Bulletin KRASEC. Phys. & Math. Sci, 2015, V. 10, №. 1, pp. 59-65. ISSN 2313-0156

DOI: 10.18454/2313-0156-2015-10-1-59-65

MSC 81V35

THE DEVELOPMENT OF RADIATION MONITORING TECHNOLOGY FOR URBAN ENVIRONMENT

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The results of monitoring of meteorological and radiation parameters in Tomsk Observatory of Radioactivity and Ionizing Radiation are presented and analyzed in this work. The advantages of new radiation monitoring technology including the investigation of radiation parameters vertical profiles are presented. The existing models of soil and atmosphere radon isotopes transport were verified for urban environment according to the analysis results of radiation monitoring data. The verification showed that the existing models do not allow describing some experimentally obtained dependences and require further development. For instance, it was experimental obtained that alpha-radiation flux density increases for some times with height up to 25 m and then is practically unchanged up to 35 m. The same is for radon. The explanation of such dependence in radon behavior is the influence of urban infrastructure. It was also experimental obtained that diurnal variations of soil radon volumetric activity measured by alpha- and beta-radiation decrease with depth until fully amplitude losses, but the moments of maximums (minimums) occur with time delay. Such behavior is dependent on thermophysical properties of soil and local meteorological conditions. It was proposed to describe the soil gas advection velocity by a function considering the soil thermal conductivity and the dependence of soil temperature on depth.

Key words: radiation monitoring, technology, ionizing radiation, radon, soil, atmosphere

Introduction

The notable indicator properties of radionuclides and ionizing radiation are known and have been actively applied for a long time to obtain knew knowledge on the dynamic processes occurring in the atmosphere and lithosphere, to upgrade the models of gas and aerosol transfer and to make forecast of hazardous phenomena of natural and anthropogenic character.

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The role of ionizing radiation and natural radioactivity, especially of radon gas, is important in radio ecology, seismology, atmosphere near-ground layer physics and in construction work. Thus, research teams and state structures make radiation monitoring of the near-ground atmosphere and study the dynamics of activity of some radionuclides in the near-ground atmosphere and soil.

Unfortunately, artificial radioactivity caused by nuclear testing, industrial disasters and technological processes is still the main direction of radiation environment control. Thus, the special attention is paid only to γ-background monitoring. Variations of field characteristics for other kinds of ionizing radiations (α-, β-radiations) have not been controlled that was explained by their low penetrability and, correspondingly, low informative value. Monitoring of soil radon and radon flux density from the earth surface is carried out mainly to make earthquake forecasts and occasionally to make radio ecological and geo-ecological surveys before construction works.

Research team [1] developed a complex approach to radiation monitoring. The main "spice" of the technology was the investigation of the vertical profile of field characteristics for ionizing radiations (IR) and for radon in soil-atmosphere system. The aim of this work was to determine the advantages in the study of radiation parameters vertical distributions in comparison to the traditional approach when only one height (depth) or one radiation parameter is under investigation.

One of the tasks of the study is the development of a technique for subject processing of meteorological and radiation parameter monitoring archive data which is determined by the application area of the results: radiation ecology and biology; construction works; seismology or atmosphere physics. The results of radiation monitoring were used to verify the existing models of radionuclide transfer and the peculiarities of ionizing radiation transfer for urban environment as well.

Instrumentation and methods

Radiation monitoring at Tomsk Observatory of Radioactivity and Ionizing Radiation has been carried out since 2008 and its technology is constantly upgrading. At present, the radiation monitoring includes synchronous continuous automated high sampling rate (1-10 min) measurements of IR field characteristics (α-, β-, and γ-radiations), radon and thoron flux densities (RFD and TFD) from the soil surface, and volumetric activity (VA) of radon, thoron and daughter products of their decomposition (DPD) at the depths up to 5 m and the heights up to 35 m. The scheme of monitoring of ionizing radiation field structure and dynamics and natural radioactivity in the near-ground atmosphere and in the soil surface layer is shown in Fig. 1.

The complex approach to radiation monitoring allowed us to obtain new important scientific findings. In contrast to the traditional assumptions, a new dependence of radon volumetric activity (VA) (alpha-radiation flux density) on height above the ground surface was discovered (Fig. 2).

Monitoring of atmospheric-electric and meteorological parameters is carried out simultaneously at the Institute of Monitoring of Climatic and Ecological Systems SB RAS (Akademgorodok, Tomsk) [1].

Traditional models show exponential decrease of radon volumetric activity with height. Our results showed that alpha-radiation flux density (FD) increases by some times with height up to 25 m and then is practically unchanged up to 35 m.

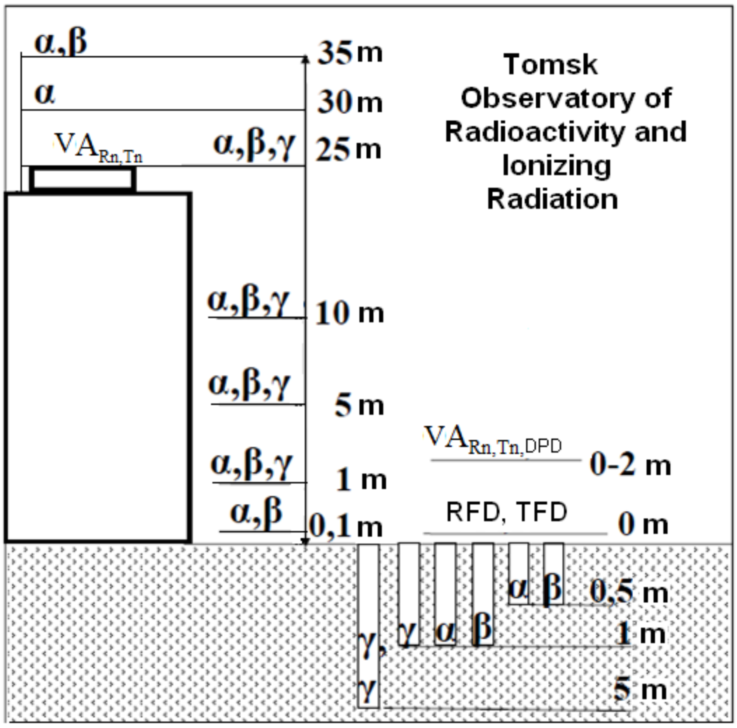

Fig. 1. Scheme of monitoring of IR field structure and dynamics and natural radioactivity in the near-ground atmosphere and in the soil surface layer

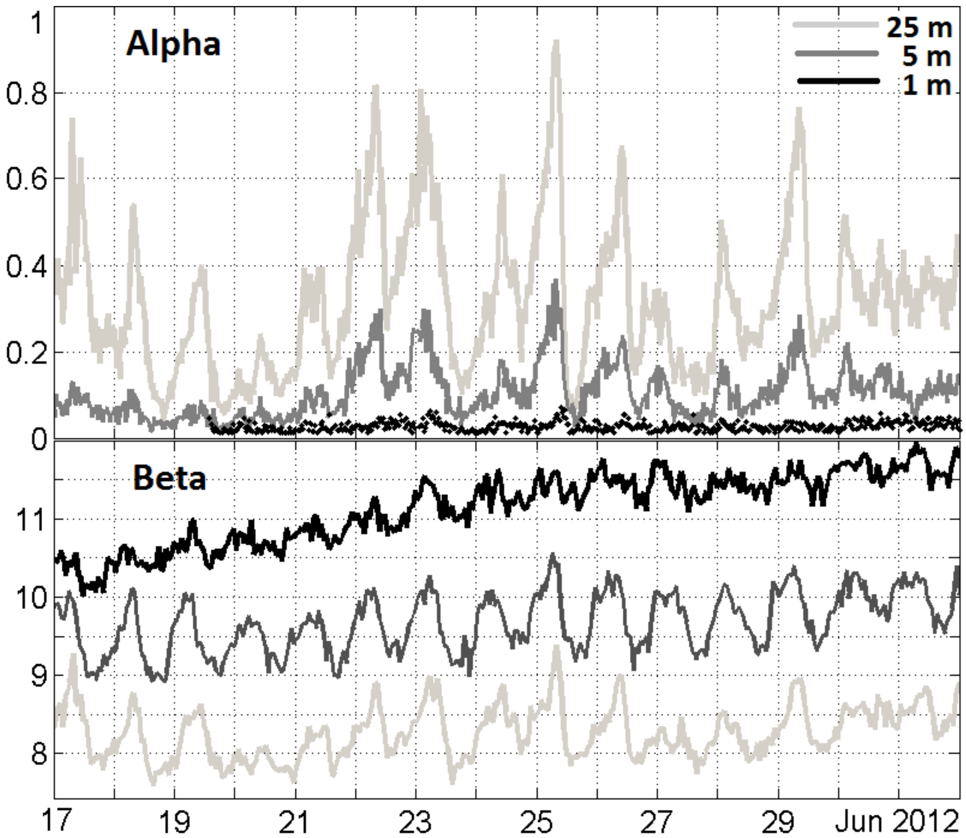

Fig. 2. Dependence of alpha- and beta-radiation flux densities on height

The same is for radon. The explanation of such dependence in radon behavior is the influence of urban infrastructure. There are high buildings around the testing site which may affect the turbulent processes and air mass transfer. Moreover, some of the detectors (Fig. 1) are located on a mezzanine of IMCES building.

Furthermore, radon VA increase with height should also be taken into account when simulating radon level inside the rooms of multistory buildings since airing may cause not radon level decrease, according to traditional assumptions, but to its increase. As for the widely known model of radon transfer in the soil, considering only diffusion transfer, it is meant for averaged over a long period (several days and more) characteristics of RFD or radon VA in the soil to estimate the radon potential of territories, but it is not meant for intra-day variation simulation.

Diffusive-advection model of radon isotope transfer in the soil [1, 2] has a wider application and allows us to describe the majority of experimental data but it does not lack some disadvantages since the advection velocity is the constant value. This assumption does not enable us to describe experimentally obtained data series on radon soil field characteristics having diurnal and seasonal variations. Moreover, our research team discovered that the times of maxima (minima) in diurnal variations (Fig. 3 and 4) depend on the depth of detector position and correlate with soil temperature changes at different depths. The X-axes in Fig. 3 and 4 show the number of a day of the year.

Analysis of the experimental data obtained at Tomsk Observatory of Radioactivity and Ionizing Radiation showed that improvement of both radionuclide transfer model for urban atmosphere and of soil radon isotope transfer model is required by the change of model constant coefficients by approximation functions determined on the basis of experimental data.

The advection velocity should be described by the function of soil depth and time. Experimentally obtained diurnal variations of radon VA decrease with depth and the moments of maximums (minimums) occur with time delays. Such behavior is dependent on thermophysical properties of soil and local meteorological conditions. When there is no precipitation, diurnal and seasonal temperature changes affect the radon VA diurnal variations the most.

Annual and diurnal temperature changes may be described by a sinusoidal function of time and depth [4, 5]. Thus, the expression for advection velocity function is upgraded as follows:

$$v(x,t) = \frac{A_0 v_0}{T_a} \sin\left(\omega t + \phi(z) - z/d\right) exp\left(-z/d\right),$$

where v_0 is the average advection velocity experimentally determined for soil layer of 1 m thick, m/s; T_a is the average surface temperature, $^\circ C$; A_0 is the temperature change amplitude on the soil surface, $^\circ C$; ω is the radial frequency; $\phi(z)$ is the delay time (initial phase) in z function, c; $d = \sqrt{2k/(C\omega)}$ is the depth of temperature change attenuation in the soil, i.e. at this depth temperature amplitude decreases by $= 2.718$ times in comparison to that on the soil surface (A_0), m; k – thermal conductivity coefficient, J/m; C is the volumetric heat capacity, J/m^3.

This presentation of advection velocity allows us to describe the influence of temperature and thermal conductivity on radon VA in diurnal and annual variation. Thus, to make numerical simulation of the structure and variations of both atmospheric radiation background and radon transfer in the soil, it is necessary to know and to control a number of meteorological values (pressure, temperature, wind velocity, atmosphere turbulence and precipitation characteristics and so on).

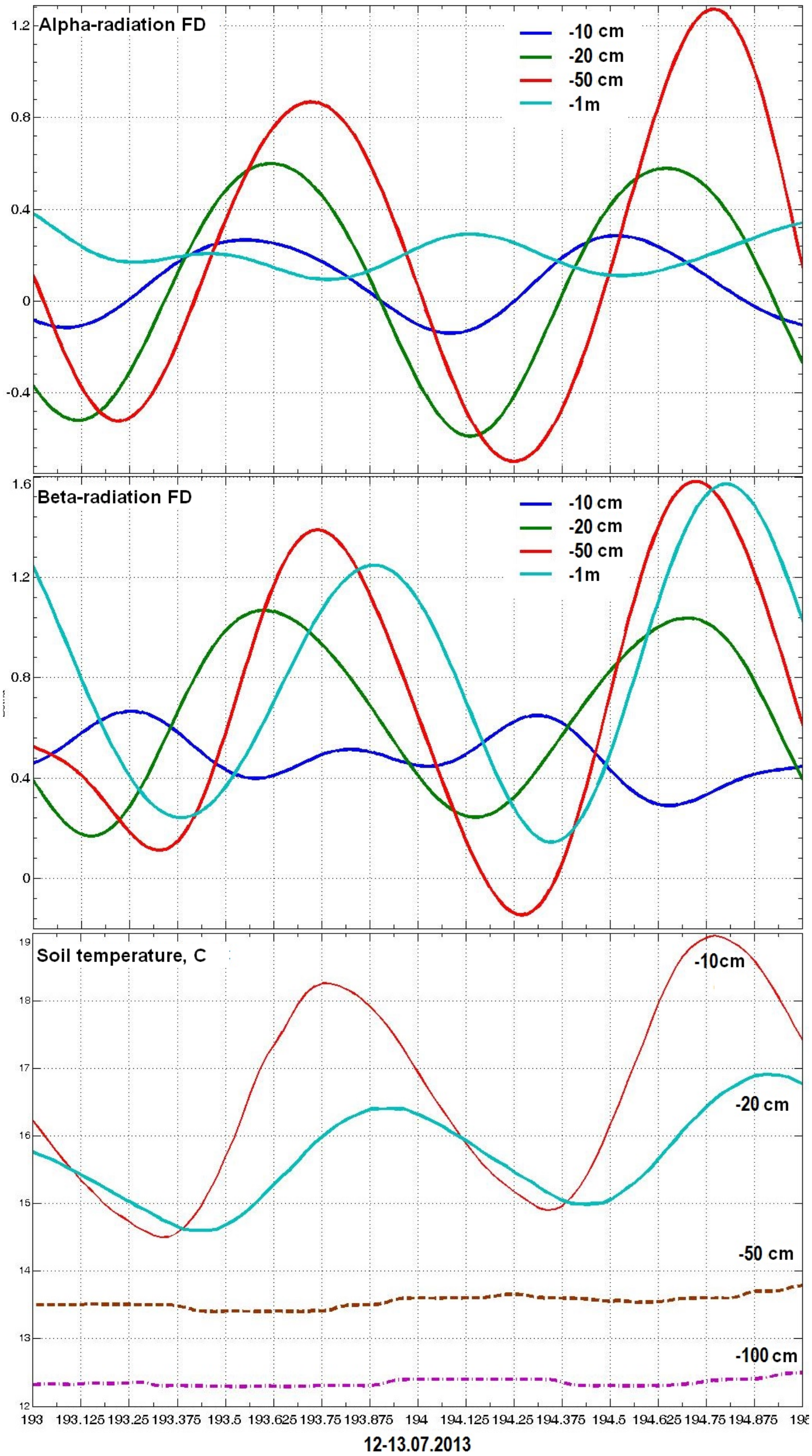

Fig. 3. Diurnal variations of soil temperature and radon VA in the soil measured by: alpha-radiation and beta-radiation at different depths

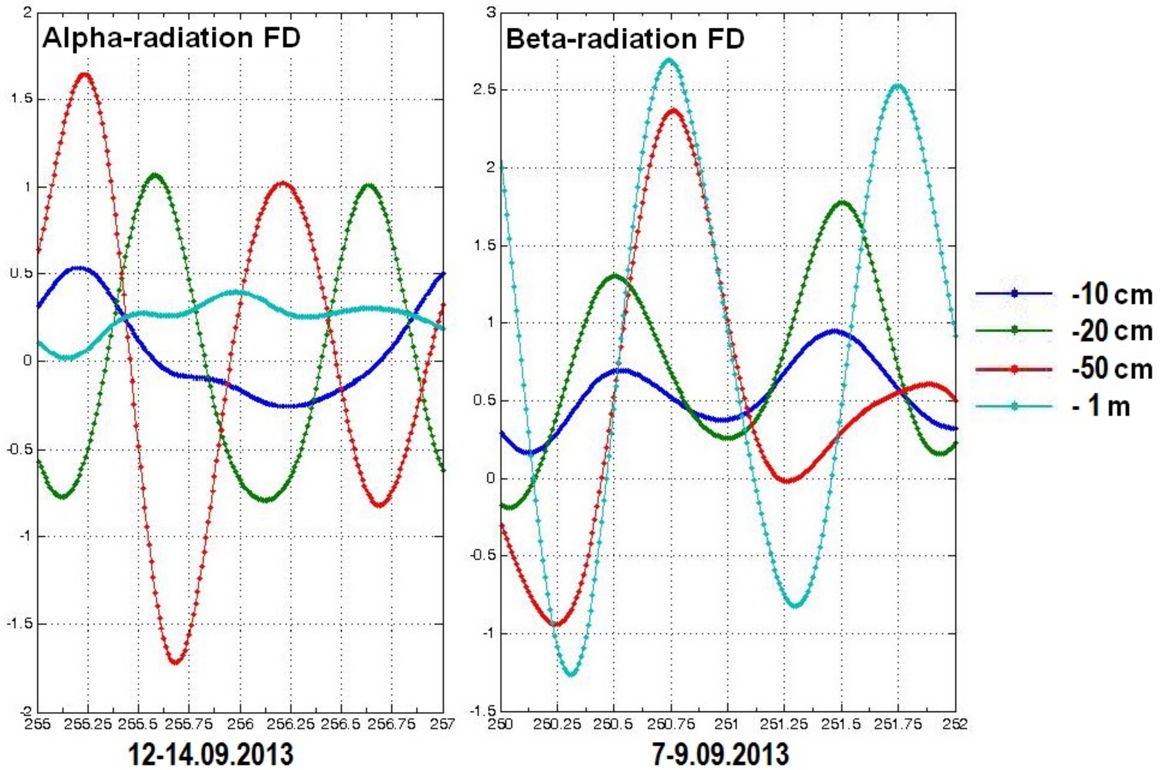

Fig. 4. Radon VA diurnal variations in the soil measured by alpha- and beta-radiations at different depths

Conclusions

Further development of radiation monitoring technology for urban environment is the upgrading of the models for gas and radionuclide transfer in different environments, construction of new algorithms and methods of control of both radiation values and meteorological atmospheric-electrical and actinometric values. It allows us to obtain new data on the structure and dynamics of ionizing radiation fields and natural radioactivity in the near-ground atmosphere and near surface soil layer, to determine the features and regularities in their behavior and the relations with meteorological processes of intra-day, diurnal and synoptic scales.

One of the results of the monitoring is the constantly refilling data library, including the data bases on the characteristics of radiation fields and radionuclide VA in the soil and in the near-ground atmosphere, atmospheric-electrical and meteorological values, on the reoccurrence and intensity of extreme events associated with meteorological phenomena in a seismically safe region with sharply continental climate in the conditions of the current changes. The data bases and monitoring results may be useful in Rospotrebnadzor, Rosgidromet, Federal Rescue and Public Health Services as well as in scientific organizations which make forecasts of change of stress-strain state of the Earth crust.

The work was supported by FTsP no 14.575.21.0105.

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Original article submitted: 25.05.2015