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Periodic variations in time of atmospheric radioactive nanoparticles

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In the article the authors present the data of periodic variations in time of radon emanations in the ground layer of the atmosphere, which were measured for the period from January 1 to August 3, 2016. Harmonics of diurnal, 4-day and longer periods are revealed. The authors interpreted the 4-day variations, which can occur due to "lunar tides", that is, from soil uplifts due to the increase in gravitational tidal forces. The mechanism of radon emanation to the Earth's surface is complex. The mechanism of radon emanation to the Earth's surface is complex. In particular, the transportation of radon from the inner surfaces of the earth's crust is carried out by the diffusion of aerosols onto the surface, to which the radon atoms coagulate, due to electrostatic attraction. Such radioactive aerosol nanoparticles located in the surface layer of the atmosphere have the greatest impact on the risks of cancer, since the probabilities of their settling on the lung tissues are several orders of magnitude higher than the radon itself in the atomic form.

Key words: periodic variations in time of radon emanations, diffusion of aerosols, coagulation, atmospheric radioactive nanoparticles.
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1 Introduction

The study of spatial topologies of radon emanations in the surface layers of the atmosphere is extremely topical, primarily due to the direct effect of radon on human health [1]. Earth's crust from the very beginning of its formation contains natural radioactive elements, creating a natural radiation background. Radioactive isotopes of potassium-40, rubidium-87 and members of three radioactive families originating from uranium-238, uranium-235 and thorium-232 are present in rocks, soil, atmosphere, waters, plants and tissues of living organisms. The only gaseous product that is produced during the decay of three families of natural radionuclides is radon. 39 radon isotopes are known (all are radioactive), of which 3 are natural: ^{119}Rn, ^{220}Rn and ^{222}Rn. In 1 m3 of air under normal conditions, $7 * 10^{-6}$ g of radon is contained [2].

The energy range of alpha particles in the 5.5 MeV region is of particular interest because it is in this region that the energies of all α-particles emitted during the radioactive decay of three natural radon isotopes – ^{219}Rn, ^{220}Rn, ^{222}Rn and their daughter decay products (DPR). Historically, the harmful effect of radon on the human body was noted back in the 16th century, when the mysterious mining disease of miners attracted medical attention for a long time: the death rate from lung cancer among miners was 50 times higher than among other people.

Much later, an analysis of the causes of death of mine workers in the uranium mines of Europe in southern Germany and the Czech Republic showed that 30 to 50 percent of miners working in uranium mines die from lung cancer [3]. The study of radiation damage in vital organs from radon is an urgent task due to the fact that according to the data of the International Commission on Radiological Protection (ICRP, publications No. 50 and No. 65), most of the oncological diseases of the lungs and bronchi are caused precisely by radon isotopes and, in particular , their DPR [3, 4]. Developed countries legislatively solve this problem [5], and create special services. Therefore, the problem of radiation safety of housing has been intensified in recent years on the basis of radon research in many countries [6].

Radon enters the atmosphere of the premises in various ways: a) from outside air; b) from the ground base of the building; c) is allocated from building materials or enclosing structures made with the use of rocks; d) water from the building's internal water supply system; e) fuel burned in the building (household gas, coal, peat, oil shale).

In the world literature, the most detailed information on changes in the time of radon concentration in near-earth air was obtained during a six-yearly hourly recording of it (Chester, New Jersey, USA) [7]. The average arithmetic value of volumetric activity for six years of observation was 8 Bq/m^3. In the years 1977-1988. with small deviations from year to year, maximum concentrations were observed in summer and minimum in winter [8], in August the seasonal maximum was 3 times the minimum in February. In addition, there are also daily fluctuations in radon concentration in the air: the maximum level is noted at night, but at noon it decreases to the minimum value. This kind of diurnal variation has a so-called "normal" character [8]. In this case, the diurnal variations are associated with the formation and destruction of an inverse temperature layer in the atmosphere. The inverse layer, characterized by a minimum convective air flow, is formed in the surface layer due to the night cooling of the earth's surface. Suppressed convection contributes to the accumulation of radon released from the soil in the surface layer. With the beginning of warming up of the earth's surface, the inversion is disrupted, which leads to a decrease in radon concentration in the surface layer. Thus, the amplitude of radon concentration correlates with the amplitude of temperature variations.

According to the International Commission on Radiological Protection (ICRP), the Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) of the United Nations, the greatest part of the radiation dose (about 80% of the total) received by the population under ordinary conditions is associated with natural radiation sources. More than half of this dose is due to the presence of radon gas and its DPR in the air of buildings in which a person spends more than 70% of the time. Getting into the human body, radon promotes the processes leading to lung cancer. It is believed that radon is the second most frequent (after smoking) factor that causes lung cancer. Lung cancer caused by radon radiation is the sixth most frequent cause of death from cancer [9].

Despite the fact that the oncological danger of radon has been known for a long time, until 1980, no standards for the maintenance of radon and its daughter products in the premises were established in any country of the world. And only at the end of the 20th century, when it became clear that the radon problem, including the issues of rationing and lowering radiation doses, is of significant importance, the relevant standards were introduced [10].

2 Experimental procedure and methodology

The measurements were carried out by electronic radiometric equipment – radon radiometer and its DPR – "RAMON-02A", developed in the Republic of Kazakhstan [11]. For stationary location in a room or in a specially installed radioecological observation station, it is intended for automatic monitoring of the content of equivalent equilibrium volumetric activity (EEVA) of radon Rn-222 in air in residential and industrial premises, as well as in atmospheric air. This device produces EORA radon measurements in the range from 4 to $5 \cdot 10^5$ Bq / m^3. It uses an alpha-spectrometric method of measurement based on surface-barrier semiconductor detectors, and as an filter material, from which the accumulated alpha activity of radon is removed, an absorbent tape is installed, calculated for at least three thousand measurements.

The territories of Almaty are characterized by the existence of extensive zones of tectonic faults. World literary data show that elevated levels of radon emanations are associated with existing tectonic faults. Therefore, an object located in the tectonic fault zone was selected for the study. To measure the temporal topology of the emanation of radon isotopes in a continuous mode in buildings and premises, a cabinet was selected, located in the Physics and Technical Faculty of the KazNU named after. al-Farabi on the third floor. The authors of the project installed a stationary installation in the vicinity of the large Almaty tectonic fault, on one of its branches on the campus of the university, in order to increase the effect, that is, to register more powerful emanations of radon isotopes. To measure the equilibrium and nonequilibrium components of radon isotope emanation, two measuring instruments were placed in the cabinet with positions at a height of 1 m from the floor level. The measurements were carried out for 10 months with a periodicity of 2 hours. The device is automated to collect the results of measurements in a common database, with the update of the database at a frequency of 5 days. Figure 1 shows the time dependence of activity activity for the period from January 1 to August 3, 2016.

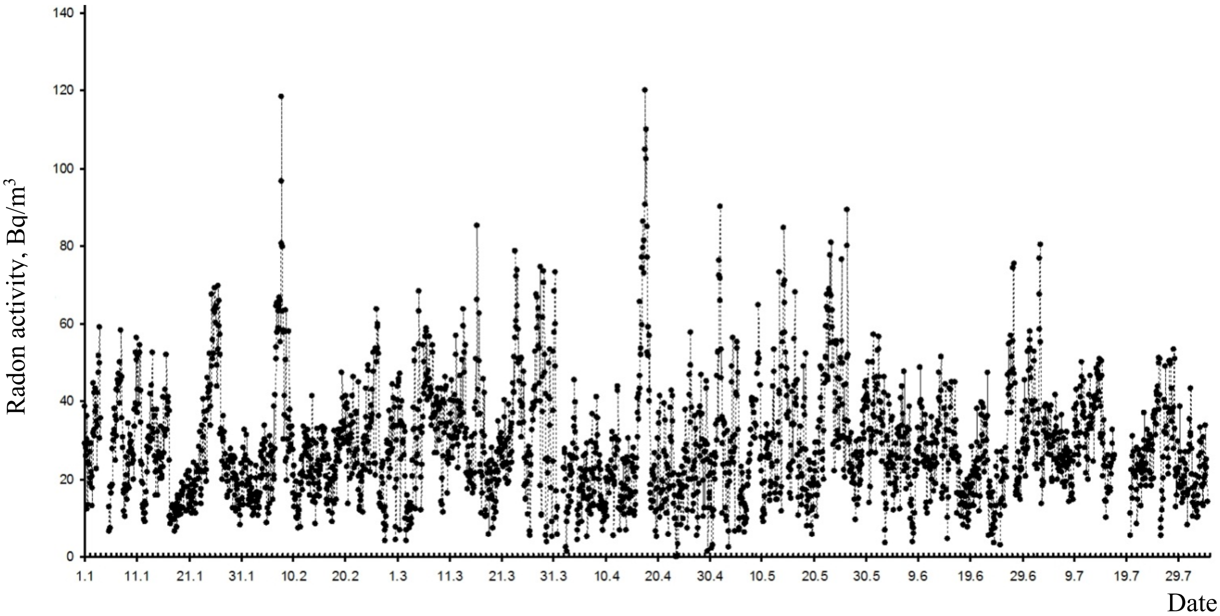


Figure 1 – Radon activity in the period from January 1 to August 3, 2016

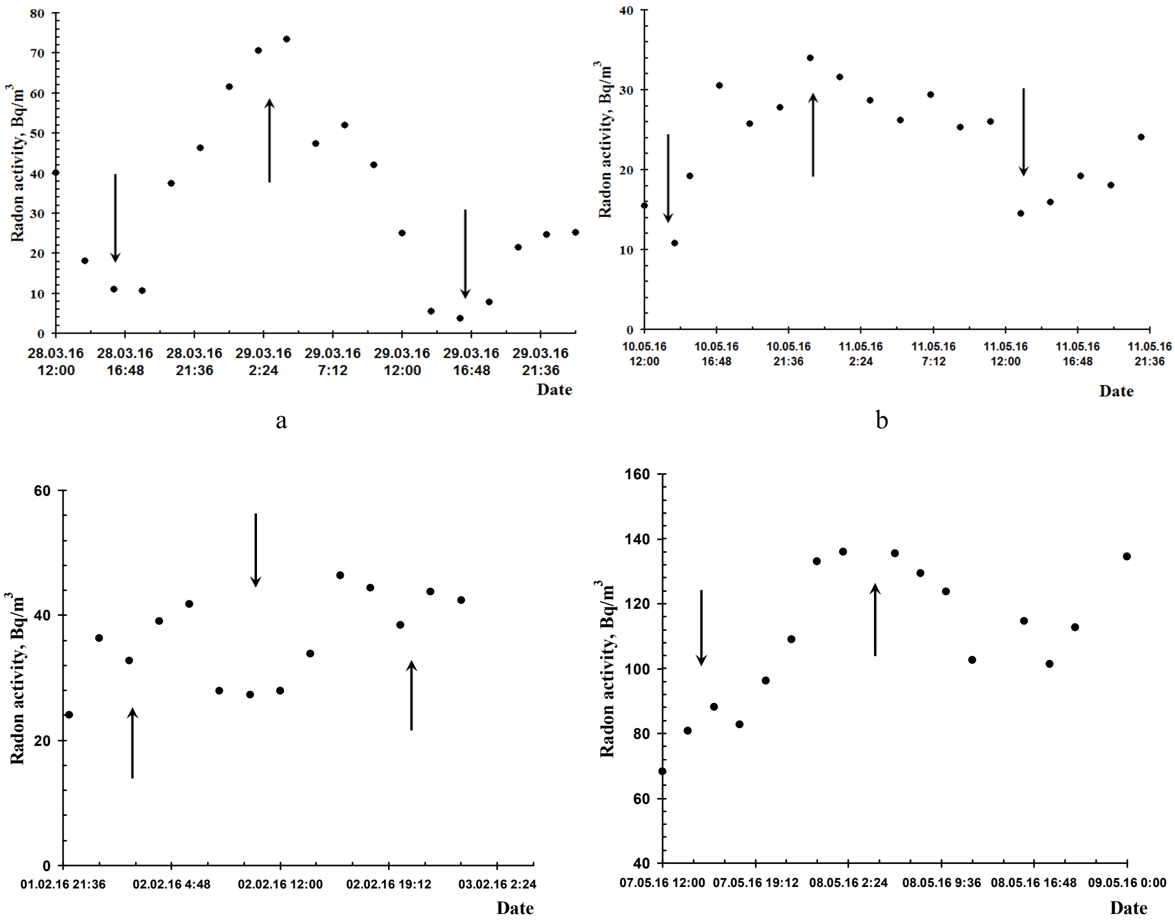
3 Analysis of experimental data

First, diurnal variations "day-night" are found, in which the emanation of soil radon increases at night, due to the difference in the pressures of the cold night air of the atmosphere and still warm soil air. Essential potential barriers for emanation are soil moisture, as well as the presence of water surfaces of rivers and lakes. In this case, in rainy weather, emanation in the open atmosphere decreases, and inside the premises it rises sharply, which poses a certain threat of increasing the risk of cancer morbidity.

In Figure 2 (a-d) shows the dependence of radon activity on time on a scale convenient for studying diurnal variations and revealing the "day-night" effect. From these figures, the desired effect is clearly visible (marked by arrows): the daily maximum (night) is more than 2 times larger than the daily minimum (day). This effect significantly increases the risk of oncological morbidity of the population, because at night, rest rooms, as a rule, are highly sealed and slightly ventilated. This effect is confirmed in the whole northern country – Sweden. When a campaign was announced to significantly increase heat retention and improve the tightness of living quarters, Sweden received a large surge in cancer incidence [4]. The authors of this work have studied the effects of radon radiation on the occurrence of an increased risk of cancer [15-19].

The authors of this work, in addition to the known diurnal variations, experimentally detected, measured and determined the periodic 4-day variations of the emanation of soil radon. In Figure 3 (a, b) presents experimental data on a scale convenient for detecting longer-term variations than diurnal variations.

Interpretation of the phenomenon is related to the possible dependence of the radon emanation not only on earthquakes [12-14], but also on "lunar tides", that is, on soil uplifts due to the known increase in gravity in the system "Earth-Sun-Moon" in geometry π and $\pi/2$, which fall, exactly, for a period of four days [20, 21].



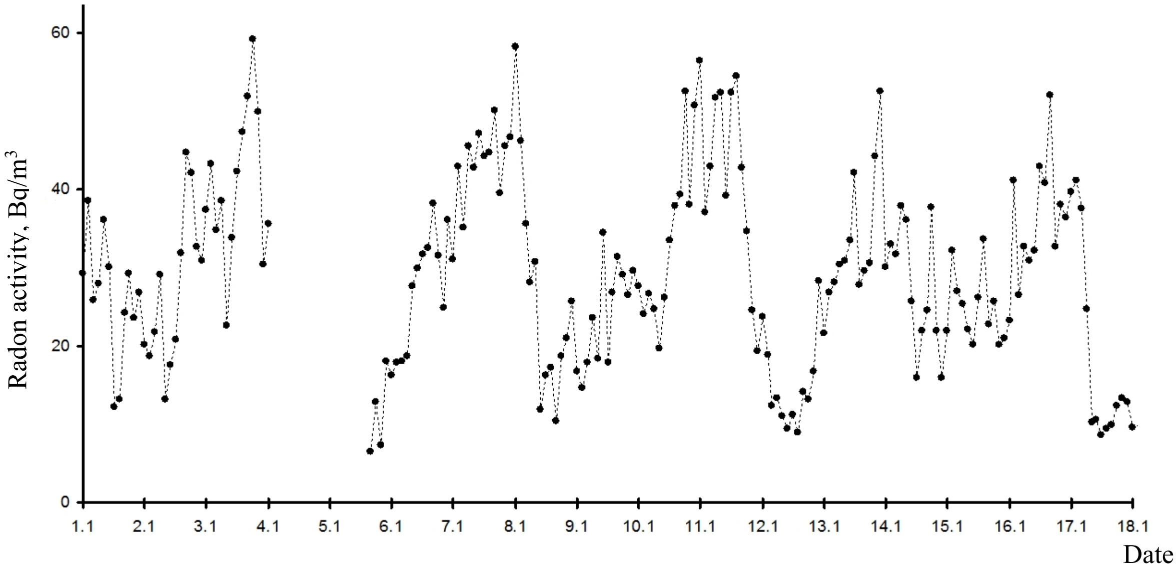
a b

c d

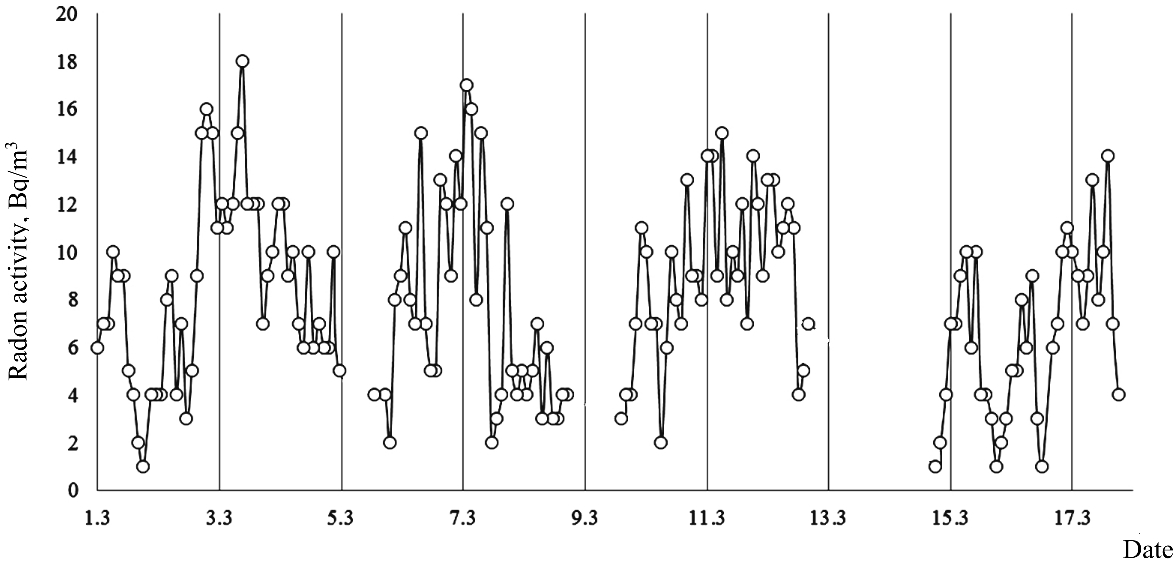
a) during the period from 28.03.16. 12:00 to 29.03.16. 21:36; b) from 10.05.16. 12:00 to 11.05.16. 21:36;
c) from 01.02.16 21:36 to 03.02.16 02:24; d) from 07/05/16 12:00 to 09/05/16 00:00

Figure 2 – Daily fluctuations in radon concentration in the atmospheric air of residential and industrial premises, increasing the risk of cancer morbidity

Another potential barrier to radon emanation is frozen soil, ice and snow cover, which is detected with continuous measurements – the so-called "seasonal effect". The release of radon from the soil is reduced in the presence of snow, an increase in atmospheric pressure and during heavy rains. Measurements were made of the temporal topology of radon isotopes in a continuous mode in Almaty. The results are shown in Figure 4 (a, b). It can be seen that the specific activity reaches a maximum in spring, with minima in winter and in autumn. Thus, from figure a) the effect "spring-autumn" is clearly visible. In addition, the specific activity of radon isotopes in summer is also in relative minima, due to the rainy and cold summer of 2016. Figure b) gives the distribution of specific activity by months, showing the effects indicated above.



a



b

Figure 3 – Results of measurements of 4-day temporal variations:
a) during the period from 1 to 18 January 2016; b) during the period from 1 to 18 March

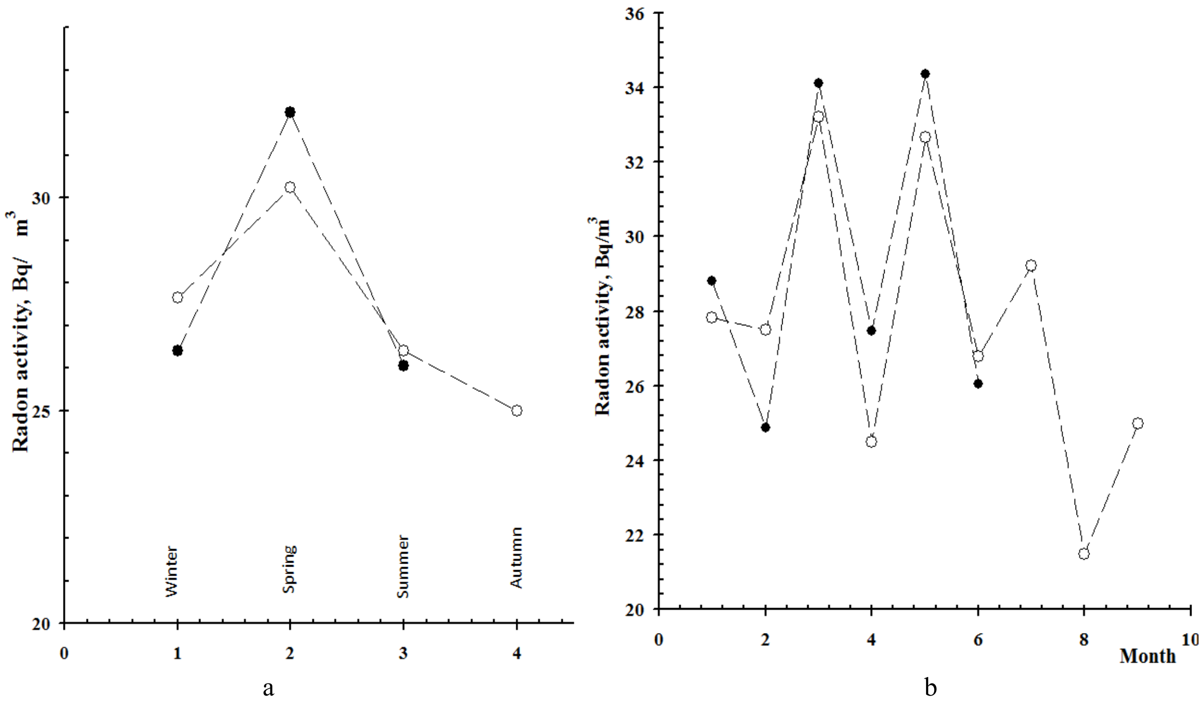


Figure 4 – Seasonal variations in the specific concentration of radon indoors:
a) the effect of "spring-autumn"; b) time variations by months

4 Conclusions

In this article the authors present the data of periodic variations in time of radon emanations in the ground layer of the atmosphere, which were measured for the period from January 1 to August 3, 2016. Harmonics of diurnal, 4-day and longer periods are revealed. The authors interpreted the 4-day variations, which can occur due to "lunar tides", that is, from soil uplifts due to the increase in gravitational tidal forces. The mechanism of radon emanation to the Earth's surface is complex. In particular, the transportation of radon from the inner surfaces of the earth's crust is carried out by the diffusion of aerosols onto the surface, to which the radon atoms coagulate, due to electrostatic attraction. Such radioactive aerosol nanoparticles located in the surface layer of the atmosphere have the greatest impact on the risks of cancer, since the probabilities of their settling on the lung tissues are several orders of magnitude higher than the radon itself in the atomic form. The distribution of radon isotope activity in the atmospheric surface layer in the atomic and aerosol states was studied in [11].

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