Radiation Protection Dosimetry Vol. 105, No. 1–4, pp. 623–626 (2003)
Published by Nuclear Technology Publishing

^{131}I CONTENT IN THE HUMAN THYROID ESTIMATED FROM DIRECT MEASUREMENTS OF THE INHABITANTS OF RUSSIAN AREAS CONTAMINATED DUE TO THE CHERNOBYL ACCIDENT

A. A. Bratilova†, I. A. Zvonova†, M. I. Balonov†, N. G. Shishkanov‡, V. I. Trushin§ and M. Hoshi‖
†Institute of Radiation Hygiene, Mira st. 8, 197136, St Petersburg, Russia
‡Medical Radiological Research Center, Obninsk, Russia
§Russian Scientific Roentgen-Radiological Center, Moscow, Russia
‖Research Institute for Radiation Biology and Medicine, Hiroshima University, Japan

Abstract — The method of processing and the results of measurements of ^{131}I content in the thyroids of Russian people performed in May–June 1986 are presented. The contribution of radiation from Cs radionuclides in the human body was taken into account in the processing of measurement data with an SRP-68-01 device. The greatest individual ^{131}I content was found in the thyroids of inhabitants of the Bryansk region, up to 250–350 kBq, and in the Tula and Orel regions, up to 100 kBq. The average ^{131}I thyroid activity in the middle of May 1986 reached 80 kBq for inhabitants of some settlements in the Bryansk region, 5–8 kBq in the Tula region and 5 kBq in the Orel region.

INTRODUCTION

Soon after the accident at the Chernobyl nuclear power plant, measurements of ^{131}I activity in the thyroid were started in residents of contaminated territories in Russia. Thyroid radiometry was performed using all the available devices, which were sometimes inadequate and not calibrated for the quantitative measurement of ^{131}I activity in the thyroid gland. Thus, derivation of reliable quantitative estimations of ^{131}I thyroid content from measurements that were performed in conditions of high external gamma radiation and in the presence of other gamma emitters in the whole body turned out to be complicated, and for some devices even impossible.

Most of the ^{131}I thyroid measurements in residents of contaminated areas of Russia soon after the Chernobyl accident were performed with non-specific transportable scintillation radiometers of the SRP-68-01 type, recording gamma radiation with an energy above 25 keV. Thus, when measuring ^{131}I content in the human thyroid, the device simultaneously registered radiation from ^{134}Cs and ^{137}Cs radionuclides in the whole body and external radiation. The procedure for assessing the ^{131}I content of the thyroid by direct measurement should consider this supplementary radiation.

The methods for ^{131}I activity estimation by thyroid measurements with the SRP-68-01 device in the Russian population, as well as patterns of ^{131}I accumulation in the thyroids of inhabitants of the Bryansk, Kaluga, Tula and Orel regions of Russia, are presented in this paper.

Contact author E-mail: bratilov@comset.net

METHODS FOR ESTIMATION OF ^{131}I IN THE THYROID OF THE POPULATION FROM DIRECT MEASUREMENT DATA

Broad-scale measurements of ^{131}I content in the thyroids of the population of contaminated areas were started on 14–15 May 1986 in regional hospitals with radionuclide diagnostic equipment. However, the remoteness of regional centres from rural territories with the highest contamination and the low capacity of diagnostic laboratories made it necessary to organise examinations directly at the places of residence. In 1986, SRP-68-01 radiometers were most frequently used to monitor the internal exposure in contaminated localities. SRP-68-01, used for geological survey of uranium ores, has an NaI(Tl) scintillation detector, Ø 30 × 25 mm, an arrow-type indicator and a scale calibrated with ^{226}Ra on 30, 100, 300, 1000 and 3000 μR h^{-1}. Measurements were performed without a collimator and with an energy threshold of about 25 keV, that slightly varied from device to device.

The measurements with the SRP-68-01 radiometer in the Bryansk and Kaluga regions were performed in three variants of measurement geometry: two measurements (at the neck and at the thigh or at the neck and at the liver) or one measurement at the neck only[1–3]. If measurements of a person of age u were made in two positions (neck and thigh or neck and 'liver'), ^{131}I activity in thyroid (in kBq) has been calculated by the formula[1,3]

$$G = K(u)\,[P_n - a_n(u) \times P_f - b_{n/2}(u) \times (P_2 - a_2(u) \times P_f)], \quad (1)$$

where P_n, is the dose rate over the neck (μR h^{-1}), P_2 is the dose rate over the thigh or liver (second measurement of the same person) (μR h^{-1}), P_f is the background dose rate at the measurement point (μR h^{-1}), $K(u)$, is the calibration factor (kBq (μR h^{-1})$^{-1}$), $a_n(u)$ and $a_2(u)$ are the background shielding factors by a whole body in different detector positions (relative units) and $b_{n/2}(u)$ is a factor accounting for difference of measurement geometries in detector positions at the neck and liver or thigh with regard of extra-thyroid gamma radiation (relative units).

The calibration factor for the SRP-68-01 device was determined by different research groups to be in the range from 0.16 to 0.37 kBq (μR h^{-1})$^{-1}$[3–5]. The average value of $K(u)$ for adults, 0.21 ± 0.06 kBq (μR h^{-1})$^{-1}$ was adopted for thyroid dose calculations[6]. The calibration coefficient for children of less than 3 years of age is 0.6 of that for the adults, by the age of 10 this ratio increases up to 0.71 and by 15 years up to 0.85[5,10].

The shielding factors of the external background by the human body, $a_n(u)$ and $a_2(u)$, and geometric factors, $b_{n/2}(u)$, were estimated from later human measurements, when ^{131}I had already decayed. The background shielding factors slightly decreased from 1.0 to 0.9 with increasing weight and of an individual size[2]. The value of the geometric factor, $b_{n/2}(u)$, i.e. the ratio of the extra-thyroidal radiation dose rate with the detector positioned close to the neck to that at the liver, was estimated to be $b_{n/liv}(u) = 0.87 \pm 0.07$ for all ages. For a second measurement above the thigh $b_{n/thigh}(u) = 1 \pm 0.15$ for ages under 18, and $b_{n/thigh}(u) = 0.9 \pm 0.1$ for adults.

The contribution of gamma radiation from caesium radionuclides distributed in the body in the case of a single thyroid was estimated based on available two-position measurements in a significant fraction of people for each day of the survey[3,6]. All the two-position measurements were used for determination of individual 'caesium contribution' factors X_i:

$$X_i = \frac{P_2^i - a_2 P_f}{P_n^i - a_n P_f}. \quad (2)$$

All individual values of X_i were averaged for each day of measurement. Processing of all the two-position measurements of people in the Bryansk and Kaluga regions during the measurement period from 21 May to 7 June 1986, revealed a linear dependence of the mean value of the contribution factor $X(t)$ on the date of measurement and the absence of statistically significant differences between age groups. Figure 1 presents the plot of $X(t)$ dependence on time for cases when the second measurements were made above the liver.

Frequency distributions of individual 'contribution factors' X_i for each measurement day are close to the normal distributions with an average variation coefficient of 0.33. The symmetry of X_i distributions indicates that possible surface contamination of people's bodies and clothes did not significantly influence the measurement data.

The average values of $X(t)$ for each measurement day were used for calculation of ^{131}I activity in thyroid (in kBq) in the case of a single measurement with a detector positioned at the neck:

$$G = K(u)\,[P_n - a_n(u)\,P_f] \times [1 - b_{n/2}(u)\,X(t)], \quad (3)$$

where $X(t)$ was determined by the empirical function

$$X(t) = -(0.48 \pm 0.11) + (0.034 \pm 0.003)\,t, \quad (4)$$

where $24 \leq t \leq 40$ (days) is the time after the radioactive contamination of the area.

The minimal detectable activity (MDA), when using Equation (1), depends on the background and on the results of two measurements for one person. The measurement error was estimated to be from 1 to 100 μR h^{-1}, differing by 3–5% from the measurement result. The error of the device's indicator was taken as the standard deviation of a measurement. Activity values, counted from the minimal statistically valid difference between the results of measurements at the neck and liver, or neck and thigh (with a 95% confidence level), were accepted as the MDA of the method. For measurements done in the Bryansk region on 31 May to 7 June 1986, the MDA was estimated in the range from 0.3 to 19 kBq for different combinations of background value and measurements of neck and liver, with an average value of 2 kBq.

When estimating ^{131}I activity by Equation (4), the empirical parameter $X(t)$ forms another factor of uncertainty, which was estimated by a regression plot with confidential intervals, as shown in Figure 1.

Less than 10% of thyroid measurements performed in the Bryansk region gave activity estimations lower than the MDA. In the Kaluga region, about 50% of measurements performed from 26 May to 4 June were below MDA values. For further dose calculations and estimation of the averages for settlements, they were substituted with the values equal to half of the MDA values.

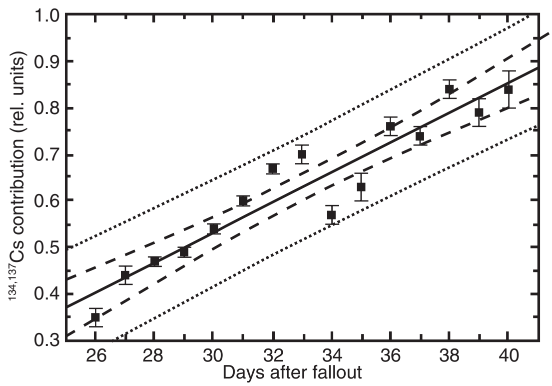

Figure 1. Time dependence of the contribution of gamma radiation from extra-thyroidal radionuclides to the dose rate at the neck, measured by SRP-68-01, Bryansk region. Dotted lines indicate 95% confidence intervals for the distribution of individual and average parameter values.

^{131}I content in the thyroid for 40,000 inhabitants of the Bryansk and Kaluga regions of Russia measured with SRP-68-01 was estimated using the above methods. About 5500 inhabitants of the Bryansk, Tula and Orel regions had been measured with the radiodiagnostic equipment.

^{131}I CONTENT IN THE THYROID OF RUSSIAN INHABITANTS MEASURED IN 1986

The examples of measured ^{131}I activities in thyroids of individuals from the Bryansk, Orel and Tula regions are presented in Table 1. Since no statistically significant differences in ^{131}I content in the thyroids of people of different ages were found, the average values in the table were given for merged groups.

The highest individual and average for the settlement ^{131}I activities in the thyroid were registered in the middle of May in the Krasnogorsky district: the individual values reached 250–360 kBq, the maximal average for the village of Barsuki was 80 kBq. In the Novozybkov and Zlynka districts of the Bryansk region at the same time the average ^{131}I content in the thyroids of residents was 5 to 10 kBq.

The frequency distribution of measured individual ^{131}I thyroid activities on particular dates had an asymmetric character. Table 2 represents the averaged statistical parameters of the distribution of measured ^{131}I activity in the thyroids of people from settlements for different measurement dates. This can be rather satisfactorily described by a log-normal distribution.

Table 1. Examples of the average ^{131}I thyroid activity (kBq) in Russian inhabitants measured in May–June 1986.

Settlement and ^{137}Cs soil contamination, (MBq m^{-2})	Date in 1986	Number of measurements	^{131}I in thyroid (kBq)	Standard deviation (kBq)
Vyshkov, Bryansk region, 1.2	3–5 June	1036	2.5	3.7
Zlynka, Bryansk region, 1.2	1 June	412	2.5	3.2
Krasnaya Gora, Bryansk region, 2.7	16–17 May	57	27	35
Mirnyi, Bryansk region, 1.3	19–20 May	34	18	17
Novozybkov town, Bryansk region, 0.7	19–21 May	32	6.1	3.5
	23 May	85	4.4	3.9
	31 May	662	2.3	4.2
Orel city, Orel region, 0.05	24 May	668	1.7	1.3
Plavsk town, Tula region, 0.5	15–16 May	90	5.3	5.7

Figure 2 shows the dynamics of ^{131}I thyroid content reduction in residents of Novozybkov town in May–June 1986. The half-time of ^{131}I activity in the thyroid was 8.6 days. The uncertainty of this estimation is characterised by a geometric standard deviation of 1.2. It needs to be noticed that from 4 May 1986 contaminated local milk was not delivered to kindergartens and schools in Novozybkov town, and from 10 May not to the commercial shops either. From the middle of May fresh milk was delivered to the town from relatively clean districts which contributed to the restriction of thyroid dose.

Data on the correlation of ^{131}I thyroid activity and ^{137}Cs soil contamination are shown in Figure 3. These data were received from Novozybkov and Zlynka districts of the Bryansk region from 31 May to 2 June 1986. Every point represents the average ^{131}I content in the thyroid of inhabitants of one settlement where at least seven people were measured (from 7 to 110). The rather big dispersion of values could be explained not only by the measurement statistics but also by the different conditions of radionuclide intake. Different dates of putting cattle to pasture and different times of application of protective measures, like cessation of local milk consumption influenced the accumulated ^{131}I activity in the thyroid of inhabitants. A linear approximation of the average ^{131}I thyroid activity on soil con-

Table 2. Statistical parameters of the frequency distribution of the measured ^{131}I activity in thyroids of Russian inhabitants after the Chernobyl accident. Standardised to the arithmetic mean value.

Arithmetic mean	Median	Standard deviation	5% quintile	95% quintile	Geometric mean
1	0.73	1.1	0.22	2.3	0.73

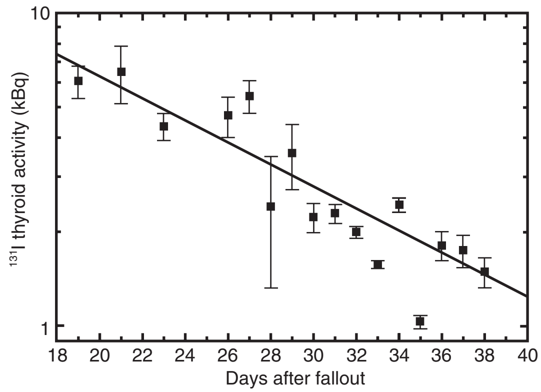

Figure 2. Dynamics of the average ^{131}I thyroid activity in inhabitants of Novozybkov town after the Chernobyl accident. T_{ef} = 8.6 d.

taminated with ^{137}Cs can be used for the experimental data:

$$\overline{G} = (0 \pm 0.5) + (3.0 \pm 0.6) \times 10^{-3}\ \sigma_{137}, \quad (5)$$

where $\overline{G}$ (in kBq) is the average ^{131}I content in the thyroid of inhabitants in a locality with ^{137}Cs soil contamination of σ_{137}, kBq m^{-2}.

The methodology of estimation of ^{131}I activity in the thyroid of inhabitants from the results of *in vivo* measurements was used for reconstruction of the thyroid dose(6), which resulted in the recent publication of a reference book giving the average thyroid dose for the Russian population who lived in contaminated settlements of the Bryansk, Tula, Orel, and Kaluga regions in 1986(7).

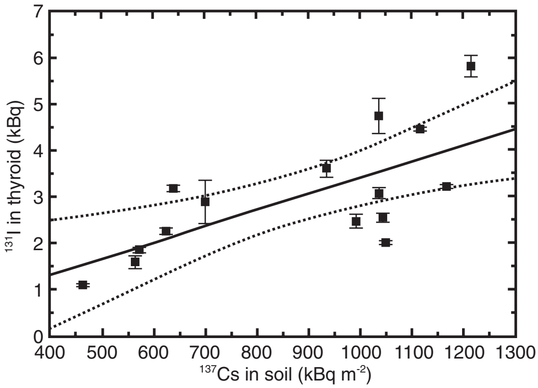

Figure 3. Dependence of the average ^{131}I thyroid activity in inhabitants of the Novozybkov and Zlynka districts of the Bryansk region measured from 31 May to 2 June 1986 on ^{137}Cs soil contamination in the place of residence.

CONCLUSIONS

Methods for the estimation of ^{131}I activity in the thyroids of inhabitants of territories contaminated with radionuclides due to the Chernobyl accident have been described based on the results of direct thyroid measurements with an SRP-68-01 device with exclusion of the contribution of gamma radiation from extra-thyroid radionuclides. The absence of such correction leads to an overestimation of ^{131}I thyroid content measured at the end of May to the beginning of June 1986 by up to two to four times.

The highest individual ^{131}I thyroid content, up to 360 kBq, was registered in the middle of May 1986, in inhabitants of the Krasnogorsky district of the Bryansk region. The average ^{131}I thyroid content for settlements reached 80 kBq. At the same time, in five other contaminated districts of the Bryansk region the average ^{131}I thyroid content in inhabitants was 10–20 kBq, in the most contaminated districts of the Tula region 5–8 kBq and in the Orel region about 5 kBq.

Reduction of ^{131}I in the thyroids of inhabitants of the town of Novozybkov, Bryansk region, occurred with a half-time of 8.6 days.

Measured ^{131}I thyroid activities are distributed asymmetrically, and they can be described by a log-normal function with the following parameters (in quotas from the arithmetic mean): median 0.73, standard deviation 1.1, 5% and 95% quintiles 0.22 and 2.3, respectively. This geometric mean of the log-normal distribution is almost equal to its median.

REFERENCES

1. Zvonova, I. A., Balonov, M. I. and Bratilova, A. A. *Thyroid dose reconstruction for population of Russia suffered after the Chernobyl accident.* Radiat. Prot. Dosim. **79**(1–4), 175–178 (1998).
2. Pitkevich, V. A., Khvostunov, I. K. and Shershakov, V. M. *Influence of dynamics of ^{131}I fallout due to the ChNPP accident on value of absorbed doses in thyroid for population of Bryansk and Kaluga regions of Russia*. Radiat. Risk **7**, 192–215 (1996) (in Russian).
3. Zvonova, I., Balonov, M., Bratilova, A., Vlasov, A., Pitkevich, V., Vlasov, O. and Shishkanov, N. *Methodology of thyroid dose reconstruction for population of Russia after the Chernobyl accident*. In: Harmonization of Radiation, Human Life and the Ecosystem. Proc. 10th International Congress of the IRPA, International Conference Center Hiroshima, Hiroshima, P-11-265 (2000).
4. Ulanovsky, A. V. and Drozdovich, V. V. *Influence of radionuclides spread in a human body on thyroid dose estimation due to direct measurements*. Pre-print IPE-27, Minsk (1997) (in Russian).
5. Kaidanovsky, G. N. and Dolgirev, E. I. *Calibration of radiometers for mass control of incorporated ^{131}I, ^{134}Cs and ^{137}Cs nuclides with the help of volunteers*. Radiat. Prot. Dosim. **71**(3), 187–194 (1997).
6. *Thyroid dose reconstruction of radioactive iodine exposure in thyroids of inhabitants living in settlements of Russian Federation that were radioactively contaminated due to the accident at the Chernobyl NPP in 1986*. MU 2.6.1.1000–00 (2000) (Moscow: Russian Ministry of Public Health) (2001).
7. Balonov, M. I. and Zvonova, I. A. (eds.). *Average doses of the thyroid exposure for people of different ages who lived in 1986 in the settlements of the Bryansk, Tula, Orel, and Kaluga regions contaminated with radionuclides due to the accident at the Chernobyl NPP.* (Moscow: Ministry of Public Health of Russia) (2002).