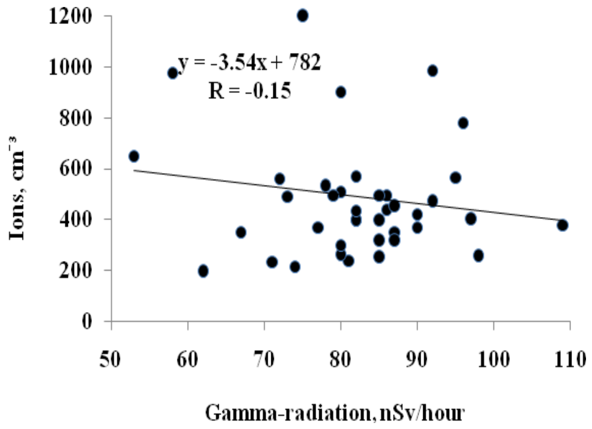

Fig. 7 Correlation between gamma - radiation and small ions concentration in 20 locations of Tbilisi

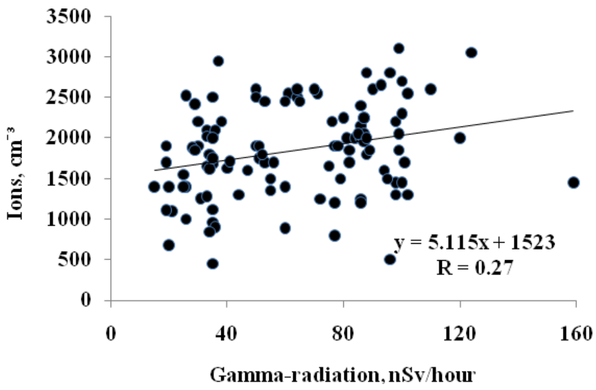

Fig. 8 Correlation between gamma - radiation and small ions concentration in 111 locations of Western Georgia

As it follows from table 1 the mean values of Radon, Aerosol and Ions content are respectively equal: 4.4, 2235 and 815; the minimum values - 0.8, 238 and 215; the maximum values - 13.1, 9060 and 1935. The greatest variations for the investigated parameters for Aerosol is observed (C_v = 74.0%), the smallest – for Ions (29.9%).

The coefficient of linear correlation between the values of Radon, Aerosol and Ions content are respectively equal (table 1, fig. 1-3): - 0.47 (for pair Radon - Aerosol), -0.33 (for pair Aerosol - Ions) and -0.45 (for pair Radon - Ions).

In table 2 and fig. 4-7 results of correlation and regression analysis of connections between Ions, Radon, Aerosol and Gamma-Radiation in 20 locations of Tbilisi city are presented. As for the stationary point of measurement, on the pollution boundary of Tbilisi city the correlation between the content of ions, radon and aerosols remain both on the sign and on the significance. Concerning the connection of gamma-radiation with the content of small ions, as in the case with radon and cosmic rays [8,9] under the conditions of Tbilisi city this connection changes with the direct correlation to the negative (R=-0.15). It should be noted that gamma-radiation, as radon and cosmic rays, contribute to the formation of secondary aerosols (R=0.24 for pair Gamma-Radiation – Aerosol, table 2).

The example to the normal connection of gamma-radiation with the content of small ions in table 3 and in fig. 8 is given. In this case usual physical regularity is observed - ionization rate is directly proportional to small ions content in air (R=0.27). The correlation between the cosmic-ray intensity and the summary air electrical conductivity (or the concentration of small ions) in Dusheti (40 km from Tbilisi) has well-known physical nature also (R=0.34), whereas in Tbilisi this connection is negative (R=-0.19) [9].

So, under the conditions of Tbilisi city in contrast to the well-known physical regularities, an increase of the air ionization leads not to the increase, but to the decrease of the concentration of small ions.

The negative correlation of the air ionization with small ions concentration has not direct, but indirect nature, through the catalyzation of the formation of secondary aerosols.

The well-known balance equation relating the formation and disappearing of light ions Y taking into account the influence of the ionizing radiation on the formation of secondary aerosols can take the form:

$$dY/dt = q - \alpha' Y^2 - \beta NY - \beta' N(q)Y$$

where: q is the intensity of ion formation, α'- recombination coefficient, N - usual aerosol concentration, $N(q)$ – 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 Y is completely possible.

Thus, intensification by air ionization of the aerosol pollution of the atmosphere under the conditions of Tbilisi city is so strong which leads also to worsening in the air quality from the point of view of its ionic composition. The Tbilisi type of smog (feedback effect between the intensity of the ionizing radiation and the concentration of small ions) can occur, also, in other strongly contaminated cities and localities.

IV. Conclusions

In Tbilisi city according to the data of the complex monitoring of small ions concentration, radon, aerosol, cosmic rays and gamma-radiation the effect of feedback of intensity of ionizing radiation with the small ions content in atmosphere is discovered. 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 Tbilisi type of smog can occur, also, in other strongly polluted cities and localities. In the future we plan also the complex analysis of connections of the small ions and aerosol content with the intensity of gamma radiation, cosmic rays, radon, solar radiation, also with data about surface ozone, humidity, etc. in the conditions of Tbilisi city. The area of propagation of this type of smog around the city is also of interest.

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.

Besides ecological aspects of the indicated type of smog it is important to also estimate its climatic effects (influence on the solar radiation, precipitation, thunderstorm activity, etc.).

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References

[1] J.A. Chalmers, *Atmospheric Electricity*, Leningrad, Gidgometeoizdat, pp. 1-421, 1974, (in Russian).

[2] T.S. Muraleedharan, M.S. Subba Ramu, and K.G.Vohra, “Experimental Studies of the Formation of Aitken Nuclei in the Atmosphere”, Proc. 11th Int. Conf. on atmospheric aerosols, Condensation and Ice Nuclei, Budapest, Hungary, 3-8 September. Vol.1, pp. 52-57, 1984.

[3] R.G. Harrison, Radiolytic particle production in the atmosphere, Atmos. Environ, vol. 36, pp. 159-160, 2002.

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

[5] A.G.Amiranashvili, V.A. Amiranashvili, T.G. Gzirishvili, J.F. Kharchilava,and K.A. Tavartkiladze, *Modern Climate Change in Georgia. Radiatively Active Small Atmospheric Admixtures*, Institute of Geophysics, Monograph, Trans. of M. Nodia Institute of Geophysics of Georgian Acad. of Sci. ISSN 1512-1135. Vol. LIX. pp. 1-128, 2005.

[6] A.G. Amiranashvili, “On the Role of Cosmic and Radioactive Radiation on th the Formation of the Secondary Aerosols in Atmosphere”, Int. Conference “Near-Earth Astronomy 2007” Abstract, Terskol, Russia, 3-7 September 2007.

[7] A. Amiranashvili, T. Bliadze, D. Kirkitadze, G. Nikiforov, A. Nodia, A. Chankvetadze, and V. Chikhladze, “Surface Radon as the Air Pollution Catalyst by Secondary Aerosols in Tbilisi”, Transactions of Mikheil Nodia Institute of Geophysics, vol. LXII, ISSN 1512-1135, Tbilisi, pp. 197-206, 2010, (in Russian).

[8] A.Amiranashvili, “Negative Correlation Between of Light Ions Content and Radon Concentration: Particularity of Tbilisi City Air Pollution, or Norm for the Urbanized Locality?”, Proc. ICAE-2011 Conference, Rio de Janeiro, Brazil, 8-12 August 2011.

[9] A.Amiranashvili,, “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?”, Proc. Int. Sc. Conference on “Environment and Global Warming”, Tbilisi, Georgia, 15-17 September 2011, in press.

[10] A.S. Serdiukova and Yu.T. Kapitanov, *Isotopes of Radon and the Short-Lived Products of Their Decay in Nature*, M., Atomizdat, pp.1-312, 1969.