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OBSERVATION OF PERIODIC FLUCTUATIONS IN THE DOSE RATE OF GAMMA-RADIATION IN THE CHORNOBYL EXCLUSION ZONE[a]

The structure of signals from detectors for monitoring the gamma-background around the Chornobyl NPP was considered. It is shown that they are not random, they contain certain regular components. A comparison of the signals obtained on several detectors at the same time undeniably demonstrates that the patterns obtained are not occasional and not erroneous effects.

Keywords: gamma-background, Chornobyl exclusion zone, count rate variability.

1. Introduction

In recent years, there has been an active discussion about observations of the variability of radioactive decay half-life in time. The positions of opponents today are expressed in [1], and supporters – in [2]. The paper provides additional data about observations of such effects.

In the Chornobyl 30-km exclusion zone around the Chornobyl Nuclear Power Plant (ChNPP) (Ukraine), a gamma-background control system operates. This Automated System of Radiation Control (ASRC) is a state structure, works under many normative documents, and is under IAEA control. That is its functioning is under rigid control, including the metrological one. Therefore, any peculiarities in its signals must be analyzed.

The gamma-background in this area is determined by the level of radioactive contamination of the surrounding area by fallouts from the reactor during the 1986 accident at the 4th power unit of the ChNPP. The system consists of several dozen detectors (observation posts), information from which is regularly transmitted to the server. As a result, long-term regular series of measurements are formed, the analysis of which allows drawing certain conclusions about the temporal behavior of this signal.

About the existing periodical, in the first place daily, changes in signals of the ASRC in the Chornobyl exclusion zone it was informed many times. Including, in [3 - 6] the detailed analysis was made about an assumption, that observed peculiarities of the ASRC signals are not the equipment effects, that is not the reaction of equipment to the changes in the environment.

However, the question about the possibility of the hardware nature of the detected features, in connection with what possible radical conclusions about the nature of the detected features in ASRC signals can be made, continues to arise. In this work, the detected features in the investigated signals are also analyzed from the point of view of the possibility of their hardware origin.

Theoretically, possible causes for the existence of periodicities in ASRC signals are the following:

1. Bad work of equipment (electronics).
2. Influence of environmental factors on equipment and sources (temperature, moisture, etc.).
3. Existence an addition to Poissonian decay signals, the periodical signals like cosmic rays (space weather).
4. Modulation of a decay rate by unknown "cosmophysical factors".

Based on the analysis of the features of the new data (signals) received from ASRC, we consider the possibility to conclude in favor of either of the first two, or the last two causes.

2. Material and methods

We analyze here the data of regular measurements of the automated gamma radiation background control system in the exclusion zone around the destroyed 4th power unit of ChNPP.

ASRC consists of modern detectors like Gamma TRACER of the Genitron Instrument GmbH, Germany production (with Geiger-Mueller counters). The Gamma TRACER is a detector, which is intended for permanent registration of the dose rate of gamma-emission. The detectors are hermetically

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sealed. The energy-efficient technology ensures the use of a Gamma TRACER for five years without maintenance. The detectors are completed by the USW module SkiLink for the wireless transfer of data through radio channels.

That is, recalculated into dose rate, the count rate (but not a decay half-life) is analyzed (the number of pulses from the registration of gamma-quanta of radioactive decay during a certain time interval). The analyzed regular series of measurements can be considered as a set of numbers obtained sequentially over time, that is, as a sample with certain properties. Further, various analyzing methods, including statistical ones, can be applied to it.

In our work, a time-varying signal (sample), which has the form of a noisy series, is considered as a combination of several components, namely, a Poisson sequence of radioactive decay numbers, which is modulated by several different external influencing factors.

The main technique for obtaining certain conclusions about the reality of the detected features in the ASRC signals is the comparison of signals from several detectors. The existence of the same features in the signals from different detectors at the same time indisputably indicates that these effects are not random. It is also difficult to imagine that the electronics of all detectors have the same defect that gives the detected features.

The entire measuring electronic system of the sensor, together with the power source, is placed in a sealed, weather-resistant case. An internal quality control system built into each sensor automatically provides periodic testing operations and data reliability checks. The control parameters are stored simultaneously with the corresponding measured values of the gamma-radiation dose rate.

The detectors are under regular metrological verification and are checked for similar defects (according to points 1 and 2) during maintenance.

Wavelet analysis [7] was also used to identify features, including periodicities in the signal. Unlike the Fourier transform, which decomposes the signal into infinite sinusoids, in wavelet analysis, the signal is decomposed using time-limited functions (wavelets). The result of the wavelet transformation is a two-dimensional matrix of wavelet coefficients, which is formed as a result of calculating the correlation between the wavelet and the selected part of the signal when scanning the signal with a wavelet of variable shape. This makes it possible to detect time intervals in which certain peculiarities (arising from wavelet transformation coefficients) appear in the signal. In our analysis, a Gaussian wavelet of order 10 $\psi(t) = \partial_t^{10}\left(e - \frac{t^2}{2}\right)$ was used. A feature of using this wavelet is the ability to detect periodic components in the signal. The matrix is arranged so that the time is changed horizontally, and the frequency or period of the sinusoidal components of the signal is changed vertically.

Then the matrix of wavelet transform coefficients can be represented graphically in the form of a picture, on which the values of the transformation coefficients are displayed in colors or shades of gray. Such a picture (wavelet-periodogram) gives an idea about the changes in the signal structure over time. The appearance of a regular structure in the signal at some time interval is accompanied by the appearance of regular changes in the value of the coefficients of the wavelet transformation. In turn, in the graphic picture of the wavelet coefficients (in the wavelet periodogram), they are reflected as the appearance of a horizontal row of regular spots of increased intensity.

As to uncertainty of the results, it arises in the stage of estimation of periodical components. The period is estimated as a distance between adjacent spots, and its uncertainty is determined by uncertainty in the estimation of centers of corresponding spots along the horizontal axis. For daily spots, the uncertainty is about ±1.5 h, for data in the table it is about ±1.5 days.

3. Results and discussion

In Fig. 1 it is shown the results of the monitoring for 2017 as regular hourly measurements of the gamma-field dose rate characteristics (count rates). On such a scale they look like usual noise signals with elevated variability in summer. But if you look at them on a greater scale (Fig. 2), then it's obvious, that in summer months the signal has a more regular appearance. Fig. 2 shows the wavelet transformation patterns for signals from two different observation posts. The top part of the figures shows the signal, and below it, there is a pattern of its wavelet coefficients, in which the colors or shades of gray correspond to the value of the wavelet transformation coefficients. Recall that the value of the coefficient of the wavelet decomposition of a certain signal is proportional to the value of the correlation of this part of the signal with the wavelet, and the (hidden) sinusoid in the signal gives a horizontally regular series of spots.

At first glance, it may seem that when using wavelet analysis, we replaced a noisy and not very informative graph (signal) with an also unrepresentative pattern of spots. However, if we compare the pictures of the wavelet coefficients for different observation posts, it turns out that they are practically identical. This means that the signals from these detectors have the same structure. In any case, their

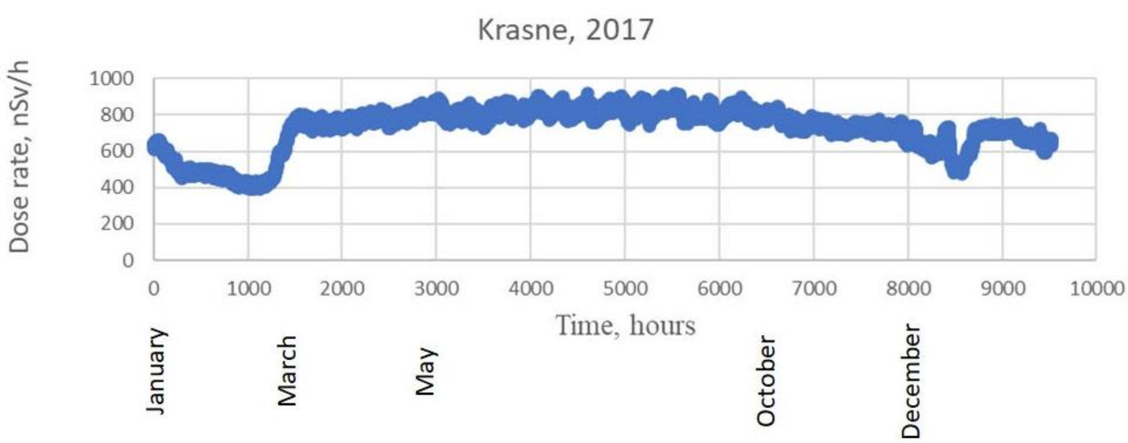

Fig. 1. Gamma background for observation post “Krasne” in 2017.
In summer months there is elevated variability of the signal. (See color Figure on the journal website.)

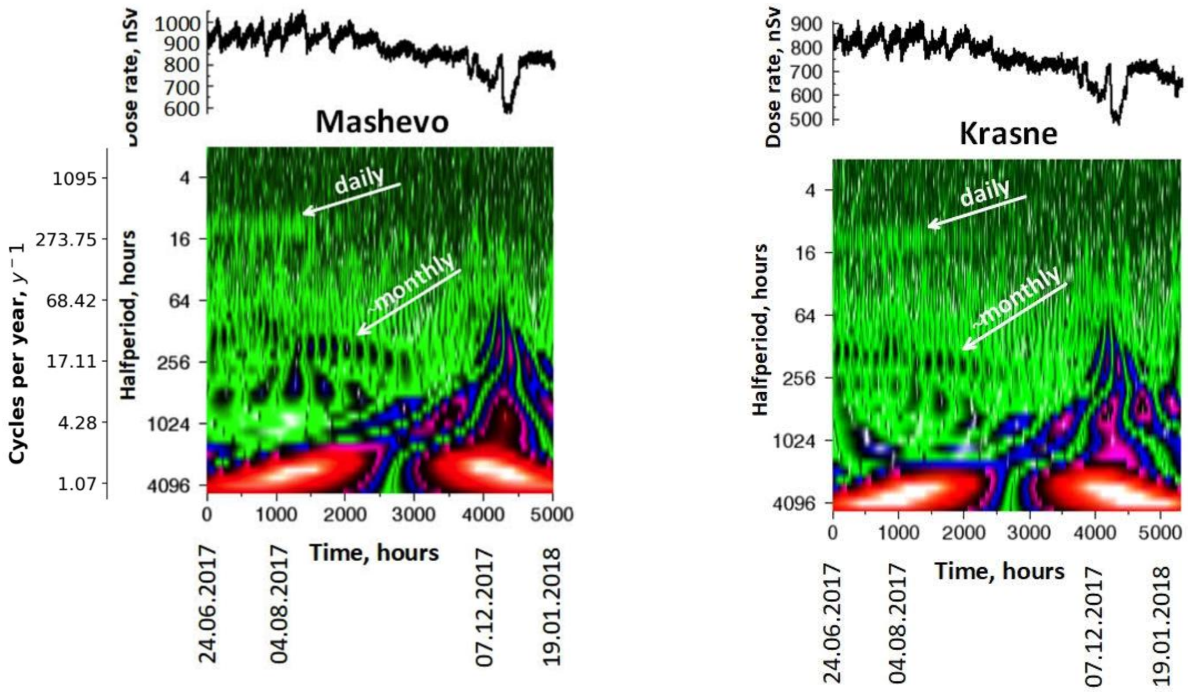

Fig. 2. Wavelet transformation of ASRC signals for 24.06.2017 - 19.01.2018. Above is the signal, below is a picture of its wavelet coefficients. *On the left*, is the Mashevo observation post; *on the right* – is the observation post Krasne. The pictures are almost identical. The upper arrow indicates a band of elongated narrow spots of the diurnal course; the lower arrow – is for a series of spots with intervals of 10 - 20 days (half-period). For convenience in comparing with the literature data on the left, the axis is given in the cycles per year. (See color Figure on the journal website.)

large-scale component is very similar. For any point on the picture of the wavelet transformation (which is called a wavelet periodogram for convenience), its “time-period” coordinates can be determined. Such estimates for the system of spots shown by the lower arrow are given in a table for three observation posts (the third one is not shown in Fig. 2). The coordinates of these spots coincide with the uncertainty of estimating the position of the spots’ centers. Therefore, we conclude that the large-scale pattern of spots in the above drawings is not accidental.

Now consider the light band in the upper left part of the wavelet-periodograms (upper arrow), which corresponds to the half-period of 12 h, that is, it reflects changes within one day. Fig. 3 shows a close-up of the corresponding part of the graph from Fig. 1. At this scale, it is clearly visible that the signal is a) a noisy sinusoid of daily changes, on which b) modulation in the form of saw teeth is superimposed: during 5 - 8 days the average value of the sinusoid increases, and then for 1 - 2 days a sharp decline is observed, after which the process of rise and fall is repeated. To prove that this is indeed a regular phenomenon, the signals from two observation posts strictly for the same spots are given in Fig. 3. As in the wavelet pictures of Fig. 2, it can be seen that the changes on a daily scale are also practically identical.

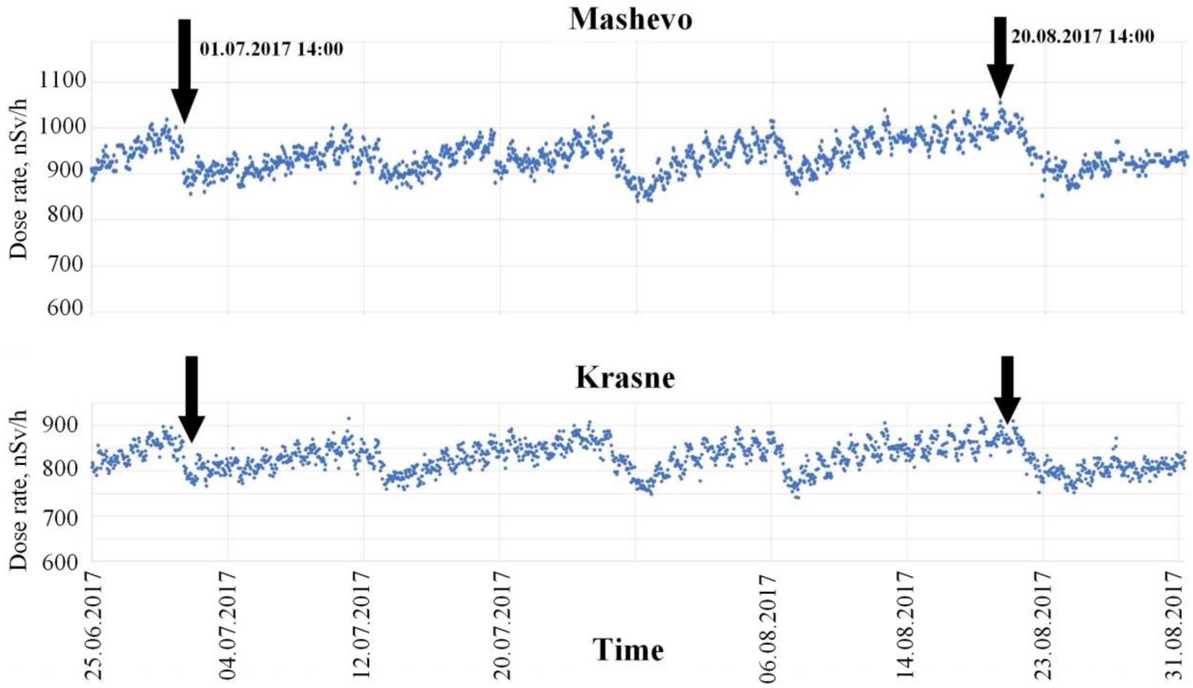

Fig. 3. Comparison of the signal from the ASRC observation posts Krasne and Mashevo for the same dates (26.06.2017 - 01.09.2017). Small peaks are the diurnal course. The arrows correspond to the same dates (01.07.2017 14:00, and 20.08.2017 14:00). (See color Figure on the journal website.)

Time of appearing of spots systems with the approximately 30-day period for different observation posts

Burakivka	Krasne	Mashevo
–	16.08.2017	18.8.2017
24.08.2017	24.08.2017	25.08.2017
01.09.2017	31.08.2017	02.09.2017
08.09.2017	07.09.2017	09.09.2017
17.09.2017	15.09.2017	16.09.2017
24.09.2017	23.09.2017	24.09.2017
02.10.2017	01.10.2017	02.10.2017
–	10.10.2017	12.10.2017
–	19.10.2017	22.10.2017

In the Table, the results of the quantitative evaluation of the spot system are given: the dates for the appearance of the series of spots shown by the lower arrows in Fig. 2. The shift between the data in the first approximation gives an idea of the degree of coincidence of the position of the spots.

4. Conclusions

In a signal that should be random, manifestations of several types of modulation of this basic noise-like signal have been detected. Changes within one day are visible. Variability with an interval of 6 - 8 days in the form of "saw teeth" is superimposed on this periodicity.

From Figs. 1 and 2 it can be concluded also, that the brightness of the manifestations of the signal structure depends on the season. The diurnal cycle is visible only in the summer months, and after October and until March - April it is practically absent, or the intensity of daily changes drops to almost zero. At the same time, modulation in the form of "saw teeth" continues to be observed in November. That is, there are teeth even when there is no daily cycle, which means the independence of these two processes.

From the wavelet coefficients in Fig. 2 and the corresponding table of spot positions, it follows that there is also a larger-scale structure of similarity: a system of spots is found, which is not as regular as the diurnal course, its variability is in the range 20 - 38 days, but which is reliably repeated in the signals from different detectors.

In our previous studies [3 - 6], it was concluded that the changes observed in the ASRC signals, mainly diurnal, cannot be explained by the instability of the equipment or the influence of meteorological factors on its operation. Thus, when checking the quality of the temperature stability of the used equipment, the range of dose rate deviations should not exceed 10 nSv/h when the standard operating temperature range is changed from –20 to +50 °C (Gamma TRACER user manual, clause 4.1.2.). This parameter was repeatedly checked and confirmed during the work.

The variability revealed in this work, especially in the form of “saw teeth”, and the simultaneous observation of such variability by different detectors is additional evidence of the reality of the phenomenon of periodical components’ existence. The original experimental results of the given work, which concern its task are as follows:

the existence of variability in the form of “saw teeth”;

existing of clear daily and “saw teeth” changing, approximately only from May to September;

repeatability of the results in signals from different detectors both in general and in detail (outwardly random spots’ system is repeated for different detectors (see the Table)).

This list does not include a clearly seen daily course as such, an analysis of which has been published earlier. We do not see a possibility of assign appearing of “saw teeth”, the duration of which reaches up to eight days, to bad work of the equipment. Combined our data with [3 - 6], where even for diurnal changes the possibility, that this is an equipment effect, was rejected, the influence of environmental conditions in the form of ’saw teeth’ is even more unlikely. Thus, the observed variability of ASRC signals is not the result of incorrect measurements but is a property of the signal himself. In comparing our data with literature data [1 - 2], it is also possible to assume, that the factor, which causes such variability, is placed outside the Earth.

Analysis of the nature of the sources of influence (radiation from the Sun, stars, the structure of Space-Time, the influence of relict neutrinos, etc.) is not the task of this study. But we would like to point out two works that were not included in the reviews [1, 2], issues which are close to those we investigated, and in which the problem of connection of periodicities, existing in the decay signals, with cosmic factors are considered in one way or another. In [8], long-term measurements of the natural gamma-background were carried out and a search was made for correlations of the received signals with some geophysical factors. P. A. Sturrock [9] reviewed the experiments performed in various laboratories to search for common peculiarities (periods) in signals, with the aim of summarizing the existing results from the standpoint of the existence of the possibility that cosmic neutrinos’ influence on radioactive decay, finding correlations with processes on the Sun, etc. Our work fully fits with such a general physical problem, and our results are very close to [9].

Nevertheless, as to the nature of such periodic components, if based only on the results of our work, the question still remains either in our data, the influence of unknown cosmophysical factors on the decay rate is observed, or the contribution of external factors such as cosmic rays to the signal is observed.

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СПОСТЕРЕЖЕННЯ ПЕРІОДИЧНИХ КОМПОНЕНТ У СИГНАЛАХ ГАММА-ФОНУ В ЧОРНОБИЛЬСЬКІЙ ЗОНІ ВІДЧУЖЕННЯ

Розглянуто структуру сигналів від детекторів системи моніторингу фонового гамма-випромінювання навколо Чорнобильської АЕС. Показано, що вони не є випадковими, містять періодичні складові. Порівняння сигналів від різних детекторів за один і той же період часу незаперечно свідчить, що отримані залежності є не випадковими і не помилковими ефектами.

Ключові слова: гамма-фон, Чорнобильська зона відчуження, варіабельність швидкості лічення.

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