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Avtandil Amiranashvili
Ivane Javakhishvili Tbilisi State University

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?

Avtandil Amiranashvili

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

1. 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 et al., 1984; Amiranashvili et al., 2004, 2005, 2007, 2010]. 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. The preliminary results of the analysis of the connection of total light ions content with radon and neutron component of cosmic rays intensity in surface boundary layer of Tbilisi city are given below.

2. METHOD AND DATA DESCRIPTION

Concentration of light ions (cm^{-3}) was measured by Gerdien's type instrument. 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 [Serdiukova and Kapitanov, 1969]. The neutron component of cosmic rays was measured by neutron monitor. 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 (imp/hour) was measured continuously.
Work gives the results of measurements from June 2009 through May 2010. In the work also used archive data about cosmic-ray intensity in Tbilisi and summary air electrical conductivity in Dusheti (1969-1982). The measurements of air electrical conductivity were conducted by the Gerdien type instrument (10^{-15}/ohm·m). 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 (from 9 to 17-18 h).

The following designations will be used below (besides those pointed out above and well-known): σ_m - standard error (68% - confidence interval of mean values), C_v - coefficient of variation (%), A - coefficient of skewness, K - coefficient of kurtosis, α - the level of significance. R – coefficient of linear correlation; R^2 - coefficient of determination, 95% (+/-) - 95% - confidence interval of mean values. The dimensionality of the investigated parameters are omitted further to be more convenient.

3. RESULTS

The results in table 1 and fig. 1-4 are given.

As it follows from table 1 the mean values of X1, X2 and Y are respectively equal: 3.7, 9023 and 870. The minimum values of X1, X2 and Y are respectively equal: 0.7, 8630 and 215. The maximum values of X1, X2 and Y are respectively equal: 13.1, 9274 and 2516. The median and mode are respectively equal: for X1 - 2.9, for X2 – 9135 and for Y – 693; for X1 - 2.6, for X2 – 9000 and for Y – 882. The greatest variations for the investigated parameters for X1 is observed (C_v = 54.8%), the smallest – for X2 (1.3%). The relative range (Range/Mean) changes from 335 % (for radon) to 7.1 % (for cosmic rays. The distribution functions of the all studied parameters in the general population are not the normal (the corresponding ratios between values of mean, median and mode; values of A and K).

The coefficient of linear correlation between the values X1, X2 and Y are respectively equal: - 0.48 (for pair X1 – Y) and -0.19 (for pair X2 - Y). In other words, 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 light ions. This effect is clearly demonstrated by fig. 1 and 2. The correlation between the cosmic-ray intensity and the air electrical conductivity in Dusheti is represented in fig. 3. In this case usual physical regularity is observed - ionization rate is directly proportional to air electrical conductivity (or the concentration of light ions).

Table1. The statistical characteristics of daily mean radon content in air, intensity of cosmic rays and sum light ions concentration in Tbilisi (06.2009-05.2010)

Parameter	Radon (X1)	Cosmic rays (X2)	Light ions (Y)
Mean	3.7	9023	870
Min	0.7	8630	215
Max	13.1	9274	2516
Range	12.4	644	2301
Median	2.9	9135	693
Mode	2.6	9000	882
St Dev	2.0	118	325
σm	0.11	6.3	17.3
Cv (%)	54.8	1.3	37.4
Range/Mean, %	335	7.1	264
As	1.17	-0.90	1.47
K	1.46	0.59	3.95
Count	354	354	354
	Correlation matrix		
Radon	1	0.12	-0.48
Cosmic rays	0.12	1	-0.19
Light ions	-0.48 (α=0.0001)	-0.19 (α=0.001)	1
	$Y = a + b \cdot X1 + c \cdot X2$ ($R^2 = 0.25$)		
a 95% (+/-)	4195.8 ±2279.2		
b 95% (+/-)	-74.81±14.79		
c 95% (+/-)	-0.338±0.253		
Share of radon, %	107 (in the limits of variation scope)		
Share of cosmic rays, %	25 (in the limits of variation scope)		

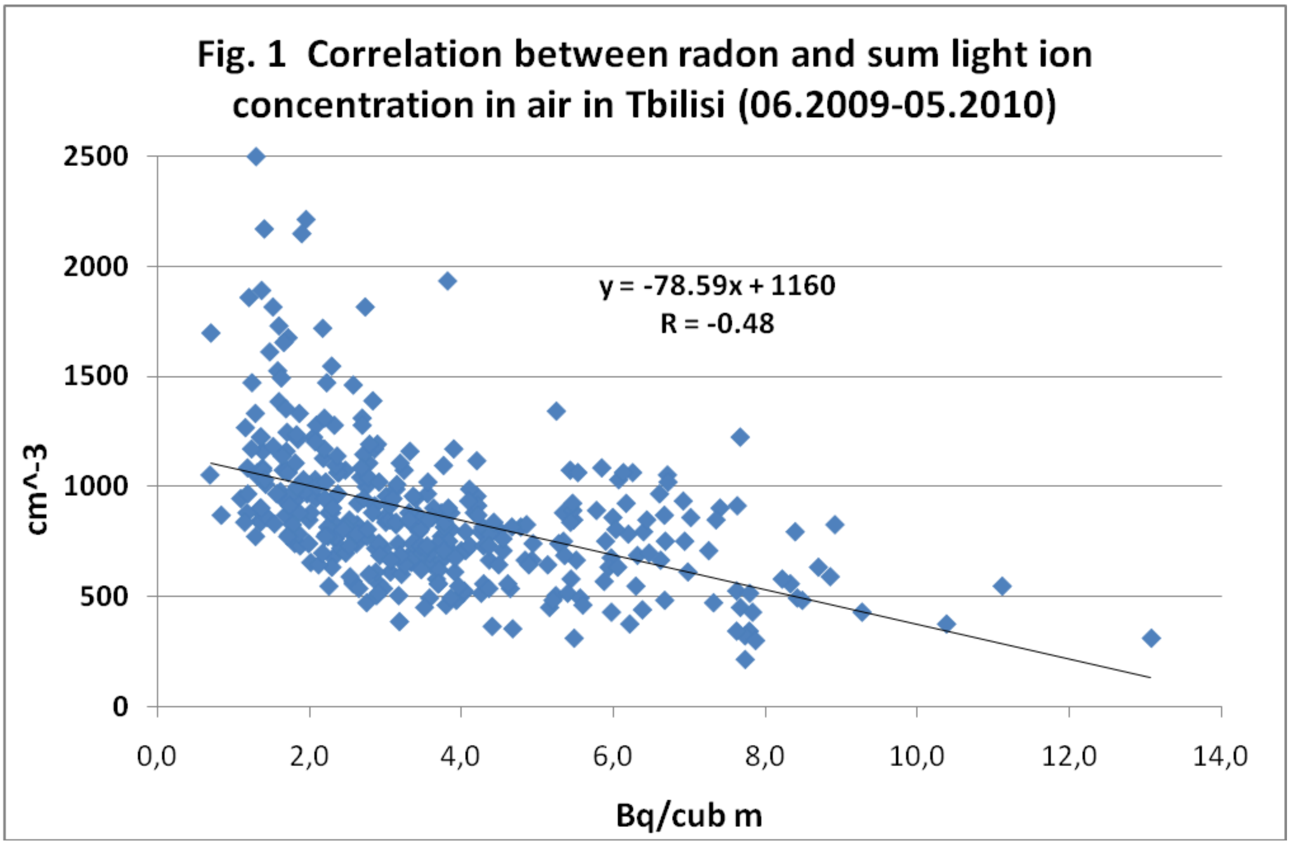
Fig. 1 Correlation between radon and sum light ion concentration in air in Tbilisi (06.2009-05.2010)
y = -78.59x + 1160
R = -0.48
2500
2000
1500
1000
500
0
cm^-3
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
Bq/cub m

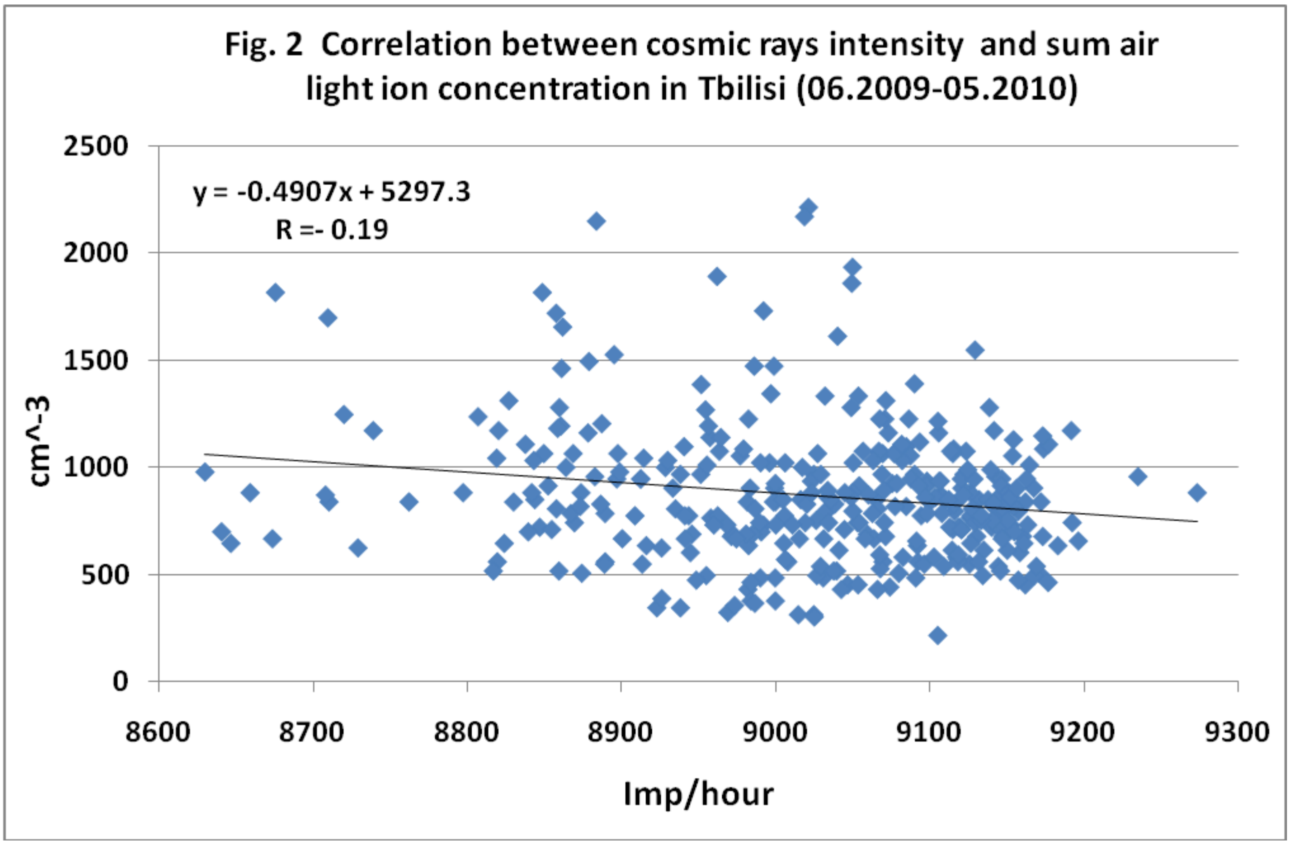
Fig. 2 Correlation between cosmic rays intensity and sum air light ion concentration in Tbilisi (06.2009-05.2010)
y = -0.4907x + 5297.3
R =- 0.19
2500
2000
1500
1000
500
0
cm^-3
8600
8700
8800
8900
9000
9100
9200
9300
Imp/hour

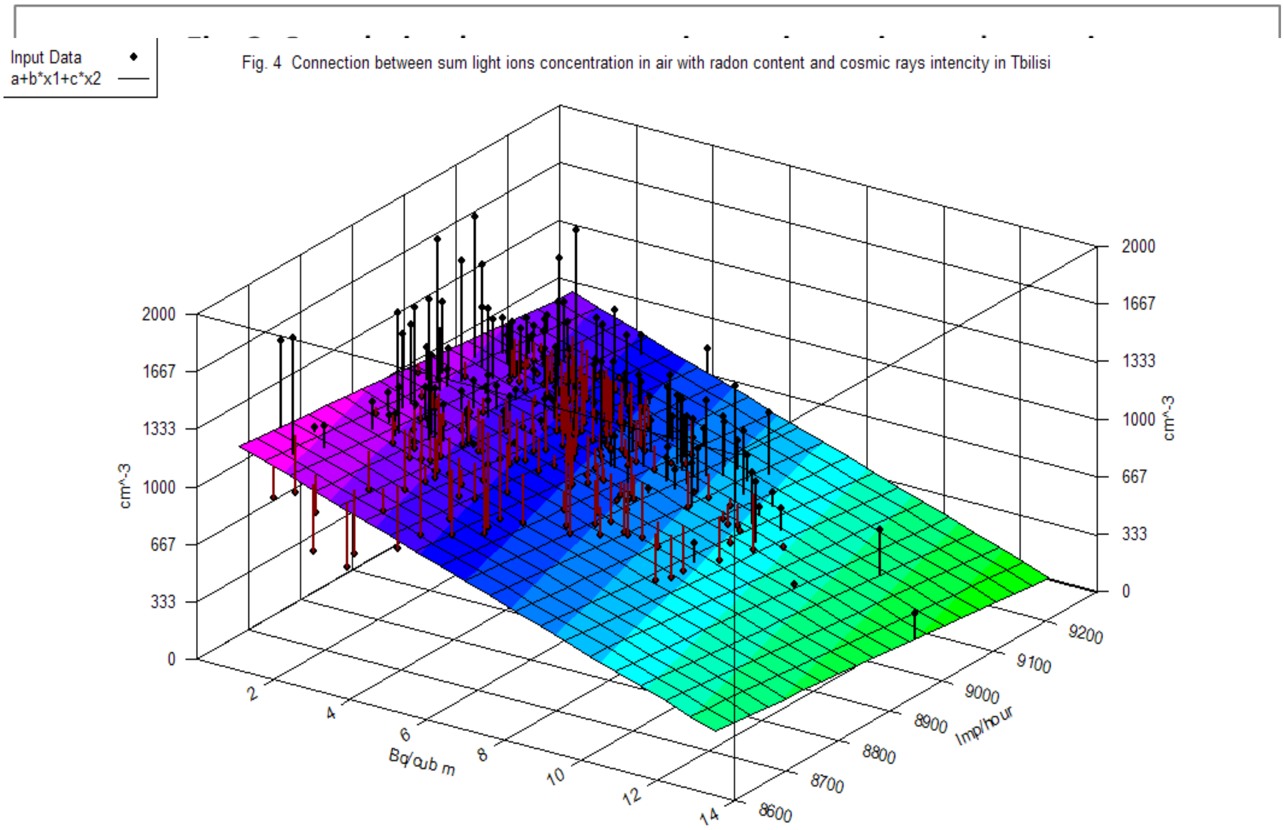

Fig. 4 Connection between sum light ions concentration in air with radon content and cosmic rays intencity in Tbilisi

In table 1 and fig. 4 the equation of the multiple linear regression of daily mean summary light ions concentrations with daily mean radon and intensity of cosmic rays is represented. As follows from this equation the changeability of ion concentration mainly depends on the changeability of radon content in air (107 %), and less - on the changeability of cosmic rays intensity (25 %).

The negative correlation radon content and cosmic rays intensity with light ions concentration has not direct, but indirect nature, through the catalyzation of the formation of secondary aerosols. We also provided a study of influence on the formation of the secondary aerosols (respectively - the special features of connection with the content of ions) of gamma radiation. Possibly the connections of the content of light ions with the gamma radiation will be analogous to connections with radon and cosmic rays.

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 radon and cosmic rays 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 between the intensity of the ionizing radiation and the concentration of light ions) can occur, also, in other strongly contaminated cities and localities.

4. CONCLUSIONS

In Tbilisi according to the data of the complex monitoring of light ions concentration, radon and cosmic rays intensity the effect of feedback of intensity of ionizing radiation with the light 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 study of connections of the light ions content with the intensity of gamma radiation in the conditions of Tbilisi city.

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მაიონიზებელი გამოსხივების ინტენსივობის უკუკავშირის ეფექტი ატმოსფეროში მსუბუქი იონების შემცველობასთან. პარადოქსი (სმოგის თბილისური ტიპი) თუ ჩვეულებრივი მოვლენა ძალზე დაბინძურებული ქალაქებისათვის?

ავთანდილ ამირანაშვილი

ივანე ჯავახიშვილის სახ. თბილისის სახელმწიფო უნივერსიტეტის
მიხეილ ნოდიას გეოფიზიკის ინსტიტუტი
avto_amiranashvili@hotmail.com

ატმოსფეროში მსუბუქი იონების კონცენტრაცია მნიშვნელოვნად განსაზღვრავს გარემოს ეკოლოგიურ მდგომარეობას როგორც უშუალოდ, ასევე როგორც ჰაერის სისუფთავის ინდიკატორი აეროზოლური დაბინძურების ასპექტით. მიწისპირა ფენაში მსუბუქი იონების წარმოქმნა ხდება რადონისა და მისი ნახევარდაშლის მოკლევადიანი პერიოდის მქონე პროდუქტების ალფა გამოსხივების (40%), ნიადაგის გამა-გამოსხივების (40%) და კოსმოსური სხივების (20%) ხარჯზე. იონების გაქრობა წარმოებს მათი რეკომბინაციით და აეროზოლებთან მიერთებით. ჩვეულებრივ პირობებში მსუბუქი იონების კონცენტრაცია ყოველთვის პირდაპირ არის დაკავშირებული მაიონიზებელი გამოსხივების ინტენსივობასთან.

თბილისში მსუბუქი იონების, რადონის და გალაქტიკური კოსმოსური სხივების ნეიტრონული კომპონენტის ინტენსივობის 2009-2010 წლებში კომპლექსური მონიტორინგის მონაცემების მიხედვით გამოვლენილია შებრუნებული სურათი – მაიონიზებელი გამოსხივების ინტენსივობისა და ატმოსფეროში მსუბუქი იონების შემცველობის უკუკავშირის ეფექტი. ამ ეფექტის ერთერთი მიზეზი შეიძლება იყოს ატმოსფეროში მეორადი აეროზოლების წარმოქმნის პროცესების კატალიზაცია სქემით გაზი ნაწილაკი, რომელიც წარმოებს უფრო ინტენსიურად, ვიდრე იონების წარმოქმნა.

მოყვანილია შესაბამისი მაგალითები მაიონიზებელი გამოსხივების კავშირისა მსუბუქი იონების შემცველობასთან ატმოსფეროს დაბინძურების სხვადასხვა პირობებისათვის.

საკვანძო სიტყვები: რადონი, კოსმოსური სხივები, მსუბუქი იონები, ატმოსფეროს დაბინძურება

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