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STUDY OF DISTRIBUTION OF BETA-POLLUTION IN THE CITY OF ALMATY

The present work is devoted to the study of the distribution of beta activity of natural radionuclides in the surface soil of Almaty in the spring. The soil samples were collected during the period April-May 2018 in different parts of the city of Almaty. Sample preparation of soil samples was limited to soil selection, which was dried overnight, crushed, its residual moisture was measured, and its beta spectrum was further measured. The exposure time of the measurements of one spectrum averaged 90 minutes. In addition to the background beta particles generated by cosmic rays, the influence on the intensity of the beta spectrum is exerted by the existence of temporal variations in radon emanation, and within a day the radon activity in air can vary in a relatively wide range. Consequently, the concentration of daughter decay products (DDPR) on aerosols of air will affect the background of beta particles. In this connection, after each measurement of the soil sample, background spectra of beta particles were measured. As a result of the performed measurements and analysis of the intensity distribution of beta contamination of surface soil in different parts of Almaty, the emergence of radionuclide radionuclides of radon DDPR in the surface layer of the atmosphere and atmospheric precipitation was determined, which is mainly due to aerosol particles. In turn, radon atoms emanating from the lower soil layers coagulate with aerosol particles. The degree of concentration of beta radionuclides of radon DDPR depends on the chemical composition of the soil cover, on meteorological conditions and on its own chemical properties, on which the ability of migration and accumulation in the surface soil layer depends. The obtained integral values of beta radionuclides of radon DDPR show the spatial fractal spread and correspond to the literature data taking into account abundant precipitation during the sampling period.

Key words: daughter products of radon decay; beta activity; natural radionuclides; beta contamination; natural background radiation.

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Алматы қаласының бета-ластануының таралуын зерттеу

Бұл жұмыс Алматы қаласының жер бетіндегі топырақтағы табиғи радионуклидтердің бета-белсенділігінің көктем кезеңіндегі таралуын зерттеуге арналған. Топырақ үлгілері 2018 жылдың сәуір-мамыр айларында Алматы қаласының әртүрлі бөліктерінде алынды. Топырақ үлгілерінен сынама дайындау, бір тәулік ішінде кептіріліп, ұсақталған, оның қалдық ылғалдылығы өлшенген және одан әрі оның бета-спектрі өлшенген топырақты іріктеп алуға негізделді. Бір спектрді өлшеудің экспозициялық уақыты орташа алғанда 90 минутты құрады. Ғарыш сәулелері генерацияланатын фондық бета-бөлшектерден басқа бета-спектрдің қарқындылығына радон эманациясының уақытша вариациясының болуы әсер етеді және бір тәулік ішінде ауада радон белсенділігінің мәні салыстырмалы кең ауқымда өзгеруі мүмкін.

Осының салдарынан ауа аэрозольдарында ыдыраудың ұрпақтық өнімдерінің (ЫҰӨ) шоғырлануы бета-бөлшектердің фонына әсер етеді. Осыған байланысты, топырақ үлгісінің әрбір өлшемінен кейін бета-бөлшектердің фондық спектрін өлшеу жүргізілді. Орындалған өлшеулер мен талдау нәтижесінде Алматы қаласының әртүрлі аудандарында, негізінен аэрозоль бөлшектері есебінен жүзеге асырылатын, атмосфераның жерге жақын қабатында және атмосфералық шөгінділерде радон ыдырауының ұрпақтық өнімдерінің табиғи радионуклидтері пайда болғандығы анықталды. Өз кезегінде, төменгі топырақ қабаттарынан эманацияланған радон атомдары аэрозоль бөлшектерімен коагуляцияланады (біріктіріледі). Радон ыдырауының ұрпақтық өнімдері бета-радионуклидтерінің шоғырлану дәрежесі топырақ жамылғысының химиялық құрамына, метеорологиялық жағдайларға және жеке химиялық қасиеттеріне байланысты, ал ол өз кезегінде жер бетіндегі топырақ қабатында болатын көшіп-қону және аккумуляциялану қабілетіне байланысты. Радон ыдырауының ұрпақтық өнімдері бета-радионуклидтерінің алынған интегралдық мәндері кеңістіктік фракталдық шашырауды көрсетеді және сынама алу кезеңінде мол жауын-шашынды есепке ала отырып, әдеби деректерге сәйкес келеді.

Түйін сөздер: радон ыдырауының ұрпақ өнімдері; бета-белсенділік; табиғи радионуклидтер; бета-ластану; табиғи радиациялық фон.

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Изучение распределения бета-загрязненности города Алматы

Настоящая работа посвящена изучению распределения бета-активности природных радионуклидов находящихся в поверхностной почве г. Алматы в весенний период. Заборы образцов почвы были выполнены в период апрель-май 2018 года в различных частях города Алматы. Пробоподготовка почвенных образцов сводилась к отбору почвы, которая в течение суток просушивалась, измельчалась, измерялась ее остаточная влажность и далее измерялся ее бета-спектр. Время экспозиции измерений одного спектра в среднем составляло 90 мин. Помимо фоновых бета-частиц, генерируемых космическими лучами, влияние на интенсивность бета-спектра оказывает существование временных вариаций эманации радона, и в течение суток значение активности радона в воздухе может меняться в сравнительно широких пределах. Вследствие этого концентрация дочерних продуктов распада (ДПР) на аэрозолях воздуха будет влиять на фон бета-частиц. В связи с этим, после каждого измерения почвенного образца, выполнялись измерения фонового спектра бета-частиц. В результате выполненных измерений и анализа распределения интенсивности бета-загрязненности поверхностной почвы в различных районах города Алматы было определено возникновение природных радионуклидов ДПР радона в приземном слое атмосферы и атмосферных осадках, которое осуществляется, в основном, за счет аэрозольных частиц. В свою очередь атомы радона, эманирующие из нижних почвенных слоев, коагулируют с аэрозольными частицами. Степень концентрации бета-радионуклидов ДПР радона зависит от химического состава почвенного покрова, от метеорологических условий и от собственных химических свойств, от которых зависит способность миграции и аккумуляции в поверхностном почвенном слое. Полученные интегральные значения бета-радионуклидов ДПР радона показывают пространственный фрактальный разброс и соответствуют литературным данным с учетом обильных осадков в период забора проб.

Ключевые слова: дочерние продукты распада радона; бета-активность; природные радионуклиды; бета-загрязненность; природный радиационный фон.

Introduction

The study of the distribution of natural radionuclides in the atmosphere and earth, with the help of which the radiation background of the earth is formed, is an urgent task. This is due, above all, to cancer caused by radionuclides that enter the human body through the respiratory tract and digestive system. With internal irradiation of the human body, such natural radionuclides as potassium-40, which are mainly contained in the nervous and muscular tissues, radium deposited in bone tissue, radon isotopes and its decay products (DDPR), accumulating in the respiratory tract, and radioactive isotopes of carbon-14, rubidium-87 [1]. For example, radon has long been recognized as the cause of lung cancer and in 1986 it was identified by the World Health Organization as a carcinogen for the lungs (WHO, 1986, IARC, 1988). The main source of information about the risks of lung cancer caused by radon was epidemiological studies of miners (ICRP, 1993), and later studies provided informative data on risks at low levels of exposure (for example Lubin et al., 1997; NRC, 1999; EPA, 1999, 2003; Tomášek et al., 2008).

It was established that the contribution of internal irradiation (1.34 mSv / year) in the effective equivalent dose capacity is approximately 2 times higher than the contribution of external irradiation (0.65 mSv / year). Among the radionuclides that make the greatest contribution to the dose rate of internal irradiation, short-lived decay products of radon-222 (about 60%) are on the first place. Next are potassium-40 (13%), radon-220 (13%), and lead-210, polonium-210 (8%).

Determination of DDPR activity in soil is directly related to radon emanation, which, in turn, has a direct effect on the lungs and airways of a person. The activity of radon isotopes and their DPR in air, soil and water, as well as the doses received by a person during their irradiation are regulated by our legislation [2-6].

Method and results of measurements

In this paper, samples of soil from the surface layer of the earth were collected from various places in Almaty. For the period of sampling from March to May 2018 in Almaty, the maximum precipitation was observed, in March – 74 mm; April – 120 mm; May 129 mm at an average annual value of 40 mm. 18 soil samples were taken at a depth of 0-5 cm from the surface in various locations and parts of the city to measure their beta spectra. The measurement procedure is based on recording the spectra of beta radiation emitted by the substance of the object under study. To measure the activity of radionuclides in the studied soil samples, a scintillation beta spectrometer of the “SCS-99” Sputnik type was used. Sampling of soil samples was as follows: the selected soil was dried for 24 hours, then it was crushed, its moisture content was measured and then it was poured into a measuring container with a uniform layer with a diameter of 70 mm. The average exposure time was 90 minutes. In addition to the background beta particles generated by cosmic rays [7, 8], the influence on the intensity of the beta spectrum is exerted by the existence of temporal variations in radon emanation, as we showed in [9], and within a day the radon activity in air can vary in comparative wide limits. As a result, the concentration of DDPR on aerosols of air will affect the background of beta particles. In this connection, after each measurement of the soil sample, the background spectrum of the beta particles was measured.

Figures 1, 2 show the background beta spectrum and the beta spectrum of the soil sample. Figure 3 shows the spectrum of the excess of the flux of beta particles from the soil sample over the background beta-particles flux. As a result, the beta spectra of all samples were processed and their integral values are presented in Table 1. The map of beta-contamination distribution of Almaty was constructed for integral values (Fig. 4). Preliminary results of distribution of beta contamination in Almaty were published in [10]. All integral values do not exceed the regulated level of 200 parts / (min·cm^2) [2-6].

It can be seen from Figures 1 and 2 that the beta spectrum is of a complex nature. This is explained by the fact that several successive beta decays occur in the sample. In addition, the sample consists of a complex composition of natural beta radionuclides. So, in addition to the DDPR, in the sample of the soil surface layer there are natural beta radionuclides of potassium-40 and rubidium-87. It can be seen from the figure that the excess of the beta activity of the samples over the background is quite high. Excess of activity of the sample over the background, on average, is 10-20%. In this case, the shape of the spectrum, as shown in Fig. 3, is different for different samples. This indicates that the concentration of these or other radionuclides in the samples is different. Such a distribution of different beta-radionuclides in the samples is fractal.

To monitor the measured beta activity of the samples, Table 1 shows the sample mass and its moisture content after sample preparation. It can be seen that the controlled quantities vary in a small range. This, in turn, has small errors in the measurement of beta spectra of samples, which, in this paper, can be neglected.

Thus, the radionuclides of radon DDPR in the surface layer of the atmosphere and atmospheric precipitation are mainly due to aerosol particles. In turn, radon atoms emanating from the lower soil layers coagulate with aerosol particles. Accumulation of beta radionuclides of radon DDP depends on the chemical composition of the soil cover, on meteorological conditions and on its own chemical properties, on which the ability of migration and accumulation in the surface soil layer depends. The obtained integral values of beta radionuclides of radon DDPR show the spatial fractal spread and correspond to the literature data taking into account abundant precipitation during the sampling period.

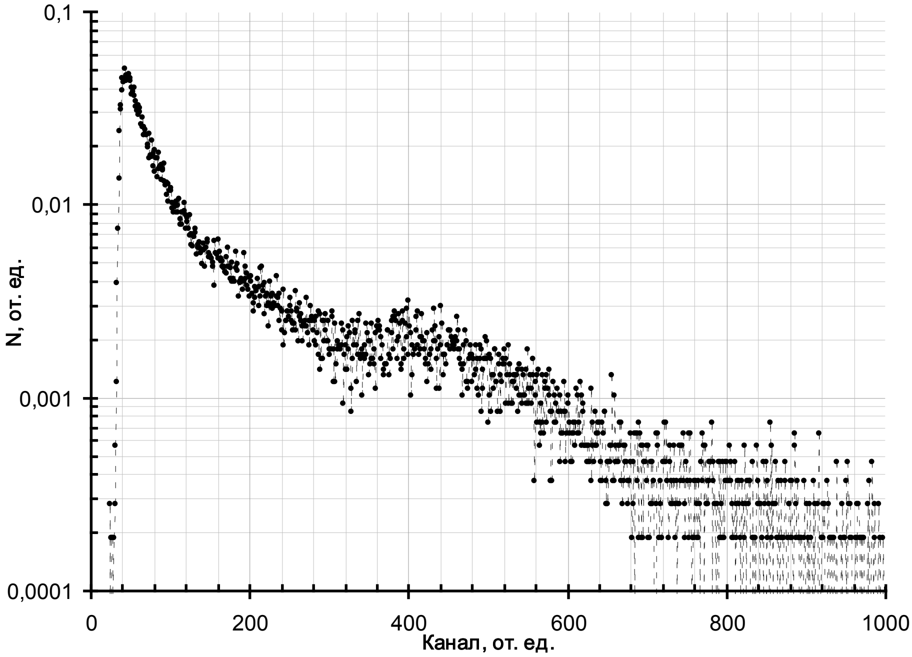

Figure 1 – Background beta spectrum

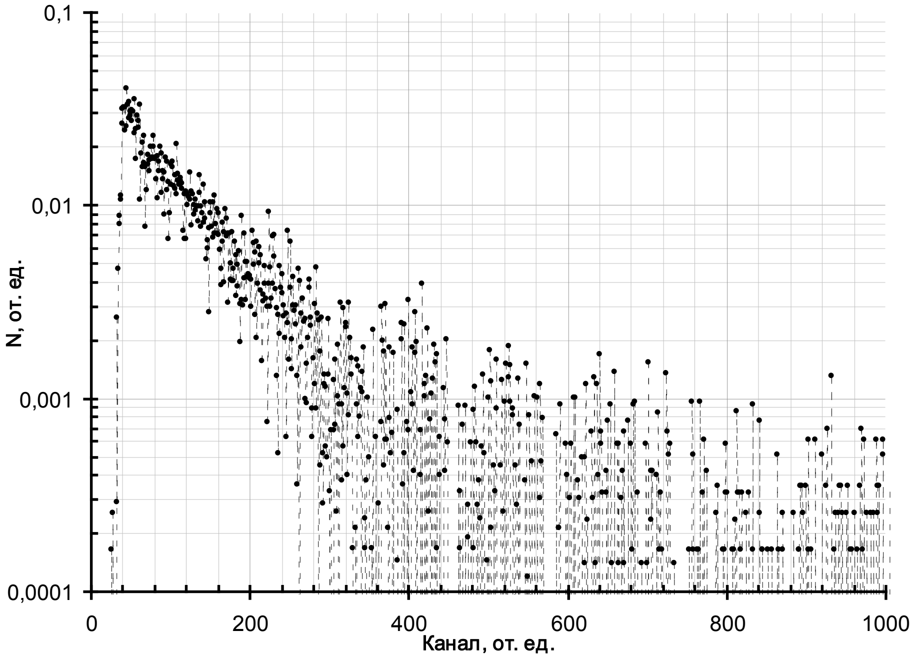

Figure 2 – A typical beta spectrum of a soil sample

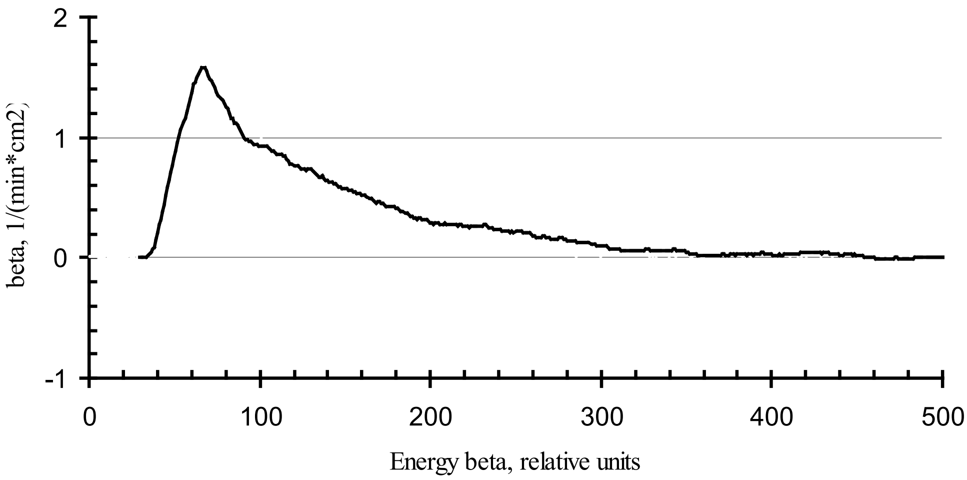

Figure 3 – Exceeding the beta spectrum of soil sample No. 1 over the background

Table 1 – Integral values of beta spectra of soil samples

No. sample	Weight of samples, grams	Humidity, %	N/(min×cm^2)
1	42	6	153
3	42	2	66
4	41	4	76
5	40	3	181
6	39	6	46
7	44	4	82
8	46	3	81
9	44	3	107
10	43	3	61
11	45	3	47
12	45	3	168
14	41	5	54
15	46	3	46
16	43	3	63
17	46	4	70
18	44	2	85

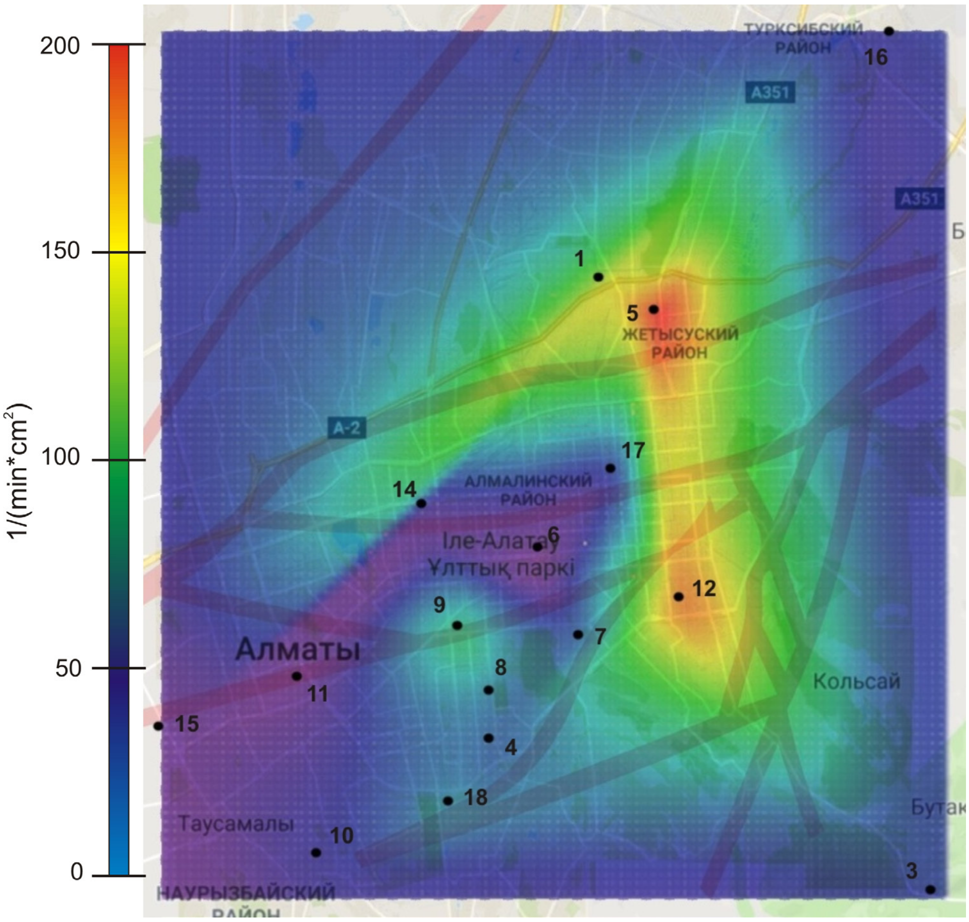

Figure 4 – Distribution of contaminants of beta contamination in Almaty

Since the radiation contamination of soil samples was studied, this distribution is scalar, but in the period of elevated precipitation levels due to flat flushing and penetration into the soil, this distribution should be considered as a vector distribution. The latter circumstance substantially changes the methodology for measuring radiation contamination, in which weather conditions must be taken into account. Taking into account the above, the obtained numerical characteristics of the radiation distribution of beta-radionuclides are of great practical importance when planning both agricultural works and residential buildings.

Acknowledgments

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