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Research Article

Radioecological modelling of ^{131}I activity dynamics in milk in the central part of Mazovia: reconstruction, verification, reliability assessments*

Oleg Konstantinovich Vlasov[1], Irina Aleksandrovna Zvonova[2], Nataliia Vladilenovna Shchukina[2]

1 *Laboratory of Radiation-environmental Informatics, A. Tsyb MRRC, (Dr.Sci.Tech.), Kaluga, Russia*
2 *P. Ramzaev Research Institute of Radiation Hygiene, Saint-Petersburg, Russia*

Corresponding author: Nataliia Vladilenovna Shchukina (shchukina@nrer.ru)

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Abstract

The work was aimed to the study the ^{137}Cs and ^{131}I transport dynamics along the trophic chain, from the atmosphere to soil, vegetation, dairy cattle, milk, and the human body. This was done with the use of the radioecological simulation model based on instrumental data from the "Warsaw" scenario of the International Atomic Energy Agency's (IAEA) EMRAS project, which were collected after the Chernobyl nuclear accident. The created simulated radioecological model was used for reconstruction of the ^{131}I radioactivity in dairy cattle milk in the Warsaw and Ostroleka areas located in the central part of Mazovia, where the cattle dairy milk radiometry was performed in April-May 1986. The aim of the study was to verify the radioecological model, to assess the reliability and uncertainty of the milk block of the computed model. It was found that the successive account of discrepancies between computed and reconstructed instrumental data of ^{131}I radioactivity dynamics in green fodder on farms in Mazovia areas and the shortage of clean fodder stocks harvest lead to a successive improvement of the agreement between computed and instrumental data of ^{131}I activity in the dairy milk. For all variants of accounting correction the ratio of computed data to instrumental data with recalculated ^{131}I activities in the atmosphere of the Ostroleka Area is on average 2.5–3 times closer to their ideal value of 1 than in calculations with instrumental data for a cloud. The prognostic properties of the computational model at the stage of reconstruction of the specific ^{131}I activity in milk, estimated as the ratio of computed data to instrumental data, can be estimated as 1.05±2.0; the values of these ratios for correction of thyroid radiation doses to the population due to the contaminated milk consumption are estimated as 1.3±2.5.

Keywords

Chernobyl accident, IAEA EMRAS project, "Warsaw" scenario, dynamic agroradioecological model, dairy farms, weather conditions, supply of farms with clean fodder, specific activity of ^{131}I in milk, verification and estimation of model uncertainties, inhalation and feed components of milk contamination, radiobiology, environmental health

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Introduction

This work is the sixth in a series of works by the authors (Vlasov et al. 2019a, 2019b, 2020a, 2020b, 2023) devoted to the study of the dynamics of the transport of ^{137}Cs and ^{131}I radionuclides along the trophic chain: atmosphere – soil – vegetation – diary cattle – milk – human body by dynamic radioecological model (Vlasov 2013a, 2013b) based on “Warsaw” scenario instrumental data of IAEA EMRAS project (Krajewski et al. 2008; Bartusková et al. 2009; IAEA 2012).

In the “Warsaw” scenario, for the study objects: 29 localities, 27 dairy farms, 24 dairy counties and two dairy areas: Warsaw Area and Ostroleka Area, the following database of instrumental data for 1986 is presented:

- dynamics of daily specific volume activities of ^{134,137}Cs, of ^{131}I aerosol, organic and gaseous forms in the atmosphere for the period from 16.04 to 02.06., measurements were carried out only in the Central Laboratory of Radiological Protection of Warsaw (milk area Warsaw Area);
- rains meteorological data at 33 weather stations at the times of their actual precipitation for the period from 24.04 to 16.05;
- fallout densities of ^{137}Cs for localities their distribution in dairy counties
- the annual variation of average daily air temperatures from 10.03.86 to 31.09.86;
- measurements of the specific activity of ^{131}I in the grass on the territory of the weather station Warszawa Obserw Astr from 03.05.86 to 18.05.86;
- measurements of the specific activity of ^{131}I in milk from 29.04.86 to 07.06.86 at 7 dairy farms in the Ostroleka Area and at 10 dairy farms in the Warsaw Area.

The database created in previous studies (Vlasov et al. 2019a, 2019b, 2020a, 2020b, 2023) is used in this study to correct the results of the reconstruction, which should increase the reliability of estimates of the specific 131I activity dynamics in milk, body of residents, and ultimately, in estimating the doses of internal radiation to the thyroid gland.

The aim of the study is to verify and assess the uncertainties of reconstructing the dynamics of ^{131}I specific activity in milk in dairy areas of Mazovia central part after the Chernobyl accident.

Materials and methods

The dynamics studies of the ^{131}I specific activity in milk at its sampling points for radiometry in the Mazovia Area are carried out using the cattle unit of the radioecological model (Vlasov 2013b).

The block is a software package for calculating the metabolism of ^{131}I radionuclides in cattle organs by numerically solving a system of linear differential equations for a multi-chamber model (Fig. 1). The coefficients of the model are tuned to experimental data on the dynamics of ^{131}I activities in organs and channels of its excretion from the body of milk cattle with a yield of 12 liters/day (Vlasov 2013b).

Verification of the model and estimation of its uncertainties was carried out based on calculations of geometric means and standard deviations of the ratio of the calculated data to the instrumental data.

To demonstrate the capabilities of this block, a scenario calculation was performed with the input data presented in Table 1.

Table 1. Multi-camera model parameters

parameter	Mazovia, Warsaw Area
fallout start time	2.4 days
grazing start time	25 days
cattle keeping mode	pasture
Time of transfer to clean feed	45 days
milk yield	11.6, l/day
green fodder consumption	50, kg/day

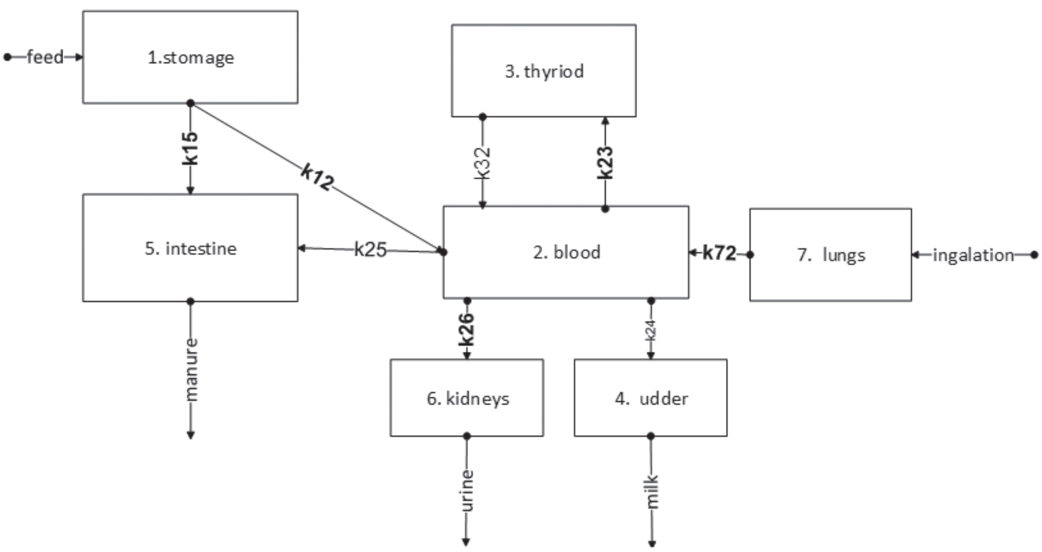

Figure 1. “Iodine” cow model (Vlasov 2013b).

An example of the dynamics of ^{131}I activities in the organs and excretion channels of cattle in the central part of Mazovia with the input data of Table 1 is shown in Fig. 2.

It can be noted from the features in Fig. 2 data, that in the calculated scenario, cattle grazing on pastures begins only 25 days after the accident. The first two maximums of milk activity during the main precipitations are due to inhalation, and the second one, about 10 times larger, with a maximum on the 28th day, due to contaminated grass pastures consumption.

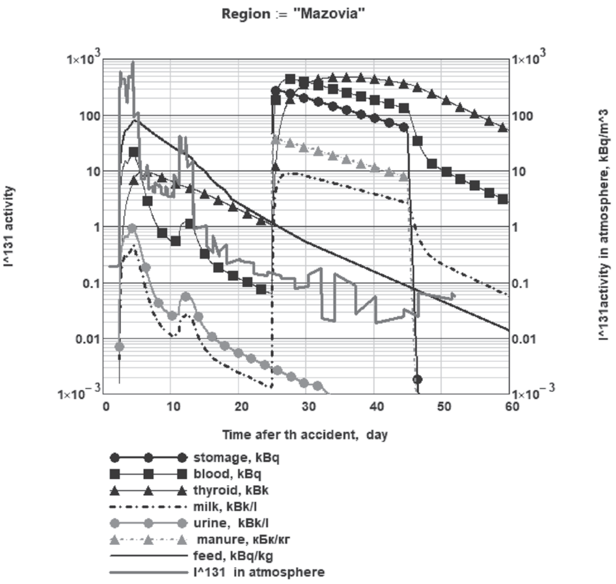

Figure 2. ^{131}I activities dynamics in the organs and channels of excretion of milk cattle breeding in the spring in the year of the Chernobyl accident in the Mazovia central part (Vlasov et al. 2020b).

The rapid decline in the ^{131}I activity in all organs and channels of its excretion from the body firstly begins after the transfer of cattle to clean feed on the 45th day. In two days, the milk activity decreases by 5 times. The activity decrease rate in all organs remains constant in accordance with the iodine radioactive decay. The slow component of its excretion rate from the thyroid gland, for times longer than 50 days.

Studies of the ^{131}I activities dynamics in milk was carried out using the radioecological database created in (Vlasov 2013a; Vlasov et al. 2019a, 2019b, 2020a, 2023) for dairy farms and milk counties in the Warsaw Area and Ostoleka Area milk areas, in which milk samples were taken for ^{131}I radiometry:

- the start time of cattle grazing calculated in the agro-climatic block of the simulation model (Vlasov et al. 2020a) according to two conditions: the average daily air temperature for several days should be above 8 °C, the biomass density of fresh pasture grass should be greater than 0.4 kg/ m^2, equals to 2 days;
- effective rains values for the major fallout period in the dairy farms area, consistent with instrumental data of dynamics of ^{137}Cs activity in the atmosphere and its fallout densities by (Vlasov et al. 2019a, 2019b, 2020a);
- reconstructed “instrumental” dynamic data of ^{131}I specific activities in the cultivated pastures grass, consistent with the database of effective precipitation and the activity of ^{131}I radionuclides in the atmosphere (Vlasov et al. 2023);
- the residuals values (the ratio of calculated to “instrumental” data of ^{131}I specific activity in the cultivated pastures grass) (Vlasov et al. 2023).

All calculations were performed using three variants of atmospheric parameters: direct calculation, homogeneous cloud, and heterogeneous precipitation.

Direct calculation: for all settlements in the region (the area where instrumental data on radionuclide activity dynamics in the atmosphere were collected), instrumental data on ^{137}Cs and ^{131}I activity dynamics and their phases of existence in the atmosphere are used. The meteorological data on precipitation at weather stations nearest to the settlements during the period of major precipitation as well as are used.

Homogeneous cloud – heterogeneous precipitation: Spatial uniformity of specific radionuclide volume activities in the atmosphere over the region – heterogeneous effective precipitation at settlements. The precipitation at settlements with constant intensity during major precipitation, reconstructed from instrumental 137Cs data in the atmosphere and precipitation densities at settlements.

Heterogeneous cloud – homogeneous precipitation: The heterogeneous cloud region includes all settlements within the area covered by the nearest weather station. For each locality in this region, data from this meteorological station regarding precipitation during the period of significant precipitation is used. The dynamics of specific radioactivity in the atmosphere above each location is normalized based on the precipitation intensity, expressed in terms of ^{137}Cs density.

Results and discussion

Estimates of the contaminated feed relative share in the diet of cattle in the districts of the central part of Mazovia

According to the “Warsaw” scenario, most private farms in the milk areas of Ostroleka Area suffered from a shortage of uncontaminated feed from last year’s harvest and the diet of milk cattle partially included freshly harvested contaminated green feed. Green fodder was included in the milk cattle diet only at half of farms on average for the period from 1.05.86 to 20.10.86.

The data on gross milk production, the forage lands structure, as well as data on ^{137}Cs fallout densities and rains for the major fallout period calculated from weather station data are presented in scenario for Warsaw Area and Ostoleka Area.

This information, as well as the calculated data of the dependences on rains of cultivated pasture grass specific activity during the main fallout, given in (Vlasov et al. 2023), were used to estimate the relative proportions of contaminated milk in the milk counties (δ^k_{milk}) in which its ^{131}I specific activity was measured. Estimates of δ^k_{milk} for the k-th district were carried out according to the following ratio:

$$\delta^k_{milk,j}(R^k_j) = \frac{\left[I^k_{inh,j} + \delta^k_{diary} \cdot I^k_{grf}(R^k_j)\right]}{\left[I^k_{inh,j} + I^k_{grf,j}(R^k_j)\right]}, \quad (1)$$

where
j is the calculation model: 1 – direct calculation, 2 – inhomogeneous cloud, 3 – homogeneous cloud;
δ^k_{diary} – the farms fraction in the district that does not have stocks of clean feed in May 1986, it is assumed that it corresponds to the average proportion of contaminated feed in the diet of cattle in the dairy district,
$\delta^k_{milk,j}$ – the radioactive fraction of milk produced in the milk county,
R^k_j – average rains for the rains major period used in the j-th calculation model, mm;
I^k_{inh} and I^k_{grf} – ^{131}I specific activities integrals in milk due to inhalation and contaminated green feed, (kBq/kg)*day; here

$$I^k_{inh,j} = I^0_{inh,j} \cdot \begin{cases} \frac{kCl^k_{j=2}}{kCl^0_{j=2}} \\ 1, j = 1,3 \end{cases}, \quad (2)$$

$$I^k_{grf,j}(R^k_j) = Q^0_{grf,j}(R^0_1) \cdot \frac{q^{max}_{grf,j}(R^k_j)}{q^{max}_{grf,j}(R^k_{j=1})}, \quad (3)$$

where
kCl^k_j is the conversion coefficient of the ^{131}I specific activity in the atmosphere for the j-th model;
$kCl^0_{j=2}$, I^0_{inh} and $Q^0_{grf,j}$ were estimated using the direct calculation model for the Warszawa Obserww Astr weather station with rains over the period of major fallout, 0.8 mm; respectively, equal to 1.72 , 14.4 (kBq/kg)*day and 696 (kBq/kg)*day; R^k_j – rains in k – milk county, мм.

An example of the radioecological parameters calculation results for the Warszawski Zachodni milk county with the farms proportion without pure feed stocks by the date of the accident equal to 30% is shown in Table 2.

The data in Table 2 and similar results for the other counties show that the specific milk activity integral due to inhalation is 35–40 times less than due to green feed. Accordingly, the radioactive milk fraction in them does not essentially depend on the calculation model. It does not significantly differ from the proportion of farms without stocks of pure feed by the date of the accident.

The results of calculations for other counties in which milk samples were taken for radiometry, shown in Table 3, demonstrate that in the Ostroleka district cattle were fully provided with stocks of pure feed from last year's harvest. Therefore, the contaminated milk fraction in this county is equal to the inhalation component fraction in the total activity in milk. According to the simulation model estimates its value is 2%. In Table 3, together with data on

Table 2. Radioecological parameters for Warszawski Zachodni milk county

Calculation model	kQ^{cloud}	R mm	q^{max}_{grf} kBq/kg	I^{milk}_{inh} (kBq/kg)*day	I^{milk}_{grf} (kBq/kg)*day	δ_{diary} / δ_{milk}, %
direct calculation	1.0	0.8	38	14.4	604	31.6
heterogeneous cloud	3.9	0.8	140.6	56	2230	31.7
homogeneous cloud	1.0	7.8	33.6	14.4	534	31.8

Table 3. Radioecological data for milk counties

Milk Area	milk county	fallout density ^{137}Cs, kBq/m^2			rains, мм		δ_{diary} / δ_{milk}, %	$N_{изм}$
		mean	min	max	R_{meteo}	R_{rec}		
Warsaw Area	Legionowski	4.1	3	7	0	40.1	20/22	24
	Minski	4.5	4	5	0	40.2	30/32	4
	Nowodworski Mazowiecki	3.8	2	6	0	30.2	50/51	5
	Warszawski	4.5	3	6	0	40.7	15/17	28
	Warszawski Zachodni++	6.7	10.5	14	0	70.8	30/31	20
	Wolominski++	5.7	6	8	10	60	30/31	4
	Falenty Duze diary*++				0.8	20.5	0.0/2.0**	8
Ostroleka Area	Ostrolecki++	4.6	3	3.5	0	00.8	50/51	20+
	Ostroleka	4.6	3	3.5	0	0	0.0/2.0**	20
	Piski	3.8	20.5	6	0	00.3	40/40	8
	Przasnyski	3.6	20.5	4	0	00.2	80/80	14
	Szczycienski	4.3	20.5	5	0	00.5	90/90.2	3
	Zambrowski	4.1	20.5	6.5	0	00.4	50/51	7

*-milk farm; + recalculation from farm instrumental data of the Ostroleka Diary of the Ostroleka Area by ratio (4); ++ recalculation from instrumental data of Warsaw Town Diary farm of Warszawski county by ratio (4); R_{meteo} and R_{rec} – precipitation for the major fallout period of 2.2–5.5 days after the accident; ** the proportion of the inhalation route in entry of ^{131}I daily admission into the milk cattle body; $N_{изм}$ – the number of consecutive measurements of milk samples in one place.

the values δ^k_{diary} and δ^k_{milk} the"Warsaw" scenario data on the ^{137}Cs fallout densities structure in the counties, rains meteorological data during the major fallout period and the number of ^{131}I activity measurements in milk at its reception points are also given.

The δ^k_{milk} values were used to adjust the calculated $Q^{C,k}_{cor,j}$ and reconstructed "instrumental" data $Q^{M,k}_{cor}$ of ^{131}I specific activity in milk in the k-th milk county according to instrumental data for the district k0 to the ratios (4) and (5):

$$Q^{M,k}_{cor}(t) = Q^{C,k}_{inh}(t) + \delta^k_{rad} \cdot \left[Q^{M,k0}_{grf}(t) - Q^{C,k0}_{inh}(t)\right] \cdot \frac{\max\left[q^{C,k}_{gr}(t)\right]}{\max\left[q^{C,k0}_{gr}(t)\right]}, \quad (4)$$

$$Q^{C,k}_{cor,j}(t) = Q^{C,k}_{inh,j}(t) + \delta^k_{rad} \cdot \delta^k_{grf} \cdot Q^{C,k}_{grf,j}(t), \quad (5)$$

were

M and C indexes refer to instrumental and calculated data;

j-calculation model;

Q^k_j and $Q^k_{cor,j}$ – direct and adjusted dependences of specific 131I activities in milk;

$q^{C,k}_{gr}$ – calculated data of ^{131}I activity dynamics in pasture grass;

$Q^k_{inh,j}$ и $Q^k_{grf,j}$ – calculated dependences of inhalation and food components of milk contamination;

δ^k_{grf} – corrections for discrepancies of calculated and reconstructed "instrumental" data of specific ^{131}I activities in pasture grass (Vlasov 2013a).

It should be noted here that the range of coefficient values

$$K^k_{cor,j} = \frac{\max\left[Q^k_{cor,j}(t)\right]}{\max\left[Q^k_j(t)\right]} \quad (6)$$

for recalculation of ^{131}I activity in milk instrumental data $K^k_{cor,j}$ according to the direct calculation models of (j = 1) and homogeneous cloud (j = 3) is equal to (0.95–1.05), for heterogeneous cloud (j = 2) is equal to (0.5–1.7).

According to "Warsaw" scenario, the complete clean feed provision was only in the Ostroleka Area county of the Ostroleka Area and on the Falenty Duze diary farm of the Warsaw Area (Table 3). The largest proportion of contaminated milk (90%) was in the Szczycienski county of the Ostroleka Area. On average, in all districts with ^{131}I in milk radiometry, the contaminated milk fraction in the WarsawArea area was 2–3 times less than in the Ostroleka Area. Taking into account that the parameters of the ^{137}Cs fallout densities distributions in these area in these areas practically coincide. These data may possibly explain the peculiarity of the ^{131}I milk activities instrumental data presented in Fig. 3.

The most detailed, more than 10 times, multiple instrumental data on the ^{131}I activity in milk dynamics in the Ostroleka Area counties were obtained for the Ostroleka diary farm, Przasnyski diary, in the Warsaw Area for the Warsaw town diary farm, Legionowski county and Falenty Duze diary farm (Fig. 3).

Note the significant irregularity of the instrumental data for all districts in the all area near their maximum values and the apparent inconsistency between the Fig. 2, Table 2 data and Fig. 3 for the Ostroleka Area.

Firstly, the instrumental data in Fig. 3 for this district, the only one in the Ostroleka Area with 100% provision of clean feed (Table 1), have the same features with the measurement data in all other districts of this area. In all these districts, the provision of clean feed was only partial, and the contamination of milk in them was mainly due to the consumption of contaminated grass pastures.

Secondly, the ^{131}I milk activity at the Falenty Daze farm at the time of the end of the fallout main was 10 times less than in the Ostroleka Area milk county.

This cartographic data is more consistent with the form of instrumental data on the ^{131}I milk activity dynamics for this district, which completely coincide with the form of the Przasnyski district data in Fig. 3b with the value δ_{diary} equal to 80%.

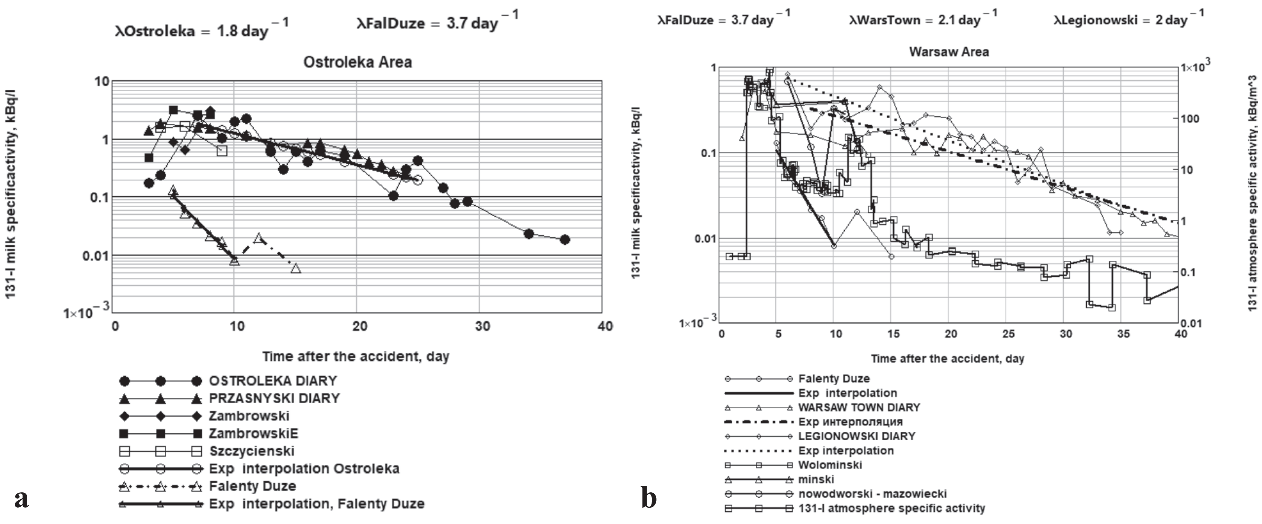

Figure 3. Instrumental data on the dynamics of milk ^{131}I specific activity (Krajewski et al. 2008; IAEA 2012): **a)** the Ostroleka dairy district; **b)** the Warsaw dairy district.

According to the cartographic data of the "Warsaw" scenario (Fig. 4) in the Ostroleka district, the value of δ_ diary was (0.5–0.8).

Considering these discrepancies in the Ostroleka area, an additional test was conducted for this area, in which the average proportion of contaminated feed was found to be 60%.

The results of study of milk contamination dynamics and the radioecological model verification

The ^{131}I milk activities dynamics calculations were carried out for counties for which in the "Warsaw" scenario multiple instrumental data are available. At the first stage, for the Warsaw Area, the following calculations were carried out sequentially for all three variants of input data on rains and ^{137}Cs and ^{131}I activities in the atmosphere:

- calculation without corrections (Fig. 4a – direct calculation);
- calculation which was carried out considering the discrepancies of the calculated and reconstructed "instrumental" green feed ^{131}I activities (Fig. 4b);
- calculation was performed taking into account the share of pure green feed in the diet of cattle in dairy districts (calculation taking into account adjustments for pollution and relative shares of farms (%) in dairy districts that do not have stocks of clean feed, Fig. 4c)
- calculation that was performed taking into account the amendments of paragraphs 2 and 3 (Fig. 4d).

The results of calculations and instrumental data of milk ^{131}I specific activities are presented for the Falenty Duze farm and Legionowski county without considering

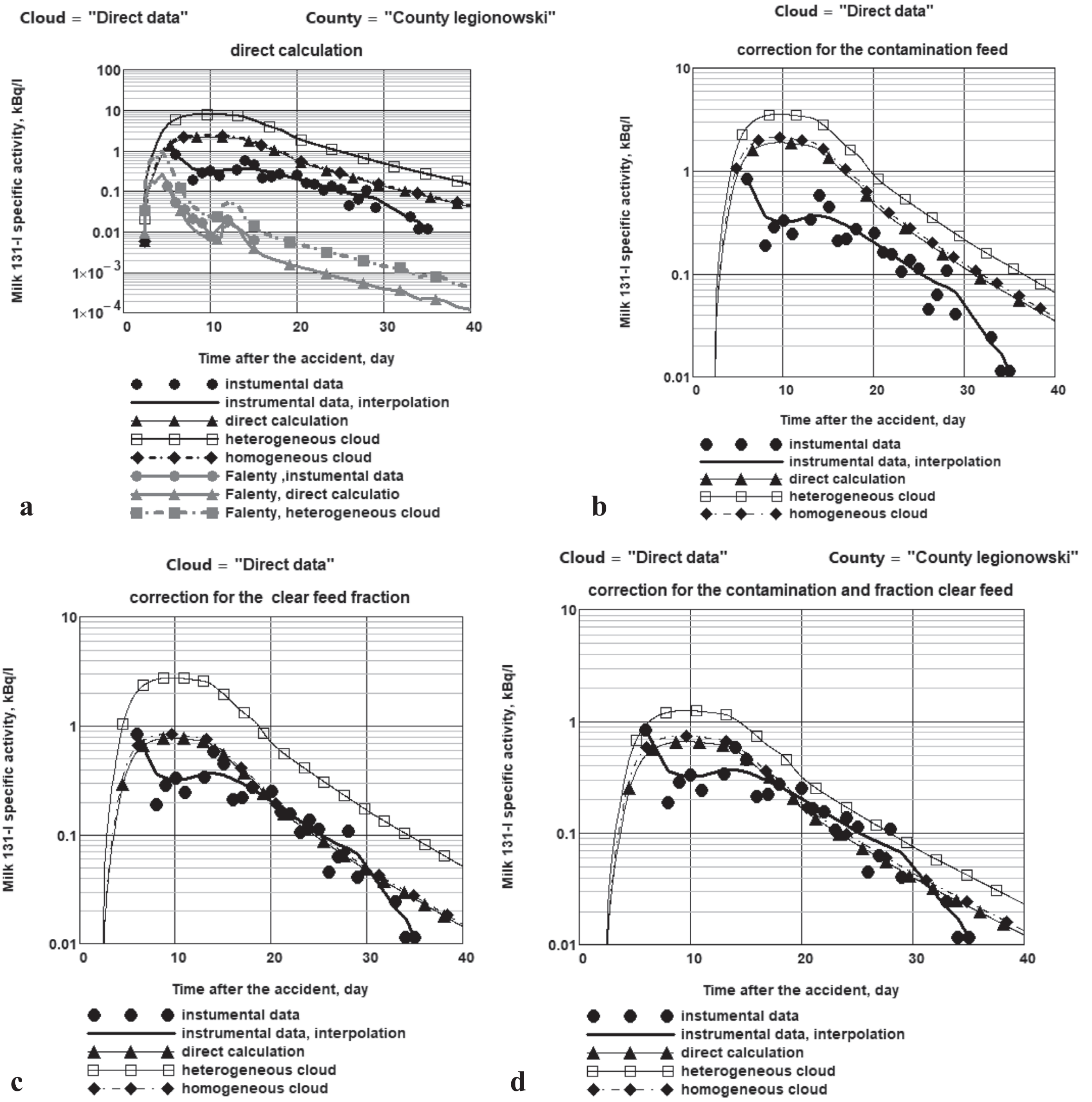

Figure 4. Dynamics of milk ^{131}I specific activity in the Legionowski county of the Warsaw Area and Falenty Duze farm: **a)** calculation without corrections; **b)** calculation which was carried out considering the discrepancies of the calculated and reconstructed "instrumental" green feed ^{131}I activities; **c)** calculation was performed taking into account the share of pure green feed in the diet of cattle in dairy districts; **d)** calculation taking into account adjustments for pollution and pure green feed.

the corrections in Fig. 4a, b for the same district, considering the adjustments for contamination and the contaminated feed fraction in the diet of cattle.

Reconstruction of the inhalation component of ^{131}I intake into milk had performed on the example of instrumental data for Falenty Duze farm whose cattle diet included only pure feed from the last year harvest. It shows that the calculated data on the homogeneous cloud model are quite satisfactorily consistent with instrumental data both according to the statistics of their relations and their form reflecting the details of dynamics of ^{131}I volumetric activities in the atmosphere.

The data in Fig. 4 show that the models of direct calculation and homogeneous cloud give almost the same calculated results. This data has 2.5 times better consistency with the instrumental data than the model of heterogeneous cloud. Moreover, the ratio of calculated data to instrumental ones for their entire series is closer to 1 than in the region of their maximum values. This is probably due to the significant irregularity of the instrumental data near their maximum values.

The dynamics of the ^{131}I specific milk activity in the Ostroleka county studies were carried out, as for the WarsawArea, using three calculation models and in two variants of ^{137}Cs and ^{131}I atmosphere volumetric activity dynamics:

- direct instrumental data of the “Warsaw” scenario obtained in Warsaw city,
- reconstructed “instrumental” data equal to direct instrumental data multiplied by the ratio of the ^{137}Cs “dry” fallout calculated density, estimated in (Vlasov et al. 2019b) from direct instrumental data of its activity in the atmosphere, to its minimum instrumental fallout density.

Instrumental and calculated time dependences of milk specific ^{131}I activities in not taking and taking into account adjustments for contamination and the pure feed part are presented in Figs 5, 6 of Ostroleka and Przasnyski counties. As well as in Fig. 7 in the form of average geometric calculation/measurement ratios histograms for instrumental data of all their series and in their maximum values area.

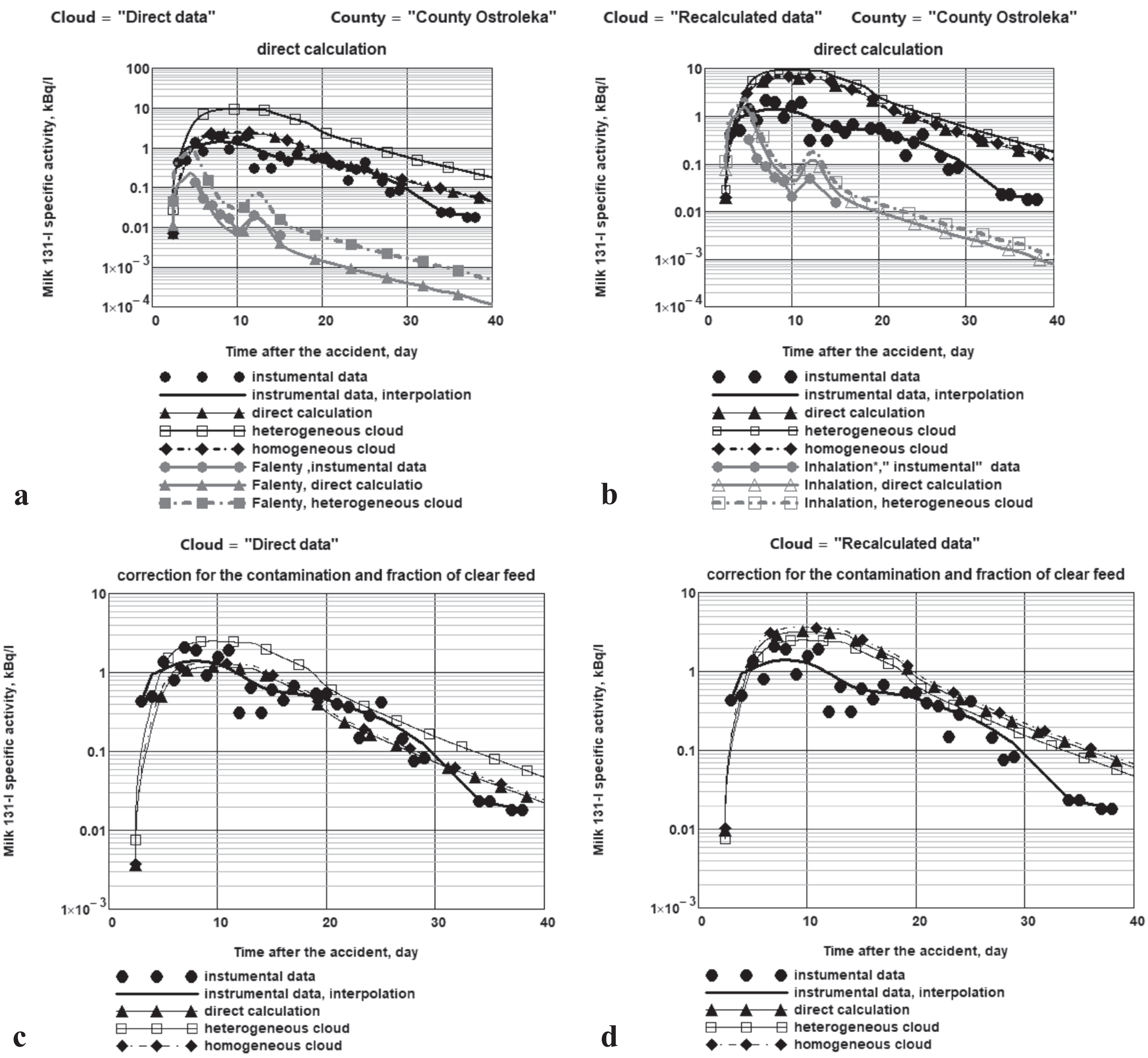

Figure 5. Milk specific ^{131}I activity in the county Ostroleka: **a)** calculation without corrections, cloud – direct data; **b)** calculation without taking into account amendments, cloud – recalculated data; **c)** calculation taking into account corrections for contamination and the share of clean feed, cloud – direct data; **d)** calculation taking into account corrections for contamination and the share of clean feed, cloud – recalculated data.

In (Vlasov et al. 2020a) when creating a mutually agreed database of input data was discussed the variant with the recalculation of specific volumetric activity ^{137}Cs and ^{131}I in the atmosphere over the Ostroleka area. In (Vlasov et al. 2023) this option was further considered in studies of grass pastures contamination dynamics. A comparison of the data in Fig. 5a, b shows the validity of using this variant.

This is confirmed by a better consistency of the calculated and instrumental data of ^{131}I activities in milk in the counties of the Ostroleka Area than in the variant with their direct instrumental data.

Note that the instrumental data for the Przasnyski in Fig. 6 county have a more regular appearance without a dip in the area of 12–18 days, as in the county Osrtoleka in Fig. 5.

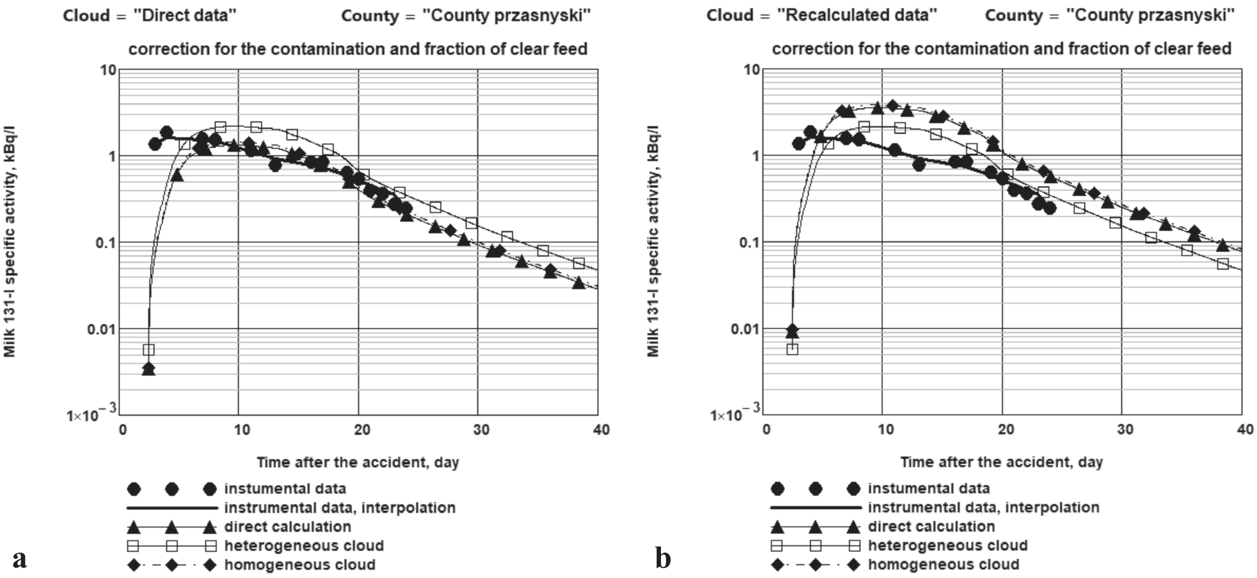

Figure 6. Milk ^{131}I specific activity dynamics in the county Przasnyski: **a)** cloud – direct data; **b)** cloud – recalculated data.

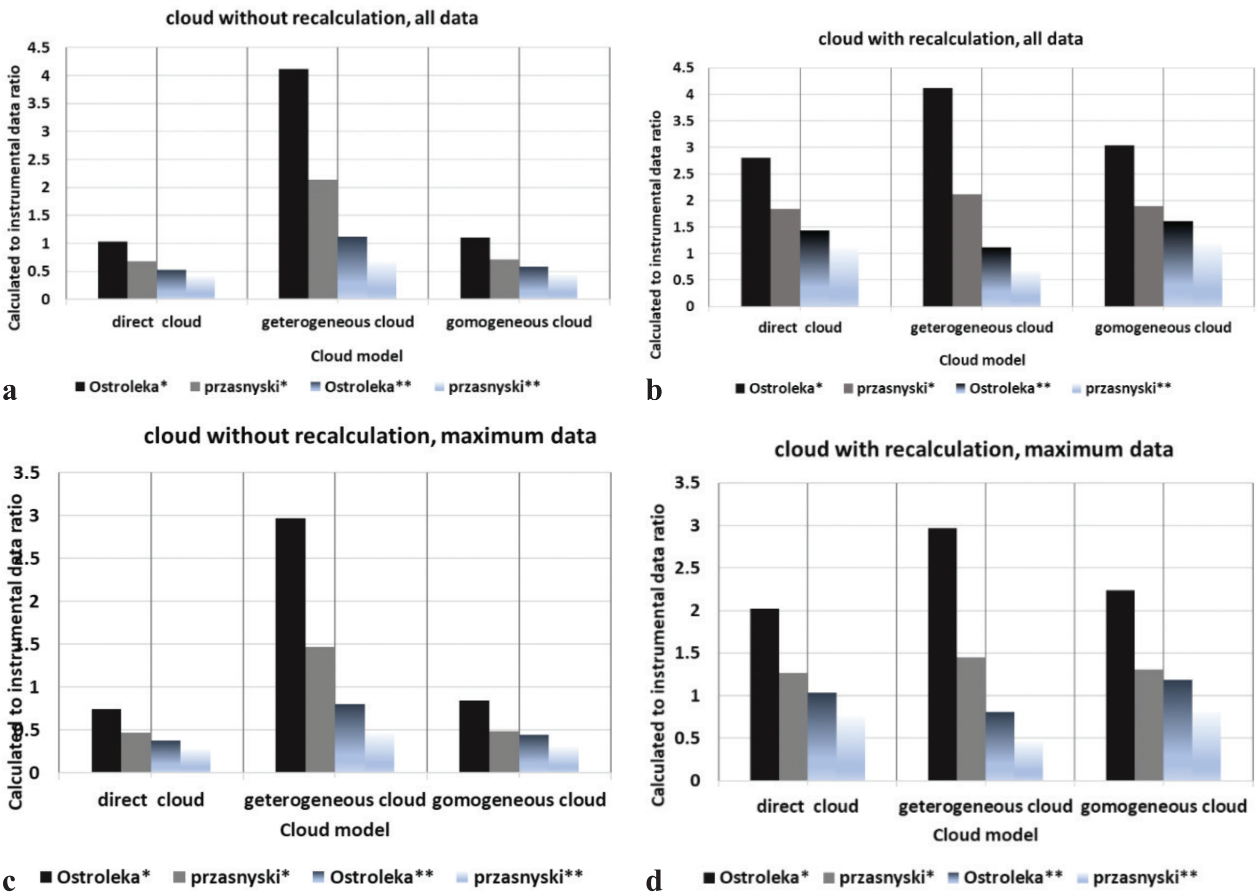

Figure 7. Histograms of geometric mean ratios of calculated data to instrumental ones of ^{131}I activities in milk for the Ostroleka and Przasnyski area: * without amendments, ** with amendments.

The analysis of the calculated and instrumental data comparison showed that the calculated data for Warsaw Area reproduce the instrumental data better after 30 days than for Osrtoleka Area, and worse for times less than 20 days. There is an almost completely satisfactory consistency of the calculated and instrumental data in the range of 20–30 days for both variants.

The improvement in the convergence of calculated and instrumental data with sequential accounting of corrections is characteristic both for all districts of both districts, and for these milk areas in whole (Fig. 8).

Note the main features of the residual errors of the calculated and instrumental data in Fig. 8:

- sequential consideration of corrections leads to an improvement in the convergence of the residual errors to 1, in all three calculation variants;
- the ratio of calculated to instrumental data with recalculated ^{131}I activities in the atmosphere of the Osatroleka Area is on average 0.25–0.3 closer to their ideal value of 1 than in calculations with direct cloud data, for all calculation variants;
- the ratio values for a series of instrumental data in the area of their maximum values are 30% greater, than for their entire series;
- the residuals for the Warsaw Area are 0.2–0.2 5 closer to 1 than for the OstrolekaArea area, in all variants of accounting for corrections.

The standard geometric mean deviations of the residuals in the form of minimum/average/maximum values respectively are equal 1.4/1.8/2.4 for the Ostroleka area, and 1.6/2.1/2.5 for the Warsaw Area respectively.

Thus, the data in Fig. 8 confirm the assumption made earlier in work (Vlasov et al. 2020a) that the specific activity of ^{131}I in the atmosphere of the Ostroleka Area is greater than the data of its measurements in Warsaw city of the Warsaw Area. Thus, according to estimates made on the basis of a comparison of the minimum precipitation densities of ^{137}Cs in these areas, the magnitude of this excess is 2.7 times, and on average it is 2.5–3 according to Fig. 8.

From the physics of radionuclide transfer along the chain: vegetation-cattle organism-milk-human body, it follows that the maximum of activities radionuclides activities in the human body due to their consumption with milk and greens will be directly proportional to their maximum activities. Accordingly, the nutritional component of internal radiation of thyroid and the entire human body along the chain will also be directly proportional to these values. With this in mind, the discrepancy in the form of the ratio of calculated and instrumental data of the specific activities of radionuclides in milk and greens can be used to adjust the calculated data of the integral of their entry into the human body according to the following ratio:

$$I^{cor} = P_{gr} \cdot I^{C}_{gr} \cdot \Delta^{-1}_{gr} + P_{milk} \cdot I^{C}_{milk} \cdot \Delta^{-1}_{milk}, \quad (7)$$

where

I^{cor} is the adjusted total integral of the entry of the activity of radionuclides with greens and milk into the human body, kBq;

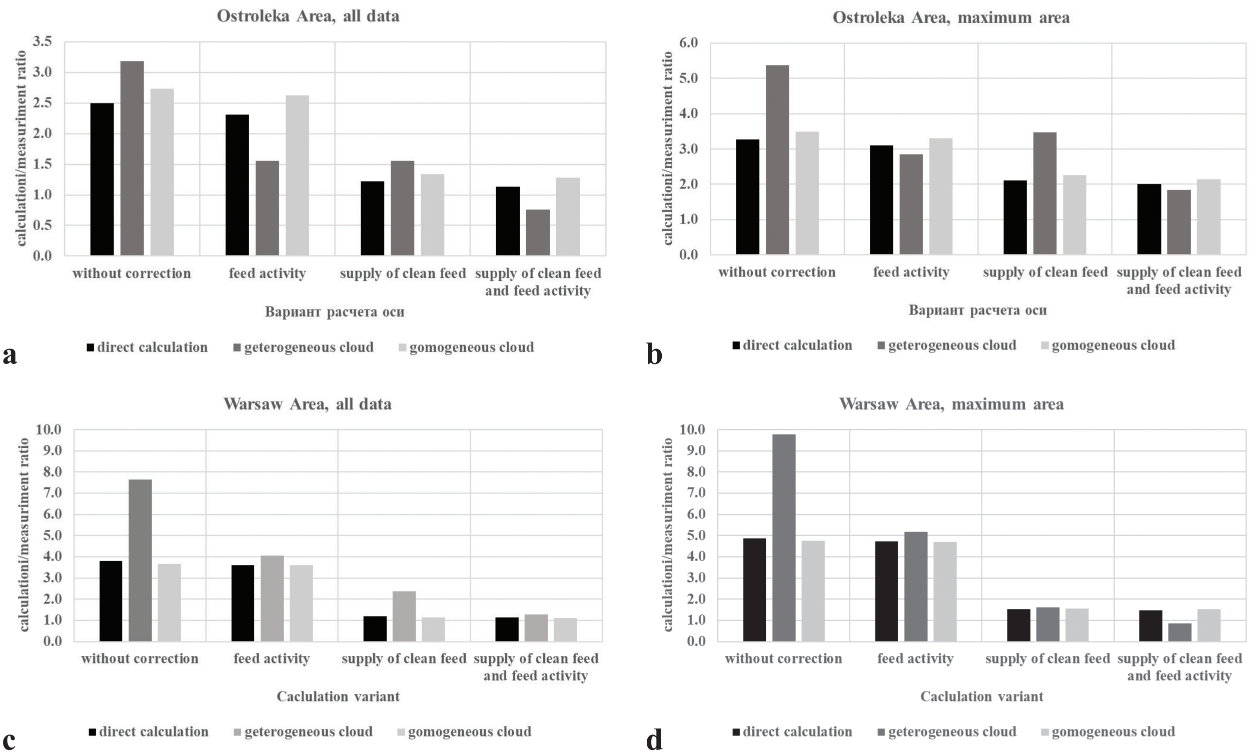

Figure 8. Ratio of reconstructed milk activities of ^{131}I to instrumental data: **a, b)** for the entire measurement area; **c, d)** the maximum values area.

P_{gr} and P_{milk} are daily consumption of greens and milk, kg/day,
I^C_{gr} and I^C_{milk} are calculated integrals of specific radionuclide activities in greens and milk, kBq/kg* day;

$$\Delta_{gr} = \left[\frac{\left(q_{gr}^{\mathrm{dir}}\right)}{\left(q_{gr}^{\mathrm{instr}}\right)} \right]_{\subset_{\max}}, \Delta_{milk} = \left[\frac{\left(q_{milk}^{\mathrm{dir}}\right)}{\left(q_{milk}^{\mathrm{instr}}\right)} \right]_{\subset_{\max}}, \quad (8)$$

Δ_{gr} and Δ_{milk} are discrepancies of calculated q^{dir} and instrumental q^{instr} data of specific radionuclide activities in greens$_{gr}$ and in milk$_{milk}$ in the scope of instrumental data maximum values $\subset_{\max}$.

* – is measured in (Vlasov et al. 2023) as 0.75±1.7.

In general, it can be assumed that the calculated model prognostic properties estimated in the form of standard geometrics means values and standards deviations of the ratio of calculated instrumental milk activity data, can be estimated as 1.05±2.0. The values of these ratios for adjusting the estimates of doses of radiation to the human thyroid, as

$$\Delta_{gr} = 0.75 \pm 1.7, \Delta_{milk} = 1.3 \pm 2.5.$$

Conclusion

The ^{131}I milk activity dynamics in the Mazovia central area was reconstructed. The reliability and uncertainty of the dynamic radioecological model block are evaluated.

The validity of the recalculation of the atmospheric contamination parameters over the Ostroleka area from instrumental data in Warsaw city is confirmed by a better adjustment of the calculated and instrumental data on the dynamics of ^{131}I activities in milk than in calculations without such recalculation.

The main numerical results of the work performed are as follows:

- it was found that consistent accounting for: a) discrepancies in calculated and reconstructed "instrumental" data on ^{131}I activity dynamics in pasture grass, green cattle feed on farms in the districts of Mazovia and b) the clean feed harvest 1985 stocks lack leads to an improvement in the adjustment of calculated and instrumental data of ^{131}I milk activities in for all counties with milk radiometry;
- the ratio of calculated to instrumental data with recalculated ^{131}I activities in the Ostroleka Area atmosphere is on average 2.5–3 times closer to their ideal value of 1 than in calculations with direct cloud data for all variants of accounting for corrections;
- the values of the ratios of instrumental data of the area for this period are 30% greater than for their entire series due to the significant irregularity of instrumental data in the scope of their maximum values in the period 5–15 days after the accident;
- the residuals for the Warsaw Area are 2–2. 5 times greater than for the Ostroleka Area;
- standard geometric mean deviations of the residuals in the form of minimum/average/maximum values are equal to: 1.4/2.4/1.8 for the Ostroleka area, 1.6/2.5/2.1 for the Warsaw Area, respectively;
- computational model prognostic properties at the stage of reconstruction of ^{131}I milk specific activities estimated as a ratio of calculated to instrumental data, can be estimated at 1.05±2.0, and the values of these ratios for adjusting the estimates of doses of radiation to the human thyroid, as 1.3±2.5 due to contaminated milk consumption.

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