Negative Correlation Between of Light Ions Content and Radon Concentration: Particularity of Tbilisi City Air Pollution, or Norm for the Urbanized Locality?

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ABSTRACT: The preliminary results of the analysis of the connection of total light ions content with radon and sub-micron aerosols concentrations in surface boundary layer of Tbilisi city are given. Measurements were conducted daily (four times a day). Work gives the results of measurements from June 2009 through May 2010. The analysis of data is carried out without taking into account weather conditions. It is shown that between the content of radon and sub-micron aerosols according to all data of measurements the direct correlation is observed (coefficient of linear correlation R composes: 0.61 for 9 h, 0.52 for 12 h, 0.51 for 15 h and 0.41 for 17-18 h). As one would expect correlation between the content of sub-micron aerosols and light ions is negative (R equal: -0.30 for 9 h, -0.33 for 12 h, -0.26 for 15 h and -0.30 for 17-18 h). Complete unexpected contingency proved to be the negative correlation between the content of radon and light ions (R equal: -0.42 for 9 h, -0.45 for 12 h, -0.43 for 15 h and -0.29 for 18 h). The possible reasons for the indicated effect, and also the role of radon in the intensification of the air pollution, the influence on the urban climate, etc. are discussed. It is proposed to introduce correction into the well-known balance equation relating the formation and disappearing of light ions taking into account the influence of radon on the formation of secondary aerosols.

1. INTRODUCTION

The light 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 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 (or from the ionization level), was set. The preliminary results of the analysis of the connection of total light ions content with radon and sub-micron aerosols concentrations 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. 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 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 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). Work gives the results of measurements from June 2009 through May 2010. The analysis of data is carried out without taking into account weather conditions.

The following designations will be used below: R- coefficient of linear correlation, R^2 - coefficient of determination, α - the level of significance. The dimensionality of the investigated parameters are omitted further to be more convenient.

3. RESULTS

The results in table 1 and 2 are given.

As follows from table 1 between the concentrations of radon and aerosols for all periods of year and time of measurement the steady positive correlation (R min = 0.175, α= 0.001 for year, R min = 0.24, α = 0.001 for the half-year period) is observed. Between the concentrations of ions and aerosols the negative correlation for the data in the year and the cold half-year is observed. The correlation between the content of aerosols and ions is absent for the warm half-year. Finally, complete unexpected contingency proved to be the steady negative correlation between the content of radon and light ions. Analogous correlation relationships for the pairs radon - Log aerosol, radon - Log ions and Log aerosol - Log ions are observed.

In table 2 the equations of the multiple linear regression of daily mean summary light ions concentrations with daily mean radon and daily mean aerosol concentrations are represented. As follows from table 2 the changeability of ion concentration mainly depends on the changeability of radon content in air.

The negative correlation between the content of radon and light ions 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 and cosmic rays radiation. Possibly the connections of the content of light ions with the gamma and cosmic rays radiation will be analogous to connections with radon.

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

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

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.

Table 1 Linear correlation between radon, aerosol and summary light ions concentrations in Tbilisi

<table>
<tr><td rowspan="2">Hour</td><td rowspan="2">Parameter</td><td colspan="3">Year</td><td colspan="3">Cold period</td><td colspan="3">Warm period</td></tr>
<tr><td>Radon</td><td>Aerosol</td><td>Ions</td><td>Radon</td><td>Aerosol</td><td>Ions</td><td>Radon</td><td>Aerosol</td><td>Ions</td></tr>
<tr><td rowspan="3">9</td><td>Radon</td><td>1</td><td>0.61</td><td>-0.42</td><td>1</td><td>0.55</td><td>-0.48</td><td>1</td><td>0.40</td><td>-0.34</td></tr>
<tr><td>Aerosol</td><td>0.61</td><td>1</td><td>-0.30</td><td>0.55</td><td>1</td><td>-0.38</td><td>0.40</td><td>1</td><td>-0.07</td></tr>
<tr><td>Ions</td><td>-0.43</td><td>-0.30</td><td>1</td><td>-0.48</td><td>-0.38</td><td>1</td><td>-0.34</td><td>-0.07</td><td>1</td></tr>
<tr><td rowspan="3">12</td><td>Radon</td><td>1</td><td>0.52</td><td>-0.45</td><td>1</td><td>0.50</td><td>-0.52</td><td>1</td><td>0.19</td><td>-0.34</td></tr>
<tr><td>Aerosol</td><td>0.52</td><td>1</td><td>-0.33</td><td>0.50</td><td>1</td><td>-0.45</td><td>0.19</td><td>1</td><td>0.00</td></tr>
<tr><td>Ions</td><td>-0.45</td><td>-0.33</td><td>1</td><td>-0.52</td><td>-0.45</td><td>1</td><td>-0.34</td><td>0.00</td><td>1</td></tr>
<tr><td rowspan="3">15</td><td>Radon</td><td>1</td><td>0.51</td><td>-0.43</td><td>1</td><td>0.44</td><td>-0.54</td><td>1</td><td>0.25</td><td>-0.33</td></tr>
<tr><td>Aerosol</td><td>0.50</td><td>1</td><td>-0.26</td><td>0.44</td><td>1</td><td>-0.34</td><td>0.25</td><td>1</td><td>-0.08</td></tr>
<tr><td>Ions</td><td>-0.43</td><td>-0.25</td><td>1</td><td>-0.54</td><td>-0.34</td><td>1</td><td>-0.33</td><td>-0.08</td><td>1</td></tr>
<tr><td rowspan="3">17-18</td><td>Radon</td><td>1</td><td>0.41</td><td>-0.29</td><td>1</td><td>0.30</td><td>-0.31</td><td>1</td><td>0.31</td><td>-0.22</td></tr>
<tr><td>Aerosol</td><td>0.41</td><td>1</td><td>-0.30</td><td>0.30</td><td>1</td><td>-0.40</td><td>0.31</td><td>1</td><td>-0.11</td></tr>
<tr><td>Ions</td><td>-0.29</td><td>-0.31</td><td>1</td><td>-0.31</td><td>-0.40</td><td>1</td><td>-0.22</td><td>-0.11</td><td>1</td></tr>
<tr><td rowspan="3">Daily mean</td><td>Radon</td><td>1</td><td>0.56</td><td>-0.49</td><td>1</td><td>0.48</td><td>-0.55</td><td>1</td><td>0.32</td><td>-0.44</td></tr>
<tr><td>Aerosol</td><td>0.56</td><td>1</td><td>-0.32</td><td>0.48</td><td>1</td><td>-0.43</td><td>0.32</td><td>1</td><td>-0.02</td></tr>
<tr><td>Ions</td><td>-0.49</td><td>-0.32</td><td>1</td><td>-0.55</td><td>-0.43</td><td>1</td><td>-0.44</td><td>-0.02</td><td>1</td></tr>
<tr><td></td><td></td><td>Daily mean</td><td colspan="2">Log daily mean</td><td>Daily mean</td><td colspan="2">Log daily mean</td><td>Daily mean</td><td colspan="2">Log daily mean</td></tr>
<tr><td>Daily mean</td><td>Radon</td><td>1</td><td>0.57</td><td>-0.54</td><td>1</td><td>0.51</td><td>-0.58</td><td>1</td><td>0.36</td><td>-0.46</td></tr>
<tr><td rowspan="2">Log daily mean</td><td>Aerosol</td><td>0.57</td><td>1</td><td>-0.38</td><td>0.51</td><td>1</td><td>-0.54</td><td>0.36</td><td>1</td><td>-0.04</td></tr>
<tr><td>Ions</td><td>-0.54</td><td>-0.38</td><td>1</td><td>-0.58</td><td>-0.54</td><td>1</td><td>-0.46</td><td>-0.04</td><td>1</td></tr>
<tr><td colspan="2">Number of obs.</td><td colspan="3">349</td><td colspan="3">174</td><td colspan="3">175</td></tr>
</table>

Table 2 The equations of the multiple linear regression of daily mean summary light ions concentrations (Y) with daily mean radon (X1) and daily mean aerosol (X2) concentrations

<table>
<tr><td rowspan="3">Coefficient</td><td colspan="2">Year</td><td colspan="2">Cold period</td><td colspan="2">Warm period</td></tr>
<tr><td colspan="6">Log(Y) = a+b·X1+c·Log(X2)</td></tr>
<tr><td>Value</td><td>95% (+/-)</td><td>Value</td><td>95% (+/-)</td><td>Value</td><td>95% (+/-)</td></tr>
<tr><td>a</td><td>3.195</td><td>0.142</td><td>3.647</td><td>0.228</td><td>2.911</td><td>0.176</td></tr>
<tr><td>b</td><td>-0.0373</td><td>0.0084</td><td>-0.0329</td><td>0.0108</td><td>-0.0638</td><td>0.0174</td></tr>
<tr><td>c</td><td>-0.0470</td><td>0.0504</td><td>-0.1844</td><td>0.0758</td><td>0.0655</td><td>0.0629</td></tr>
<tr><td>R^2 multiple</td><td colspan="2">0.297, $\alpha = 0.025$</td><td colspan="2">0.414, $\alpha = 0.01$</td><td colspan="2">0.234, $\alpha = 0.025$</td></tr>
<tr><td>Share of X1 for Log(Y),%</td><td colspan="2">15.9</td><td colspan="2">14.1</td><td colspan="2">11.0</td></tr>
<tr><td>Share of Log(X2) for Log(Y), %</td><td colspan="2">2.7</td><td colspan="2">9.8</td><td colspan="2">3.3</td></tr>
<tr><td></td><td colspan="6">Y = a+b·X1+c·X2</td></tr>
<tr><td>Share of X1 for Y,%</td><td colspan="2">102.1</td><td colspan="2">110.3</td><td colspan="2">71.1</td></tr>
<tr><td>Share of X2 for Y, %</td><td colspan="2">16.9</td><td colspan="2">53.1</td><td colspan="2">28.3</td></tr>
</table>

Thus, intensification by radon 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 sub-micron aerosols 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 cosmic and gamma radiation in the conditions of Tbilisi city.

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