The reconstruction of thyroid dose following Chernobyl

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The report presents the overview of several approaches in working out the methods of thyroid internal dose reconstruction following Chernobyl.

One of these approaches was developed (IBPh, Moscow; MRRC, Obninsk; IRM, Minsk) using the correlations between the mean dose calculation based on I-131 thyroid content measurements and Cs-137 contamination of territories. The available data on I-131 soil contamination were taken into account. The lack of data on I-131 soil contamination was supposed to be compensated by I-129 measurements in soil samples from contaminated territories. The semiempiric model was developed for dose reconstruction. The comparison of the results obtained by semiempiric model and empirical values are presented. The estimated values of average dose according semiempiric model were used for individual dose reconstruction.

The IRH (St.-Petersburg) has developed the following method for individual dose reconstruction: correlation between the total I-131 radioiodine incorporation in thyroid and whole body Cs-137 content during first months after accident. The individual dose reconstruction is also mentioned to be performed using the data on individual milk consumption during first weeks after accident. For evaluation of average doses it is suggested to use the linear correlation: thyroid dose values based on radioiodine thyroid measurements vs Cs-137 contamination, air kerma rate, mean I-131 concetration in the milk. .

The method for retrospective reconstruction of thyroid dose caused by short-living iodine nuclides released after the Chernobyl accident has been developed by Research Centre, Juelich, Germany. It is based on the constant ratio that these nuclides have with the long-living I-129. The contamination of soil samples by this nuclide can be used to assess thyroid doses. First results of I-129 contamination values and derived thyroid doses are to be presented.

1. Introduction

At present time about four hundred thyroid cancer cases among children and adolescents (of this age at the moment of irradiation) have been stated in the regions of Belarussia and Russia. These areas suffered the contamination caused by the reactor accident of Chernobyl. The observed increase in the number of thyroid cancer incidents have to be explained. Therefore it is necessary to determine the radiation exposure in the first few weeks after the accident.

The special interest to the thyroid organ is caused by the fact that its cancer probably derives from the radiation exposure by the short living iodine nuclides (I-131 to I-135; longest half life 8.04 d) and high radioiodine releases which was significantly higher than Cs-137 release.

A lot of radiation measurements (thyroid and whole body burden, environmental) have been done beginning after the reactor accident until now including about 160 000 thyroid burden determinations in Belarussia and Russia. These data may be used for dose calculations and for development of the models of the retrospective dose estimation. Before the data can be used for any calculations, they have to be carefully validated in some way.

There are also many settlements for which no radioiodine measurements are available. Fore these sites retrospective dose assessments have also to be realised. Such retrospective calculations may be based on the determined ratio of I-131 to Cs-137 contamination of the soil. Unfortunately there are only a small number of settlements with known I-131 contamination data. One of the possible ways to estimate I-131 contamination is to use the data on I-129 contamination. So the special program of I-129 measurements in the soil must be developed. The net I-129 contamination has to be taken into account because there are also I-129 contaminations due to the atmospheric atomic bomb tests, the value of which is not very well known; but both are very low. Further considerations on the error of such assessments have to be included into the calculations.

This means retrospective dose assessment is a wide field using empirical, half empirical and more or less pure theoretical calculations. In the frame of ECP 10 such investigations are done. The results are described in this report.

2. Thyroid dose reconstruction modelling on the base of the results of radioiodine thyroid content measurements vs soil radioactive contamination data.

2.1. According to the data of the Institute of Experimental Meteorology (SPA "Typhoon", Obninsk, Russia) released I-131 activity to the atmosphere from the Chernobyl accident is estimated about $6{,}3 \cdot 10^{17}$ Bq and it was much higher than released Cs-137 activity.

As distinguished from uniform caesium distribution in body about 30% of I-131 intake accumulates in thyroid. Thus it is obvious to state that after the Chernobyl accident thyroid exposure to population was one of the main factor or radiation safety due to the short living radioisotopes of iodine (mainly I-131).

By September 1995 about 400 thyroid cancer cases among children up to 14 years old were revealed in Republic of Belarussia (1) and 62 cancer cases among children and adolescents up to 18 years old at the time of irradiation - in Russia (2) (Bryansk , Kaluga and Tula oblasts, mainly in Bryansk). The observed increase in the number of childhood thyroid cancer incidents in these countries and Ukraine as well needs yet to be severely explained. But it doesn't contradict to the hypothesis of radiation causation of cancer, which is being confirmed indirectly by ascertained correlation between the weighed number of cases and average thyroid dose in the groups of the settlements (2).

Thus the dosimetry aspects in epidemiological studies have special importance.

2.2. First of all these aspects of the dosimetry investigations are aimed to clarify the individual thyroid dose estimates, calculated on the basis of direct thyroid measurements of people, and also to assess the average thyroid doses to the residents in any settlement independently whether the residents had been measured or not.

At the same time it should be taken into account that total number of the people with thyroid dose calculations based on the direct measurements of appropriate quality in Belarus and Russia is approximately 160 000. This number includes:

- 130 000 - in Belarus (3);
- 30 000 - in Russia (28 000 in Kaluga oblast (4) and 2 000 in Bryansk oblast (5)).

It is possible to estimate mean thyroid doses on the basis of these data for some settlements where representative number of direct measurements were made in May and at the beginning of June 1986 .

However much more contaminated settlements were without thyroid radioiodine content measurements. For inhabitants of these settlements the thyroid dose reconstruction can be done on the basis of ascertained tendencies of thyroid dose formation. The tendencies were revealed due to comparison of known average thyroid doses for adult population (D_{jx}) in the settlements with I-131 ground deposition densities (q_{jx}) in the vicinity of the respective settlements (j), located in area (x) (6,7). The calculations for other age groups can be done by known age dependencies.

Matching D_{jx} to q_{jx}(I-131) and the following estimation of the unknown doses on the basis of available I-131 ground deposition density in accordance with the ascertained tendencies is the best way. Unfortunately the data on I-131 ground deposition density practically are lack for Russia and are not enough for Belarus.

The most simple, reliable and accessible way is to use the available data relating to Cs-131 ground deposition density. But direct Cs-137 data usage can result in additional uncertainties because the ratio of I-131 to Cs-137 activity in the Chernobyl fallout's were able to vary in wide range. The main reasons for it are the distinction in physical-chemical properties of iodine and caesium as well as the distinction in time of fall-out for different parts of Belarussia and Russia.

I-129 (half life $16 \cdot 10^6$ years) has just the same chemical and physical (excluding the different half life) properties as I-131. Thus it is possible to accomplish the results with less uncertainty when one calculates q_{jx}(I-131) using q_{jx}(I-129) rather then q_{jx}(Cs-137). However the correct determination of average I-129 ground deposition density q_{jx}(I-129) even in the vicinity of one settlement is rather complicated technical task. Resolving this task by traditional techniques such as neutron - activation analysis and accelerator-mass spectrometry requires a lot of time and expenses.

Thus the solution of the task to determine the values of unknown thyroid doses on the basis of q_{jx}(I-131), or q_{jx}(Cs-137), or q_{jx}(I-129) has both the advantages and disadvantages.

2.3. More than 160 000 thyroid radioiodine content direct measurements for 350 settlements in some rayons in Belarus as well as for 62 settlements in three rayons in Kaluga and Bryansk oblasts in Russia were used for ascertaining the tendencies in thyroid dose exposure to population after the Chernobyl accident. Besides the mentioned data the values of ground deposition density of Cs-137 and I-131, which had been measured by specialists from Goscomgydromet of Russia and Belarus, Institute of Nuclear Physics (Minsk) (8), Institute of Biophysics (Moscow) were used in the analysis.

On the basis of this information the dependencies of D_{jx}/q_{jx} versus q_{jx} were drawn with grouping of the settlements (6).

The analysis of this sort of dependencies for all the available groups of settlements in Belarus and Russia showed that as a whole they can be approximated satisfactorily with the formula:

$$D'_{jx} = C_0 \times R_x \times q_x(\text{Cs-137}) + B_0 \times R_{jx} \times q_{jx}(\text{Cs-137}) \qquad /1/$$

where: D'_{jx} - calculated average thyroid dose for adults in area (x) and in the settlement (j), Gy; q_x(Cs-137) and q_{jx}(Cs-137) - average Cs-137 ground deposition density, respectively in area (x) and in the settlement (j), $\text{Bq} \times \text{m}^{-2}$; $R_x = (q_I/q_{Cs})_x$ and $(q_I/q_{Cs})_{jx}$ - average ratio of I-131 to Cs-137 ground deposition density, respectively in area (x) and in the settlement (j), rel.unit;

$C_0 = 3.6 \times 10^{-8}\ \text{Gy} \times \text{m}^2 \times \text{Bq}^{-1}$;

$B_0 = 1.3 \times 10^{-8}\ \text{Gy} \times \text{m}^2 \times \text{Bq}^{-1}$.

Equation /1/ is just for the groups of the settlements, located in selected areas. Each of these selected areas is characterised with approximately the uniform radionuclide concentration in radioactive cloud during the main deposition.

The following assumptions have been done:

1). Peculiarities of radioiodine intake by residents in the settlement (j) were absent. (Such kind of peculiarities as life style; relationship between levels of milk consumed from private cows and from shops; taking pills of potassium iodide; pasture period of cows and so on.)

2). The same level of standing of crop biomass.

3). The absence of essential contribution to the total activity of the fallout on the part of the radionuclides containing in the fuel parts of fallout.

Any deviation from typical variant is taken into account by inserting the additional coefficients.

Distinctions in the levels of standing of crop biomass, interception abilities of vegetation, feed intake rates and fractions of cow's intake from pasture grass are taken into consideration by inserting to formula /1/ the special coefficient too.

The most correct assessment of the values of D'_{jx} on the basis of q_x and q_{jx} can be reached in the case of adequate selection of areas (x), when each of these selected areas is characterised with the approximately uniform radionuclide concentration in radioactive cloud during the main deposition. As first step it was suggested that area (x) coincide with administrative rayon.

The parameters R_x and R_{jx} in the eq. /1/ are very variable among the others due to the distinction in physical-chemical properties of iodine and caesium and distinction in time of fall-out between different contaminated spots. That is why the data relating to I-131 and Cs-137 content in environment especially in milk, grass, and soil are of great importance. Unfortunately such data are available only for some settlements in Belarussia. There are not so much data for the settlements in Russia.

The missing data can be restored by analysing I-129 and Cs-137 content in soil samples and following assessment the values of ratio of q_{jx}(I-131)/q_{jx}(Cs-137) on the basis of estimated values of ratio of q_{jx}(I-129)/q_{jx}(Cs-137). It must be noted that for calculations we need most correct estimation of the ratio of I-129 to I-131 in Chernobyl reactor at the moment of accident.

At present time the traditional techniques for analysing I-129 content are the neutron-activation analysis and accelerator-mass spectrometry. However due to their high cost it is desirable to develop more cheap method. With this purpose the techniques of beta-x-ray coincidence may be used together with iodine extraction from the sample. This method provides the detection limit for I-129 not less than 10^{-3}

Bq/sample. The sensitivity of the method can be increased by using the greater amount of soil.

2.4. Individualised doses D'_{ijx} of internal thyroid irradiation for resident (i) living in settlement (j) located in territory (x) are reconstructed according to the following relationship:

$$D'_{ijx} = D'_{jx} \times k_i \qquad /2/$$

where D'_{jx} - see /1/ , k_i - is an age coefficient.

The value of the k_i coefficient depends on the age of individual (i) and his daily consumption of unskimmed milk during the early period after accident.

For persons who were not consuming milk are used k_i values corresponding to the zero milk consumption (inhalation intake only).

For persons in whom the information on milk consumption is unknown are used the k_i values that correspond to the values of mean daily milk consumption taken for different age groups. The values of k_i coefficient are presented in (9).

It was assumed that the concentration of radioiodine in consumed milk was similar for different persons in the settlement. It was taken into account age differences in mean daily milk consumption, breath speed, mass of thyroid gland and the speed of radioiodine turnover (7).

With the purpose to retrospectively evaluate individualised doses in persons a special questionnaire has been devised. The questionnaire helps to take into account the following factors related to the period from 26 April to 15 June 1986 influencing the value of the evaluated dose, age of an examined person, duration and time of stay in the zone of radioactive contamination, regimen of life in that period, protective measures, daily consumption of unskimmed milk, the beginning of the pasturing season in the locality. The data for infants and those exposed to radiation when in uterus are found by the mother's questionnaire (the data on breast-feeding are included). In this case thyroid dose in a child is estimated using the data of his mother by the relationships presented in (10).

2.5. The Table 1 presents the thyroid doses for adults calculated using semiempirical model /1/. Age dependence for estimation of children doses was taken from (9). The parameters q_x, q_{jx}, R_x, R_{jx}, were estimated basing on data of (11). The values of R_x, R_{jx} correspond to 1 May, 1986. The calculations relate to Nikolaevka settlement of Krasnogorsky rayon and to Novozybkov settlement of Novozybkov rayon (Bryansk oblast). It was supposed that areas (x) in /1/ coincide with administrative territories of Krasnogorsky and Novozybkovsky rayons. No countermeasures and no departure of inhabitants took place.

As it follows from Table 1 the dose values for age 3-6 years old are close to the corresponding estimations from (5) for the levels of the settlements contamination by Cs-137 in the range 570-2800 kBq/m².

Table 1. Results of the retrospective thyroid dose calculation according semiempirical model /1/ for settlements in Bryansk oblast.

Rayons	Settlements	Parameters of the model /1/				Thyroid doses by /1/, mGy			Thyroid doses by (5), mGy
		q_x, kBq/m²	q_{jx}, kBq/m²	R_x	R_{jx}	age <1 yr	age 3-6 yrs	adult	age 3-6 yrs
Krasnogorsky	Nikolaevka	460	2800	7	7	2800	1800	370	2150
Novozybkovsky	Novozybkov	640	570	7	7	1600	1000	210	750

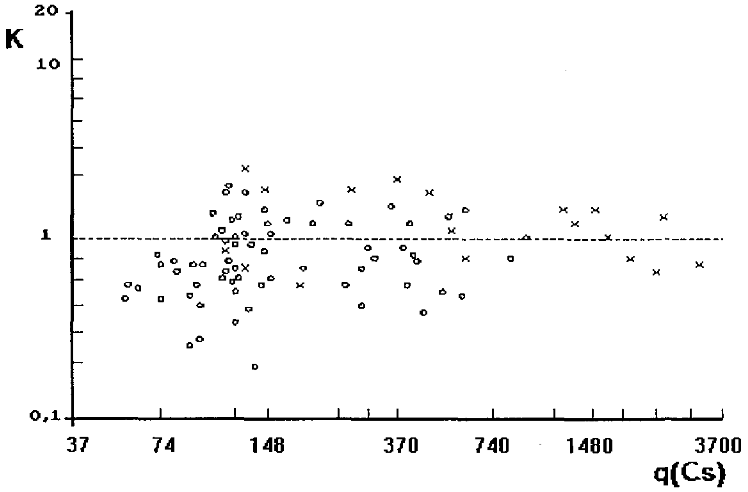

Fig 1. K = D_e/D_c - ratio of the empirical dose values, D_e, to the results of calculation according model /1/, D_c ; q(Cs) - Cs-137 contamination of the settlements, kBq/m^2. Circles - data for Bragyn rayon, crosses - data for Krasnopolsky rayon in Gomel and Mogilev oblasts of Belarussia.

It is interesting to compare the results of calculation according model /1/ with empirical values in the wide range of contamination levels. The comparison of the dose calculation performed using model /1/ with empirical estimations based on the radioiodine thyroid content measurements is presented on the Fig. 1.

It is a evident from Fig. 1 the proposed semiempirical model /1/ obviously brings the results of calculations close to the empirical values.

2.6. The developed semiempirical model /1/ was used for evaluation of mean dose values in inhabitants of every Russian settlements having Cs-137 contamination more then 3,7 kBq/m2.

Overall collective thyroid dose in 3,674,000 residents of contaminated territories of 8 oblasts of Russia (Bryansk, Tula, Kaluga, Orel, Riasan, Kursk, Leningrad) is estimated as 234,000 person·Gy (only due to internal irradiation by radionuclides of iodine) (12).This collective dose may cause about 700 cases of radiation induced thyroid cancer for all period of life after irradiation. The highest values of collective dose are in Bryansk and Tula regions, where expected numbers of radiation-induced thyroid cancer cases are about 280 and 270, respectively. The majority of cancer cases belongs to those who were children and adolescents in April-May 1986 (2).

The linear correlation is established between thyroid doses and rates of thyroid cancer cases diagnosed by the end of 1994 in children and adolescents of Bryansk oblast (12).

The retrospective evaluation of individual thyroid doses was performed in 30 of 49 cases of thyroid cancer found in those residents of contaminated territories of Bryansk oblast who were children and adolescents in April-May 1986 (2).

In 14 of 30 cases (47%) the most probable values of individual doses ranged from 200 to 2700 mGy. In the rest cases (53%) the most probable values of individual doses were 50 mGy or less. The attention attracts the fact that the typical distribution of individual doses is different for overall population of children residing in contaminated territories but not having the diagnosis of thyroid cancer: the majority of children have relatively low doses, less than 200 mGy, and the minority - the doses 200 mGy and more (4,5).

3. Dose reconstruction modelling vs parameters of radioactive contamination, milk consumption and Cs-137 WB content.

3.1. The problem of thyroid dose reconstruction for inhabitants of contaminated regions who were not measured on I-131 content in thyroid in May-June 1986 have been solved in two stages. At first, average doses for inhabitants of different age groups in a studied settlement, then individual doses based on average values were determined (5).

It was used linear proportional model for regression analysis of connection between the mean thyroid dose in the age group 3-6 years and different parameters of radioactive contamination of the environment in settlement (surface Cs-137 activity on soil, kerma rate in the air on May 10-12 1986, mean I-131 concentration in milk on May 10-12). The results of this linear regression analysis were used for the reconstruction of the mean dose in settlements. Dose values for regression analysis were calculated from the direct measurements of radioiodine content in inhabitant's thyroids in May-June 1986. Besides, the correlation between the average thyroid dose and the average Cs-134,-137 whole-body content in adult measured in July-August 1986 was studied.

It was shown (5) that the connection between parameters was reliable in all cases: correlation coefficients were within the range from 0.86 to 0.95 (number of measured pairs for each correlation dependence were from 6 to 13). The difference in the linear regression coefficients for Cs-137 soil contamination and the kerma rate in air in Bryansk oblast is less than 50 % comparatively with Tula oblast.

It was found from analysis of connection between the thyroid dose and the Cs-137,134 content in the whole body that it should be better to consider the Bryansk and Tula regions separately, presumably because of the difference in transfer coefficients from soil into plants. The regression equation obtained for the Bryansk region can be applied to the areas with poor "podzol", peat and sandy soils, and the equation for the Tula region - for the areas with "chernozem" soils.

The regression equations provide estimates of the maximum thyroid dose in the absence of protective actions. For each settlement the package of the countermeasures performed there was analysed. Finally the dose was evaluated by comparison of values obtained with different regression equations taking into account the reliability of initial parameters and introducing the correction for the performed countermeasures. The accuracy of final mean values was assumed not worse than 50%.

3.2. As far as the dose in thyroid of inhabitants was formed basically because of consumption of contaminated food of local produce, it is natural to suppose that the individual dose is proportional to the amount of the consumed milk - the basic source of the I-131 intake in the human body.

To check this suggestion the results of the thyroid control in May 1986 and the data of the poll on the nutrition regime were analysed for about 600 inhabitants of the Bryansk region. The dependence of individual dose in thyroid on the daily milk consumption appeared statistically reliable with the correlation coefficient within the limits of 0.6-0.8 for all age groups.

One can change over from the mean age dose in the settlement D (mGy) to evaluation of the individual dose D_i on the basis of these data, if the information on individual V_i (l/day) and mean V (l/day) consumption of milk of local produce in the specified age group, on the duration of its consumption by the given person t_i (days) and on the average in the village t (days) is present, with the help of the formula:

$$D_i = D \times [2 + 8 \times V_i \times t_i/(V \times t)] \qquad /3/$$

Such method for evaluation of the individual dose can be applied to groups of persons with similar behaviour and nutrition modes after the accident. If in the settlement people consumed milk from different sources (from private ownership, from a collective milk farm, from a state shop) the correction for the mean ratio of the I-131 concentrations in milk from different sources must be introduced in formula /3/.

The other opportunity of evaluation of individual thyroid dose is based on the correlation between the total I-131 intake in a body (or the dose in thyroid) and the content of caesium radionuclides in it measured later, for instance, in August-September 1986. It was shown that statistically reliable linear connection (r=0.7-0.9) between the total iodine incorporation in thyroid and the caesium content in the body exists for inhabitants of the controlled area of the Bryansk region - children over 3 years and adults, which in the main ceased the consumption of food products of local produce in May 1986 and kept these restrictions during the summer. In this case the individual dose of the I-131 irradiation in thyroid can be evaluated with the formula:

$$Di = K(T) \cdot A_i \text{ ; mGy} \qquad /4/$$

where K(T), mGy/kBq, is the age dependent coefficient, its values are presented in Table 2; T - age, years; A_i, kBq, is the Cs-137,137 content in the whole body of the investigated person in July-September 1986.

It was evaluated that possible deviation of the reconstructed by this way individual doses from the real ones by the factor of 2-3 to the both sides.

Table 2. Coefficients for determination of thyroid dose according eq. /4/.

T, years	3 - 6	7 - 11	12 - 17	>18
K(T), mGy/kBq	8	4	2	1

A retrospective evaluation of the individual thyroid doses for about 60 thousands inhabitants of the contaminated areas of the Bryansk oblast was made on the base of the developed techniques. For 2 300 children from the most contaminated settlements of the Tula oblast the same estimations were made.

4. Reconstruction of thyroid dose following Chernobyl accident on the base of I-129 measurements in the soil.

4.1. To reconstruct retrospectively the radiation dose of the thyroid received by the short-living iodine nuclides, the former concentration of these nuclides in air and food must be determined. This is tried by measuring the soil contamination of the long-living nuclide I-129 which is in known correlation with the short-living iodine nuclides produced in the nuclear reactor. Parallel to the experimental investigation of the soil activity a computer- aided model has been established to assess the infant thyroid dose. This model is guided along the idea that the I-129 analysis resulting in the determination of the integral soil contamination must be completed by the determination of the uncertainty of the intake function. First results are given.

4.2. Soil samples were taken from undisturbed ground around villages or towns in the western Bryansk region (Russia),which is situated about 200 km north east of Chernobyl. These sites had been selected because in 1986 I-131 contamination were measured in this area. Since the general distribution of I-129 with depth is unknown the soil samples had been divided into 2 cm thick layers. For details of taking soil samples see (13). To determine the I-129 soil contamination caused by

Chernobyl only, one has to subtract the background soil contamination due to atomic weapon test explosions in the atmosphere. Therefore soil samples were taken also from low-contaminated areas similar in the kind of soil and climate. In the background areas the Cs-137 soil contamination was less by three orders of magnitude. The different layers showed an increase of mass with depth; this may be explained by higher densities resulting from the pressure increasing with depth. From each layer of each village 100 g dry soil were used for analyses purpose. This means that for each layer the aliquots are not constant and correction factors had to be introduced with regard to the mean mass of all layers. The radioactivity, mainly of the nuclide Cs-137, was determined by gammaspectrometry. According to the radioactivity content of the samples the measuring time changed from 5 to 900 minutes. The concentrations of I-129 and I-127 have been measured by neutron activation analysis.

To assess the uncertainty of the intake function three theoretical cases have been modelled for different contamination patterns resulting from different time-dependent contamination and precipitation rates. All these patterns are based on the same total amount of deposited activity per square meter. For the total grass activity a value of $3\cdot10^5$ Bq/m^2 has been derived from measurement performed in the contaminated regions of Bryansk in 1986 (14). From the three differential contamination patterns corresponding intake functions have been evaluated. This function describes the time-dependent intake of short-living iodine nuclides via milk consumption. To determine the intake function the time distribution of contamination and intake is necessary, at least for short-living nuclides as I-131. The contamination of milk is directly proportional to the one of grass. The total grass contamination at a specific day was obtained by summing up all the activity deposited until this day minus the amount which has been already vanished. The assessment of the daily thyroid dose, D, of the infants has been performed according to

$$D = F\times(I_{cow} / Y) \times T \times I_{infant} \times g, \text{ Gy/day or Sv/day} \qquad /5/$$

where F represents the contamination of the grass in Bq/m^2 , Y - the yield of grass from the meadow (0.85 kg/m^2), I_{cow} - the grass consumption of the cow (65 kg/d), T - the transfer factor (grass/milk: 3×10^{-3} d/kg), I_{infant} the milk consumption (infant) 0.55 kg/d, g - the thyroid dose factor ($g_{thyr} = 3{,}5\times10^{-6}$ Gy/Bq) or effective dose factor ($g_{eff} = 1{,}1\times10^{-7}$ Sv/Bq). For the first assessments the German values of the parameters are used. Inserting Russian values may lead to some differences in the result.

4.3. For each village or town the normalised depth profiles for Cs-137 are determined including the "background" villages. The mean slope of the background depth profiles is smaller than the other ones. The so-called relaxation length is 7.5 cm in the background areas compared to about 4 cm in the regions contaminated by the reactor accident of Chernobyl. This may be explained by the longer contamination time of the atomic bomb tests. The Cs-137 contamination of the background areas is less by two or three orders of magnitude in regard to the Chernobyl effected regions.

The Cs-137 contamination for each village is calculated from the gammaspectrometrical data, the correction factor and the known area of sample taking. The results are in good agreement either with parts of the Russian average values or with parts of the Russian measurements in the year 1986 (14). The latter one is in general the result of only one measurement at one point near the villages or towns.

Until now, the determination of the I-129 concentration in soil had not been finished (October 1995). There is no clear dependence of the iodine content with depth. However, to draw a general conclusion a much broader data base is necessary. But for two villages the preliminary dose reconstruction will be given.

4.4. In general it can be assumed that contamination of soil or grass may happen only during the passing time of the plume. If the time of contamination is small compared with the effective half life of the regarded nuclide on vegetation, the influence of the time distribution of contamination is negligible. One other parameter, influencing the contamination of grass and in consequence the intake function, is the mechanism of contamination: washout or fallout. The very inhomogenious contamination in Russia and Belarus shows that washout has been the decisive process. Three different contamination patterns have been considered here. In the first case it is assumed that all the activity is deposited at the first day after the accident. Since there is no further contamination during the following days the activity concentration is reduced with time in dependence of the effective half-life of the I-131 on grass ($t_{1/2}$ = 5.9 d, (15)). The grass contamination will decrease continuously and reach half of the initial contamination at the end of the week assuming an effective half life of one week. For the calculation it is supposed here that the deposition takes place at the beginning of each day. The second function represents the case that the activity is contaminating the grass over ten days with the same amount of activity each day. This means a continuous but - due to the decay - sub-linear increase of the activity until day '10', the end of the supposed deposition. In addition to these quite simple assumptions a third function has been used here, namely a hyperbolic- like trend of the activity deposition based on literature data for the time dependence of the nuclide release (16). In this case the first six days show a slight increase of the activity followed by a very steep one until day '10' before again the decay characteristic controls the curve.

The grass contamination resulting from these patterns and the related thyroid dose have exactly the same shape since all parameters in the above equation except the contamination F are constant in time.

A summation of the daily thyroid doses results in an accumulated dose for infantile thyroids. Among the three considered cases the situation is worst for the total activity deposition at the first day. In particular between day '5' and day '10' the thyroid dose for the first case is about 0.3 Gy above the values for the two other contamination patterns (deposition over ten days) which result in nearly identical values for the integrated thyroid dose. In the period of more than 25 or 30 days there is no great difference between the three cases, and an accumulated dose of about 1 Gy has been evaluated by these model calculations which are based on the assumption that no counter- measures have been initiated. A dispersion calculation (17) shows that in these areas there was one main washout contamination during only one day.

The results of these three cases considered demonstrate very clearly that e.g. the prohibition of milk consumption from the contaminated areas would reduce the dose very effectively. In the cases of a contamination over ten days the supply with non-contaminated milk at day '5' would reduce the thyroid dose by about a factor of 5. Even in the worse case of total activity deposition at the first day this countermeasure would let expect a dose of 0.5 Gy instead of 1 Gy.

4.5. This report shall be finished by preliminary results of the retrospective dose reconstruction for the two settlements Novozybkov and Nikolaevka. The I-129 concentration in soil for the town of Novozybkov has been determinated by neutron analyses for the 2 cm layers from 0 to 10 cm depth. For the two layers 6 - 8 and 8 - 10 cm the I-129 concentration has the constant value of about 1 mBq/kg. The soil measurements of the nearly uncontaminated village of Kostenichi for the 0 -2 cm layer gives about the same value, which therefore is regarded as background value.

Subtracting this background the I-129 contamination is assessed to

Novozybkov	0,481 Bq I-129/m^2
Nikolaevka	0,446 Bq I-129/m^2

According to the ratio of $5{,}5\times10^{-8}$ for I-129 to I-131 (17) these values can be converted into a I-131 soil contamination of:

Novozybkov	8,7 (0,603 / 4,76)	MBq I-131/m^2
Nikolaevka	8,0 (3,18 / 25,1)	MBq I-131/m^2

(For a longer working time of the reactor the I-131 soil contamination will decrease). The values in the brackets are Russian measuring values. The first one is a measurement of one single soil sample for each settlement (14) at the 22 May 1986. The dispersion calculation (18) shows that the main contamination by washout happened at the 28 April 1986. The correction for a 24 day decay of I-131 results in the second values of the bracket. This results show that our assessments gives at least the same order of magnitude for the I-131 contamination as the Russian measurements of the soil contamination at the end of May 1986.

According to the very sparse grass vegetation in the contaminated area only 1/10 of the German retention factor (0.33) has been used here for the model calculations which result in the following values for the integrated thyroid doses for infants caused by ingestion of I-131 contaminated food (without counter measurements) :

Novozybkov	1,0 Gy
Nikolaevka	0,9 Gy

5. Conclusion.

5.1. The results of I-131 content measurements in thyroid gland as well as Cs-137 and I-131 soil contamination data, results of I-129 measurements in soil samples were used to develop the different models of reconstruction of thyroid doses for those settlements, where direct estimation were not performed in 1986.

5.2. It must be taken into account that ratio of I-131 to Cs-137 activity in the Chernobyl fallout's was able to vary in wide range. It may be the result of the distinction in physical-chemical properties of iodine and caesium as well as the distinction in the time of fall-outs for different contaminated territories. Very small quantity of available data concerning I-131 contamination can be restored due to analysing I-129 content in soil samples. Then the values of ratio of I-131 to Cs-137 should be assessed on the basis of estimated ratio of I-129 to Cs-137. For correct calculations it is extremely desirable to make a proper estimation of the I-131 to I-129 activity ratio in the Chernobyl reactor at the time of accident.

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