Relationship between ^{131}I and ^{137}Cs Deposition on Soil in the Territory of Belarus after the Chernobyl Accident.

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As a result of the Chernobyl accident a large part of territory of Belarus had been contaminated with radioactive fallout. One of important radionuclides was ^{131}I which caused significant thyroid exposure in the most affected areas. Direct measurements of ^{131}I activity in thyroid and determination of ^{131}I concentration in foodstuffs and air were performed only in limited areas regions of the contaminated territory. Therefore, reconstruction of thyroid doses resulting from ^{131}I intake is important problem solution of which needs information of ^{131}I deposition on soil [1].

Izrael [2] noted expediency of using an isotope ratio of ^{131}I to ^{137}Cs content in soil for assessment of ^{131}I deposition in the areas where measured data on ^{131}I are absent or limited. The relationship between ^{131}I and ^{137}Cs deposition had been obtained by Mahonko et.al. [3] on the basis of data on ^{131}I and ^{137}Cs activity concentration in more than one hundred soil samples taken in the area located between cities Kiev (Ukraine) and Tula (Russia) (north-eastern direction from Chernobyl). The regression function derived by Mahonko et.al. [3] predicts an approximately linear increase of ^{131}I content in soil with a growth of ^{137}Cs deposition ($^{131}\text{I} \sim [^{137}\text{Cs}]^{0.85}$).

The analysis of measured data performed by Orlov et.al. [4] shows that the ^{131}I/^{137}Cs isotope deposition ratio R on soil in the European part of the former USSR increases in western regions. In particular the ratio R in the western part of Belarus is larger by 4-5 times than in the eastern part. The inhomogeneous deposition of radioactive dispersed materials makes it necessary to take a regional approach to dose reconstruction. In this connection the relationship between ^{131}I and ^{137}Cs content in deposition on soil in various contaminated areas of Belarus is studied in the present paper.

The data for the analysis of ^{131}I and ^{137}Cs activity concentration in soil have been taken from the report by Slizov et.al. [5]. Their samples were collected in the southern and the eastern parts of the territory of Belarus during May-June 1986. The location of the areas where samples were taken is shown in Fig. 1. Radionuclide activity was determined by gamma-ray spectrometer with semiconductor Ge(Li)-detector at the Institute of Nuclear Energy of Belarus Academy of Sciences (Minsk). All results of the measurements were given as values of activity on 10th May 1986. The numbers of soil samples taken in the southern and the eastern areas were 139 and 213, respectively.

The southern area includes five administrative districts of the Gomel region. The distance of the farthest west point of this area is about 190 km from Chernobyl. The eastern area is located in the territory of the Gomel and the Mogilev regions, including 6 and

Fig. 1 Location (shaded) wher soil samples had been taken in the Belarus territory: the southern area and the eastern area.

5 administrative districts, respectively. The extent of the eastern area from the south end to the north end is about 110 km. The level of ^{137}Cs contamination in soil of the studied areas varies from tens to thousands of kilo-becquerels per square meters and the distribution of ^{137}Cs deposition is highly non-uniform. The wide variability of deposition provides an opportunity to investigate the relationship between ^{131}I and ^{137}Cs content in soil over a wide range of contamination.

Relative frequency distributions of ^{131}I and ^{137}Cs activity concentration in soil of areas under consideration are presented in Figs. 2 and 3. The results of performed calculations show that empirical data can be described by log-normal distribution

$$f(x) = \left(\sqrt{2\pi}ax\right)^{-1} \exp\left[-(\ln x - b)^2 / 2a^2\right] \quad (1)$$

The parameter a in (1) characterizes skewness of the distribution and is defined as

$$a = \left[2(\ln E - \ln M)\right]^{1/2},$$

where E is the mean value, and $M=e^b$ is the median of the distribution.

According to estimated parameters, the ^{137}Cs mean value characterizing the distribution of data obtained for the southern area (westward radioactive trace from Chernobyl - WRT) is larger by two times than the mean value in the case of the eastern area (northern radioactive trace — NRT) (see Figs. 2 and 3). At the same time the ^{131}I data obtained in the southern and the eastern areas are characterized by similar mean values. The observed behavior of parameters means that the isotope ratio of ^{131}I/^{137}Cs in deposition on soil in the studied areas can be characteristically different.

The empirical data presented in Figs. 2 and 3 were used to derive the relationships between ^{131}I and ^{137}Cs deposition on soil in the studied areas. It is noted that ^{131}I and ^{137}Cs activity concentration in soil are strongly variable. To minimize this variability and elucidate the relationship between ^{131}I and ^{137}Cs concentration, the empirical data were ln-transformed. As the ^{131}I and ^{137}Cs data follow the log-normal distribution, the ln-transformed quantities will obey the normal distribution which is more convenient for statistical treatment. Calculation of the relationship between ^{131}I and ^{137}Cs activity concentration have been performed without regard to the contribution of ^{137}Cs global fallout which is comparably small (~0.06 Ci/km^2) and has not remarkable influence on results. The relationships between ^{131}I and ^{137}Cs deposition are given in Fig. 4. The corresponding regression functions describing dependence of ^{131}I concentration on ^{137}Cs contamination level in soil of the southern and the eastern areas are written as

$$^{131}I = 14.58 \cdot \left(^{137}Cs\right)^{0.605} \qquad (2)$$

and

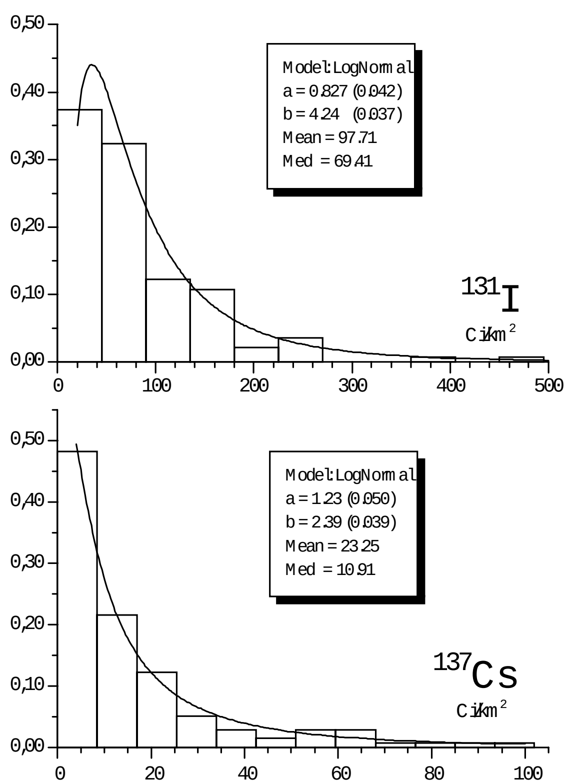

Fig. 2 Distribution of ^{131}I and ^{137}Cs activity concentration in soil of the southern area of Belarus.

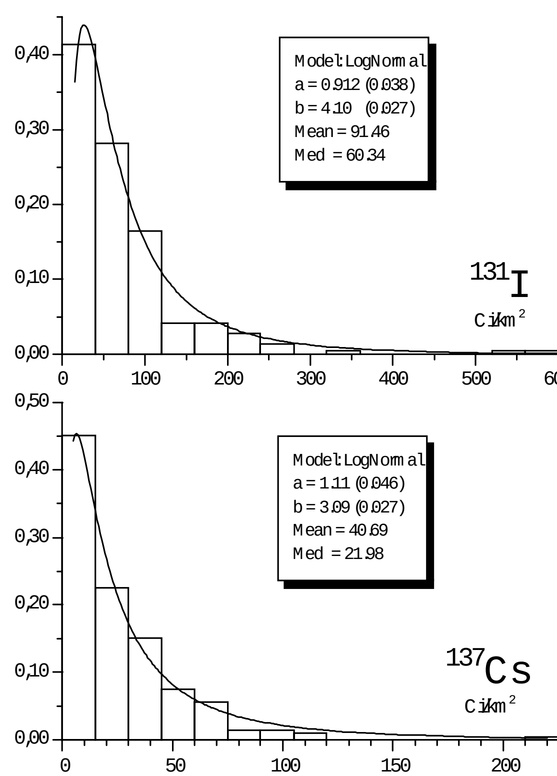

Fig. 3 Distribution of ^{131}I and ^{137}Cs activity concentration in soil of the eastern area of Belarus.

$$^{131}\mathrm{I} = 8.85 \cdot \left(^{137}\mathrm{Cs}\right)^{0.627} \qquad (3)$$

respectively, where levels of contamination are expressed with activity (Ci/km^2) on 10th May 1986.

The similar function was derived from analysis of the joined set of data including measurements for both studied areas (see Fig. 5). In this case the obtained regression equation is

$$^{131}\mathrm{I} = 11.47 \cdot \left(^{137}\mathrm{Cs}\right)^{0.591}. \qquad (4)$$

Using the regression equations (2), (3) and (4), the isotopic ratio R can be taken to be

$$R = C \cdot \left(^{137}\mathrm{Cs}\right)^{-0.40}, \qquad (5)$$

where the coefficient C is equal 14.15, 8.85 and 11.47 for the southern, the eastern and the joined (southern + eastern) areas, respectively. According to coefficient C values, the isotope ratio R in deposition on soil in the southern area is larger by 1.6 times than in the eastern one.

The relationship (5) predicts that R values increase by a factor of about 4.8 with decreasing ^{137}Cs content of soil from 50 to 1 Ci/km^2. The observed behavior is in agreement with the data of Orlov et al. [4] who show that R values obtained in the western regions of Belarus where the level of soil contamination with ^{137}Cs is low (1-5 Ci/km^2) are higher by 3-5 times than in the strongly contaminated areas of the south-eastern and the eastern parts of Belarus.

Thus the results of the present study performed for a wide range of soil contamination with ^{137}Cs predicts non-linear behavior of ^{131}I/^{137}Cs isotope ratio in the studied areas of Belarus. Use of the obtained non-linear relationship between ^{131}I and ^{137}Cs content in soil may provide a more realistic regional estimation of ^{131}I deposition and help to improve radiological assessments.

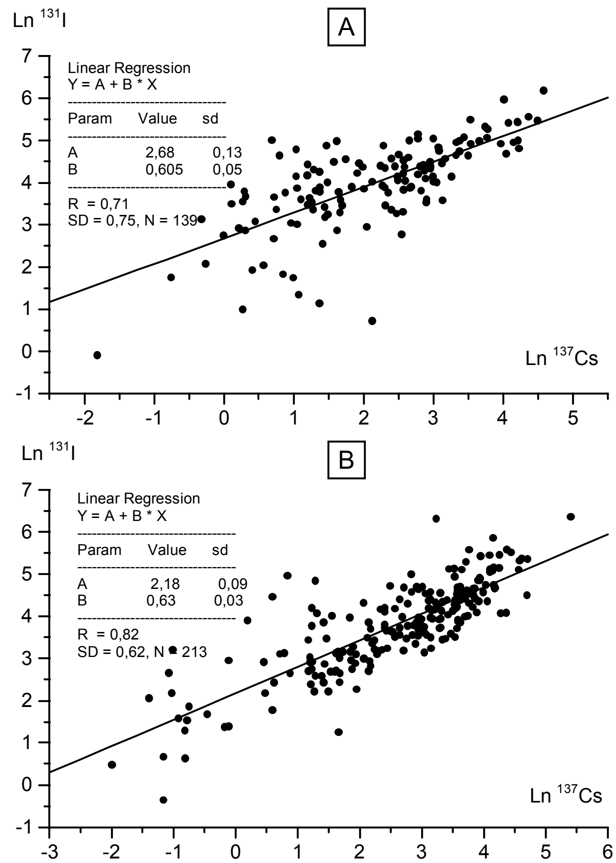

Fig. 4 Relationship between ^{131}I and ^{137}Cs activity concentration (Ci/km^2) in soil of the southern (A) and the eastern (B) areas of Belarus.

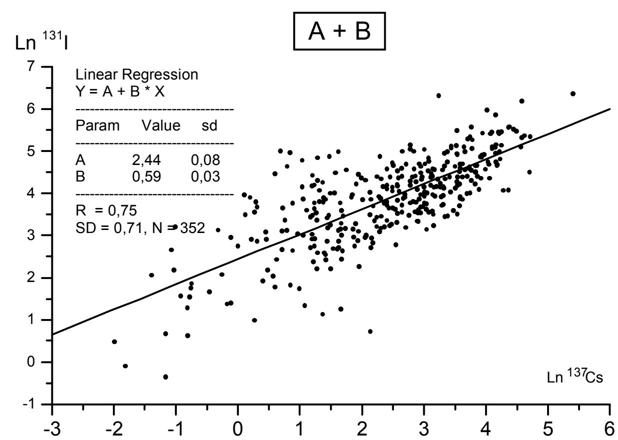

Fig. 5 Relationship between ^{131}I and ^{137}Cs activity concentration (Ci/km^2) in soil of the Belarus territory including both the southern (A) and the eastern (B) areas.

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