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Rn Intensity Variation in the Vicinity of Moussala BEO, Moussala Peak

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Abstract. Using a scintillation gamma-spectrometer with a NaI detector, the ^{222}Rn intensity variations were registered at the Moussala Basic Ecological Observatory (BEO) located at Moussala Peak at an altitude of 2925 m above sea level. The gamma-spectrometer works in a "non-stop" mode, except for a few time periods when the weather conditions or other causes interrupt its operation. The equipment can be controlled fully from any location via an internet connection with the possibility of changing the measurement conditions, downloading the necessary data, as well as turning it off and on whenever necessary. The spectra obtained are processed and analyzed in the INRNE laboratories. Furthermore, the most widespread radioactive isotopes, mainly reactor products, can be readily detected and identified.

Keywords: Radon, scintillation spectrometers, gamma radiation, radioactive isotopes.

1 Introduction

The Moussala Basic Ecological Observatory is a multi-profile scientific laboratory carrying out environmental monitoring, measurement of the natural and technogenic radioactivity, analysis of a wide range of atmospheric gasses and aerosols, and studies of some astrophysical processes. The Observatory's location is practically in the middle of Central Rila Mountain National Park, the largest such park in the Balkan Peninsula, far from any urbanized areas, at a high altitude above sea level and with a limited human presence, all of which allows one to monitor the environment excluding virtually any anthropogenic impact. The whole gamut of studies is described in detail in monograph [1].

2 Experimental

At Moussala Peak, the gamma-radiation spectrum is being measured by using a scintillation gamma spectrometer (50×50 mm NaI detector) oriented to the zenith [2]. The detector is protected (to a certain degree) from the radiation emitted by the Earth surface (mainly gamma-rays 1460 keV due to the decay of ^{40}K (naturally existing in the nearby rocks) by means of a large lead protector (diameter of 220 mm), and by being placed at ~4.5 m above ground, so that the gamma radiation registered originates mainly from the surrounding air layer and the atmosphere. The spectrometer's energy resolution is within 8–12%. The energy range chosen is from 50 keV to 6400 keV. In fact, the energy of the gamma rays emitted by all natural isotopes reaches up to ~2600 keV, however the spectrometer's remaining energy interval is used for other tasks. The gamma-rays of space origin are in fact due to numerous interactions of high-energy cosmic particles with nuclei in the atmosphere, the final result being high-energy gamma-rays (up to several tens of MeV) exhibiting a continuous energy spectrum. We limited our measurements to ~6.5 MeV bearing in mind the efficiency of the detector used, which is quite low at higher energies, so that the measurements would have to take a very long time. In the case described here, each measurement lasted 7 200 s (two hours), following the automating data recording, the spectrometer proceeded to the next measurement up to the end of the defined series, which comprised 100 spectra, and was then restarted. An example of the measured spectra is shown in Figure 1. The measurement conditions could be changed by using suitable software. The peaks in the gamma radiation spectra were processed; at the same time, the integral intensity of the high-energy gamma quanta (over 2600 keV), which are not of Earth origin, was also followed. The processing was performed by software for gamma-peaks approximation, with the operator selecting the processing conditions. The intensity of the 609.3 keV line varied four- to fivefold leading to differences in the intensity measurement error (usually 10–25%). The overall stability of the equipment was estimated

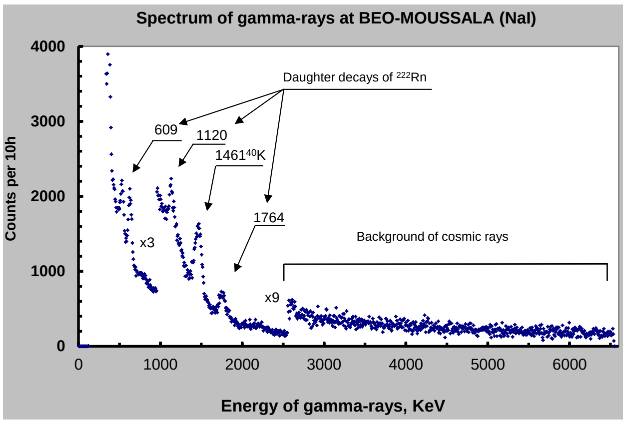

Figure 1. Gamma spectrum in the energy interval 150–6500 keV measured by a NaI detector.

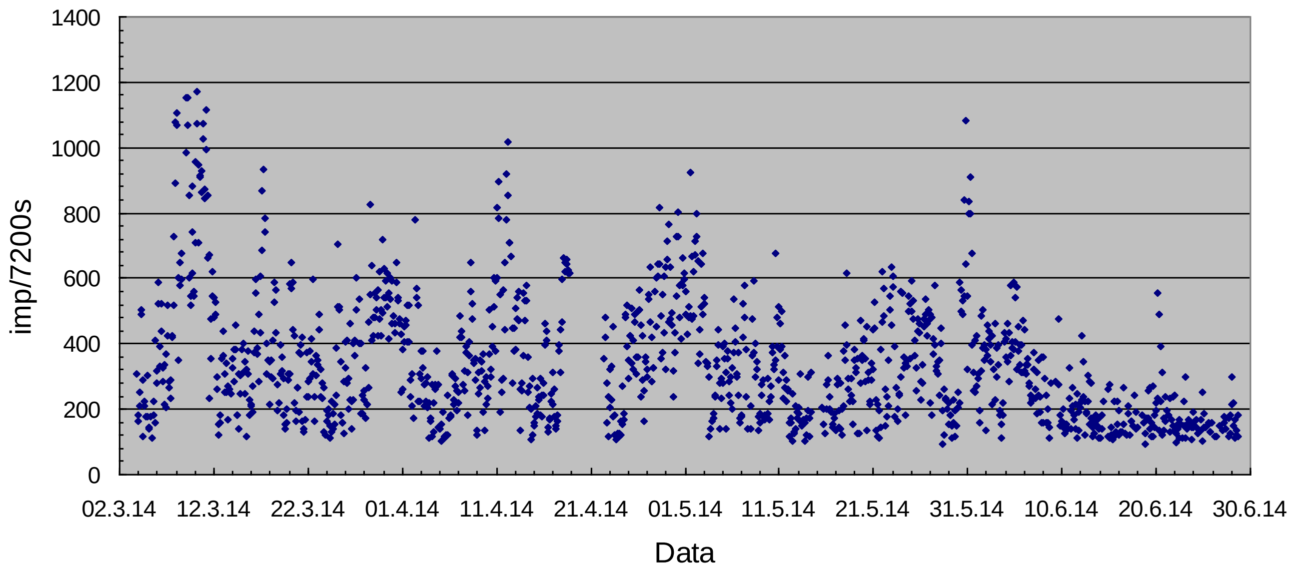

Figure 2. Relative gamma radiation intensity of ^{222}Rn during the period 02.03.2014 – 30.06.2014.

from the intensity of the 1460.4 keV line of ^{40}K, which is constant; thus, the constant intensity of the respective peak in the spectrum is indicative for the normal functioning of the equipment.

^{222}Rn is part of the decay chain with 238U as a parent nuclide. It is produced via the decay of ^{226}Ra, and has a half-life $T_{1/2} = 3.823$ d. Due to its specific chemical properties, radon, being a noble gas not reacting with the environment, is the only element of the ^{238}U decay chain than can leave (emanate from) its parent and spread in the atmosphere. It decays to ^{218}Po, whose half-life is $T_{1/2} = 3.05$ min; this is followed by the decay of ^{214}Pb with $T_{1/2} = 26.8$ min, and of ^{214}Bi with $T_{1/2} = 19.7$ min. It is this isotope that emits gamma rays that are convenient to measure, with the peak at 609 keV exhibiting the highest intensity. Due to the considerably shorter half-lives of the isotopes listed above (within 3–20 min), equilibrium is established very quickly between their decays and that of ^{222}Rn, whereby one decay of ^{222}Rn is followed immediately by the decays of the short-lived isotopes. This fact allows us to estimate the gamma intensity of 222Rn present in the atmosphere by monitoring the intensity of the 609.3 keV ^{214}Bi line.

Figures 2, 3 present time dependences of the ^{222}Rn relative gamma intensity. One can clearly see the large fluctuations of ^{222}Rn in the atmospheric air in both time periods where measurements have been carried so far. Thus, for a normal ^{222}Rn intensity level of ~160–180 imp/7200 s, at certain moments the intensity value rose to over 1000 imp/7200 s, or more than fivefold. Moreover, these variations occurred relatively quickly, within a few hours, and then, again relatively quickly (2–4 hours), the values returned to normal.

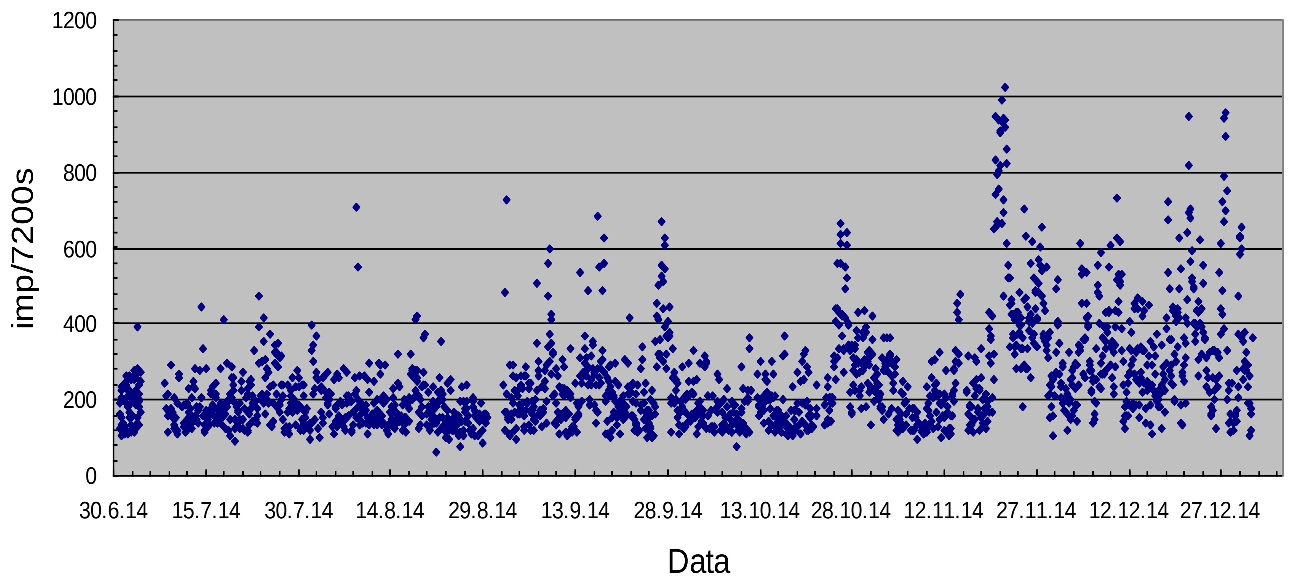

Figure 3. Relative gamma radiation intensity of ^{222}Rn during the period 30.06.14 – 27.12.2014.

3 Conclusion

We have not so far been able to propose an unambiguous explanation of these ^{222}Rn gamma intensity fluctuations. To the best of our knowledge, no similar data have been published concerning analogous regions and altitudes. One could put forward two approaches to explaining the phenomenon observed:

1. Analysis of the atmospheric conditions on the days with abnormal values, possibly revealing a transfer of large air masses from regions of relative stability, where ^{222}Rn could have been accumulated in large quantities; in addition, these regions should be of large area with uranium-containing rocks on the surface.

2. Comparison with days of increased geophysical activity in the region, bearing in mind the hypothesis that such increased activities, or abrupt tectonic processes (earthquakes), could result in releasing large amounts of radon from lower depths due to the increased temperature there. Such propositions have been offered by many researchers for a long time, but are yet to be conclusively proven.

However, whatever the case may be, thorough measurements must be performed during much longer periods, e.g., 5–6 years, and then correlations should be sought with other phenomena, be those atmospheric of geophysical.

References

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