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BACKGROUND OF THE RADON-HAZARD CLASSIFICATION OF THE TERRITORY OF THE REPUBLIC OF BELARUS BY INDIRECT MEASURES

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The work suggests a method of the evaluation of radon-hazard zones by indirect measures of radon: uranium concentration in soils and before-Chernobyl gamma background. Whereas the dependence of lung cancer incidence on radon is epidemiologically proved, the regression dependences of lung cancer morbidity on uranium concentration in soils and level of natural before-Chernobyl gamma background on the territory of Belarus have been determined. Taking into account the obtained within the present work high values of correlation coefficients, one can use these indicators to identify radon-hazard zones and to estimate indirectly the value of the radon component in the lung cancer.

Key words: radon, lung cancer, uranium concentration in soils, before-Chernobyl gamma background, linear regression, correlation coefficient.

Introduction

The evidence associating lung cancer morbidity with radon concentration in workplaces has been for the first time received by the results of the epidemiological studies carried out among the workers of uranium and other mines [8]. The conclusions drawn for a category of miners working in the conditions of high radon concentrations have been extended according to the linear non-threshold concept to the region of far lower concentrations observed in living spaces. Subsequently, the values of risk factors, as well as the sex-age dependence of lung cancer incidence were confirmed in 13 epidemiological studies conducted in 9 European countries [7]. Usually one determines a radon-hazard zone, where the concentration of radon is significantly higher than on the national average. According to the recommendations of the work [2], the radon-hazard zone can be defined as an area in which 1% dwellings have indoor radon concentrations 10 times higher than the average republican value. The identification of radon-hazard zones by the measurements in premises is quite a time-consuming and expensive procedure, and to circumscribe the zone borders, geological information is normally used [6].

The aim of the present study was to define and substantiate the indirect radon indicators, which can be used to identify the radon-hazard zones.

Materials and research methods

The subject of the investigation was the dependence of the standardized index of the average for the regions primary lung cancer incidence on the indices, weight-average for the territories with uranium-238 contents in soils and on natural exposure rate. The object of the research was the territory and population of the Republic of Belarus, except the city of Minsk.

The linear regression relation between the average for the regions of Belarus standardized indices of lung cancer incidence in years 1975, 1980, 1985, 1990 [1] and the weight-average for the regions of Belarus indices of uranium contents in soils and before-Chernobyl gamma back-

ground was determined. The earlier published data on the standardized indices of lung cancer incidence in Belarus [1] and the cartograms of before-Chernobyl gamma background [3] and the uranium concentration in the soils of Belarus [5] were used for the analysis.

The weight-average index of absorbed dose rate (ADR) in a *κ*-region was evaluated with the formula:

$$X_k = \frac{\sum s_i \cdot \bar{x}_i}{s_{tot}}, nGy/s \quad (1)$$

where S_i – area of the region with the value of average exposure rate (ER) X_i, thousand square kilometers.

$\bar{X}_i$ – average ADR value of *i* -gradation $\left(\frac{X^i_{max} - X^i_{min}}{2}\right)$, nGy/s

S_{tot} – total area of the *κ*- region, thousand square kilometers

The weight-average value of uranium concentration in the soils in a *κ*-region was evaluated with the formula:

$$X_k = \frac{\sum s_i \cdot \bar{x}_i}{s_{tot}}, \% \quad (2)$$

where S_i – area with the value of average uranium concentration X_i, thousand square kilometers.

$\bar{X}_i$ – average value of *i* -gradation $\left(\frac{X^i_{max} - X^i_{min}}{2}\right)$, %

S_{tot} – total area of the *κ*- region, thousand square kilometers

The age-standardized indices of primary lung cancer incidence per 100000 people (*n*, $0/_{0000}$) were determined according to the expression:

$$\lambda = 10^5 \cdot \sum_{i=1}^{n} \frac{W_i \cdot n_i}{N_i} \quad (3)$$

where n_i – number of morbid events in an i-age group;
N_i – number of people in the i-age group, people per year of the research;
W_i – world population standard in the i-age group, relative unit.

The world population standard, as proposed in the work [8] in 1966 is recommended by IARC and used worldwide.

Results and discussion

To assess the effect of radon on lung cancer sickness rate, the regression relation between the standardized index, average for the regions of the Republic of Belarus, of lung cancer incidence in years 1975, 1980, 1985 and 1990 and the indirect indices for radon hazard was obtained. The indirect indices for radon hazard included weight-average for the region territory values of uranium concentration in the soils of Belarus and of natural ADR. Fig. 1 shows the standardized dependence of lung cancer incidence in 1975, 1980, 1985 and 1990 on the weight-average for the region territories of the Republic of Belarus value of the uranium-238 concentration in the soils.

The above mentioned regression lines are parallel to one another and have high values of correlation coefficients – for the years of 1975, 1980, 1985 and 1990, 0.93, 0.87, 0.94, 0.89, respectively.

The before-Chernobyl natural gamma background of the territory of the Republic of Belarus is conditioned mainly by the radiation from uranium and thorium radionuclides with daugh-

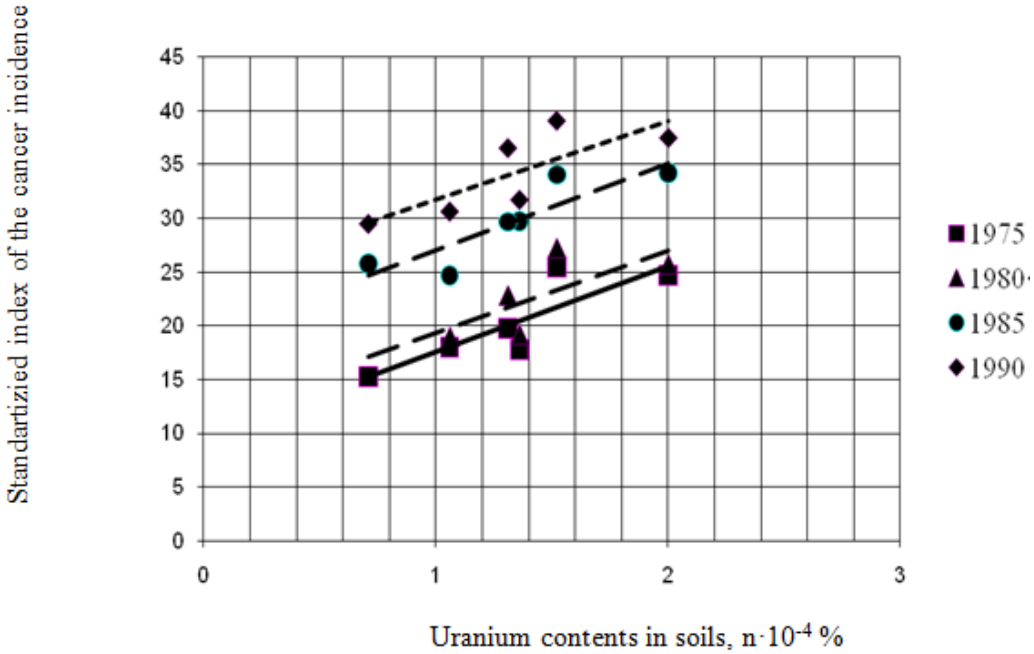

Fig. 1. Dependence of the lung cancer incidence index on the uranium concentration in the soils.

ter decay products (DDP) and K-40, which are situated mainly in the structure of soils and rocks. The radiation of ^{137}Cs, precipitated as a part of global fallout and evenly distributed throughout the whole territory of Belarus makes a relatively small contribution to the natural gamma background. As a first approximation, we assume that the unevenness of the natural gamma background on the territory of Belarus is conditional mainly on gamma radiation of radium and its DDP. Fig. 2 shows the regression dependence of the weight-average index for the region territories of the Republic of Belarus of uranium-238 contents in the soils on the weight-average for the region territories values of the before-Chernobyl gamma background.

The regression dependence has a high correlation coefficient – R=0,97 and a relatively small negative value of free term.

Figure 3 shows the regression relations between the standardized indices of primary lung cancer morbidity in the regions of the Republic of Belarus in years of 1975, 1980, 1985, 1990 and the weight-average on the territory index of natural ADR.

The regression lines are also parallel to one another and have the values of correlation coefficients somewhat lower than in those given in figure 1. For years 1975, 1980, 1985 and 1990 they make up 0.83, 0.67, 0.92, 0.83, respectively.

The similar values of the regression coefficients shown in Figures 1 and 3 (which on the average are 7,8±0,5 and 4,1±0,20, respectively) indicate a stable dependence of the standardized index of lung cancer incidence on such indirect indicators of radon hazard, as the uranium contents in the soils and the values of ADR over 15 years. Meanwhile, the index, calculated at the hypothetical zero value of exposure dose, every 5 years increases about half again as. The extreme values for the regions of Belarus in each of the investigated periods vary just about half again as. If we accept, that there is a correlation between the uranium contents in the soils, ADR and exhalation of radon, which then enters building spaces, then the received regression relations

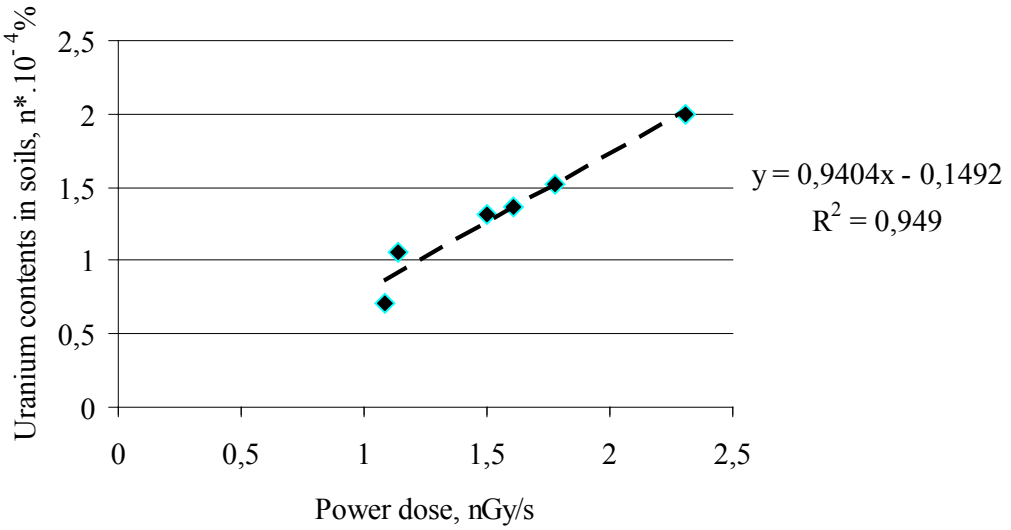

Fig. 2. Dependence of the weight-average uranium contents in the soils on the weight-average for the regions values of ADR.

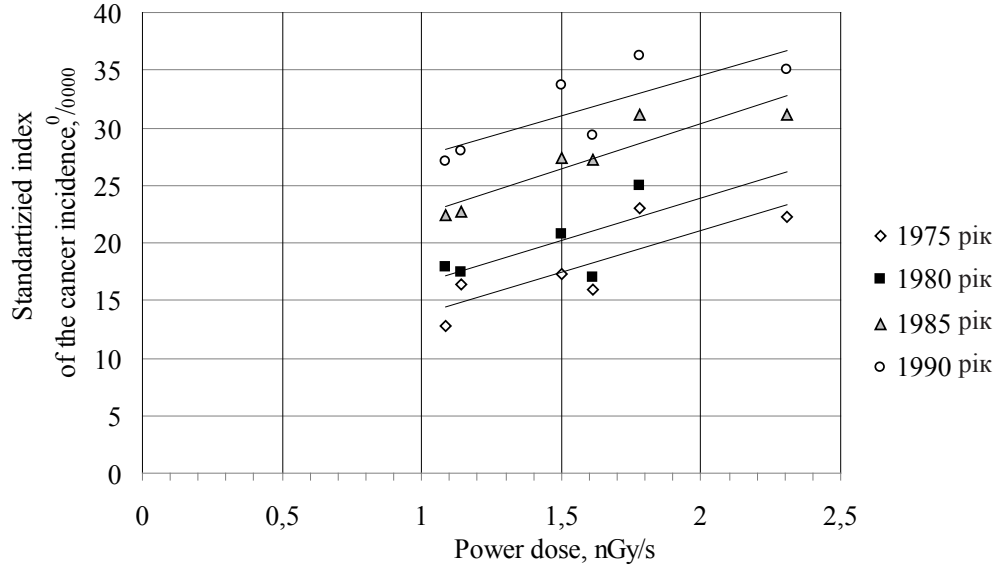

Fig. 3. Dependence of the lung cancer incidence index on exposure dose.

of the standardized index of the lung cancer incidence with ADR can be considered as a primary radon-hazard classification for the territory of Belarus.

In the presence of large-scale maps of the before-Chernobyl gamma background and the uranium contents in the soils and, using the index of soil permeability for radon, one can outline the radon-hazard zones on certain territories, which then will be investigated in detail by measuring of the radon volume activity in building spaces. The regression dependences given in Figures 1 and 3 are expressed in relative coordinates and can not be interpreted in terms of obtaining quantitative values. The analysis of the results of the large-scale researches conducted in 1992

in Gomel and Mogilev regions aimed at the determination of the radon concentration in the premises of rural localities [8] showed that there is a certain correlation between the average values of the radon volume activity in the premises with the value of the before-Chernobyl gamma background. The resulting regression is shown in Fig. 4.

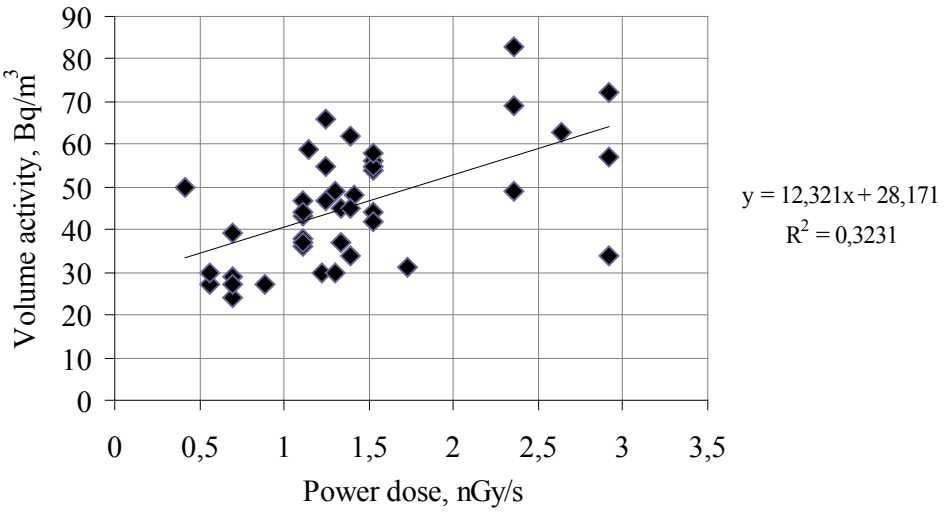

Fig. 4. Dependence of the radon volume activity on ADR.

The relatively low correlation coefficient between the volume activity and exposure rate can be explained by the variability of the values of volume concentration during a year, whereas in the conducted research in fact only single values in the summer time were obtained.

Conclusion

The received dependences of the average for the regions of the Republic of Belarus, standardized indices of primary lung cancer incidence on the weight-average in the region territories of Belarus values of uranium contents in the soils and before-Chernobyl gamma background have a high degree of correlation. Taking into consideration the presence of non-epidemiologically substantiated relation between the radon concentration in living spaces and lung cancer development, we can assume that these factors are indicators of the presence and negative effects of radon. However, the quantitative ratio of such influence, for example, the value of radon component of lung cancer, can only be obtained on the basis of epidemiological studies, the organization and conduct of which allow of using the regression dependence obtained in the present paper.

The values of the before-Chernobyl gamma background and the uranium concentration in the soils correlate with the volume activity of radon in indoor dwellings. These indices can be used during the mapping of radon high risk, both individually and collectively, as an integral indicator. The factor of soil permeability for radon can be additionally used as a constituent part in the application of this integral indicator. At the same time, in the areas with different soil types these indices should be compared with reliable estimates of the radon volume activity in indoor building spaces.

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ПЕРЕДУМОВИ ДО КЛАСИФІКАЦІЇ РАДОНОВОЇ НЕБЕЗПЕКИ ТЕРИТОРІЇ РЕСПУБЛІКИ БІЛОРУСЬ ЗА НЕПРЯМИМИ ПОКАЗНИКАМИ

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У роботі пропонується метод оцінки радонової небезпеки за непрямими ознаками: концентрацією урану в ґрунті і дочорнобильським гамма-фоном. З урахуванням того, що залежність раку легень від концентрації радону в приміщеннях епідеміологічно доведена, були отримані регресійні залежності випадків раку від концентрації урану в ґрунті й рівня дочорнобильського гамма-фону на території Білорусі. Зважаючи на високі коефіцієнти кореляції, отримані в даній роботі, можна ідентифікувати дані показники як непрямі ознаки радонової небезпеки для картування радонового ризику.

Ключові слова: радон, рак легень, вміст урану в ґрунтах, дочорнобильський гамма-фон, лінійна регресія, коефіцієнт кореляції.

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ПРЕДПОСЫЛКИ К КЛАССИФИКАЦИИ РАДОНОВОЙ ОПАСНОСТИ ТЕРРИТОРИИ РЕСПУБЛИКИ БЕЛАРУСЬ ПО КОСВЕННЫМ ПОКАЗАТЕЛЯМ

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В работе предлагается метод оценки радоновой опасности по косвенным признакам: концентрации урана в почве и дочернобыльскому гамма-фону. Учитывая, что зависимость рака лёгкого от концентрации радона в помещениях эпидемиологически доказана, были получены регрессионные зависимости случаев рака от концентрации урана в почве и уровня дочернобыльского гамма-фона на территории Беларуси. Принимая во внимание высокие коэффициенты корреляции, полученные в настоящей работе, можно идентифицировать данные показатели как косвенные признаки радоновой опасности для картирования радонового риска.

Ключевые слова: радон, рак лёгкого, содержание урана в почвах, дочернобыльский гамма-фон, линейная регрессия, коэффициент корреляции.