CURRENT STATUS OF THE STUDY ON ASSESSMENT OF $^{131}$I SPECIFIC ACTIVITY IN MILK, MILK PRODUCTS, AND LEAFY VEGETABLES BASED ON TOTAL BETA-ACTIVITY MEASUREMENTS CONDUCTED IN BELARUS AFTER THE CHERNOBYL ACCIDENT

M. Savkin$^1$, A. Titov$^1$, A. Lebedev$^1$, M. Germenchuk$^2$, A. Bouville$^3$, N. Luckyanov$^3$

$^1$ State Research Center - Institute of Biophysics, Moscow, Russia
E-mail: msavkin@srcibph.ru
$^2$Republican Centre of Radiation and Environmental monitoring, Minsk, Belarus
$^3$DHHS, NIH, NCI, Division of Cancer Epidemiology and Genetics, Bethesda, MD, USA

Abstract. In 2002, a special study was initiated on the additional collection of total beta-activity measurements in milk, milk products, and leafy vegetables conducted in Belarus in April through June 1986 after the Chernobyl accident with subsequent analysis and assessment of the $^{131}$I specific activity. This study is conducted in the framework of a long-term epidemiological study of thyroid diseases among 12,000 Belarusian children exposed to $^{131}$I in fallout from the Chernobyl accident. Within two months following the accident, a small number of spectrometric (about 160) and radiochemical (about 100) measurements of milk and milk products were made in Belarus, but a very large number (about 40,000) of measurements of total beta-activity were carried out using DP-100-M radiometric devices with gaseous discharge end-window counters as detecting elements. Almost all of the total beta-activity measurements in milk and milk products were conducted by the laboratories of the State Sanitary and Epidemiological Inspection of the Ministry of Public Health and by the laboratories of the Main Agency of Veterinary of the Ministry of Agriculture of the USSR. The ongoing study encompasses all available total beta-activity measurements for Belarus, but this paper addresses only the measurements in Gomel Region, which was the most contaminated area of Belarus. The overall number of total beta-activity measurements (milk, milk products, and leafy vegetables) that were collected from the archives of sanitary and veterinary laboratories of 17 of the 21 districts of Gomel Region is estimated to be 22,834. However, about 40% of measurements in Gomel Region were below the minimum detectable level (3.7 kBq L$^{-1}$) of the measuring DP-100-M device and cannot be used in the analysis. The methodology used to assess the $^{131}$I concentrations in milk, milk products, and leafy vegetables is described. The comparison of the estimates of $^{131}$I concentrations in milk derived from total beta-activity measurements and from spectrometric measurements shows a satisfactory agreement.

1. Introduction

Since 1997, scientists from the National Cancer Institute, together with specialists from Belarus and Russia, have been conducting a long-term cohort study (BelAm) of thyroid diseases among the exposed population. Within the framework of that study, two methods are applied in order to assess individual doses for the cohort subjects. The first method is based direct thyroid measurements, while the second is based on the content of $^{131}$I in the environment and foodstuffs; both methods make use of personal information on residence history and dietary habits. Uncertainties attached to the second method are much larger than those attached to the first method. The second method is however useful as it allows a judgment to be made on the reliability of the responses to personal interviews. In addition, the second method is the only one that can be applied in case-control studies.

The most valuable information for the application of the second method is original data on the content of $^{131}$I in cow’s milk, milk products, and leafy vegetables, which provide the main intake of $^{131}$I by the subjects. Within two months following the Chernobyl accident, spectrometric measurements of $^{131}$I were rarely done, while radiometric measurements of total beta-activity were widely carried out by the Sanitary and Veterinary laboratories of Belarus.

The purpose of this paper is to present the available information on the total beta-activity measurements in Gomel oblast, which was the most contaminated area of Belarus, and to assess the $^{131}$I concentrations in milk.
2. Procedure of total beta-activity measurements

Before the Chernobyl accident, the radiation monitoring of the environment and foodstuffs was performed by the widespread network of the departments of the State Sanitary and Epidemiological Inspection and of the Main Agency of Veterinary of the USSR. They had experience in radiochemical analysis of various radionuclides (including $^{131}$I) in soil, grass, and foodstuffs. The number of annual measurements was as high as several hundred in an Oblast. Unfortunately, before the Chernobyl accident and during two months following the accident, the Gomel and Mogilev Oblast sanitary and veterinary stations did not have any spectrometric equipment. Under the conditions of large-scale radioactive contamination of the territory of Belarus, the use of a rapid method to measure total beta-activity in the samples of foodstuffs was the only possibility to provide radiation monitoring of foodstuffs for the population.

The DP-100-M radiometric device was used to determine the total beta activity of most samples (Fig.1). This device is equipped with a control panel, a lead cylindrical house DS-000, spare parts and supplies.

The walls of the cylindrical house were made of lead. The interior surfaces of the house were covered with aluminum. The detector of ionizing radiation and shelves of organic glass were placed inside the house. The shelves were used to hold the aluminum plate filled with the sample. Three standard geometries of measurement were used:
- plate with outer diameter of 26 mm (d) and height of 10 mm; the distance from the counter window to the sample surface (h) was equal to 10 mm;
- plate with outer diameter of 40 mm and height of 10 mm; the distance from the counter window to the sample surface (h) was equal to 10 mm;
- plate with outer diameter of 40 mm and height of 10 mm; the distance from the counter window to the sample surface (h) was equal to 20 mm.

The detecting element of the DP-100-M was a gaseous discharge end-window counter, either MST-17 or T-25-BFL. These two types of detecting elements have different sensitivities to beta radiation (up to a factor of 2). The efficiency of registration of beta radiation of the detecting element could vary.
according to the thickness of the input window, but such difference was not greater than several percent according to the technical requirements.

The specific activity of the sample was calculated according to the equation:

\[ q = K \times (n - n_{bg}) \]

(1)

where

\[ q \] is the specific activity of the sample, kBq kg\(^{-1}\);
\[ K \] is a calibration coefficient relating the total radionuclide activity in the sample to the count rate, kBq kg\(^{-1}\) cpm\(^{-1}\);
\[ n \] is the count rate from the sample, cpm;
\[ n_{bg} \] is the background count rate, cpm.

According to the Instructions adopted before the Chernobyl accident [1,2], calibration coefficients were derived for fission products less than 1 year old with average beta energy of 0.3 MeV. The calibration coefficient for Geometry 3 that was used used by veterinary laboratories was 1.0 kBq g\(^{-1}\) cpm\(^{-1}\). It was indicated that for samples with other (unknown) radionuclide composition the error in the assessment of the total beta activity might be (150-200) %.

[MS: the unit should be the same; it is kBq kg\(^{-1}\) and kBq g\(^{-1}\) above, and Bq g\(^{-1}\) below]

In April 1992, a calibration procedure was carried out at the Institute of Biophysics for the main radionuclides encountered in Chernobyl fallout. Certified solutions of radionuclides were used for the calibration purposes. The results of the calibration procedure for the three measurement geometries are presented in Table I.

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Geometry 1</th>
<th>Geometry 2</th>
<th>Geometry 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>(^{131})I</td>
<td>1.9</td>
<td>1.2</td>
<td>1.8</td>
</tr>
<tr>
<td>(^{137})Cs</td>
<td>1.3</td>
<td>0.65</td>
<td>0.94</td>
</tr>
<tr>
<td>(^{134})Cs</td>
<td>1.4</td>
<td>0.84</td>
<td>1.2</td>
</tr>
<tr>
<td>(^{90})Sr</td>
<td>0.36</td>
<td>0.20</td>
<td>0.3</td>
</tr>
<tr>
<td>(^{144})Ce</td>
<td>0.15</td>
<td>0.083</td>
<td>0.13</td>
</tr>
<tr>
<td>(^{106})Ru</td>
<td>0.14</td>
<td>0.11</td>
<td>0.15</td>
</tr>
<tr>
<td>(^{89})Sr</td>
<td>0.67</td>
<td>0.39</td>
<td>0.58</td>
</tr>
</tbody>
</table>

The overall uncertainty of the measured total beta activity is calculated according to:

\[ \Delta_{\text{overall}} = \sqrt{\Delta_{\text{rd}}^2 + \Delta_{\text{src}}^2 + \Delta_{\text{sol}}^2 + \Delta_{\text{count}}^2} \]

(2)

where

\[ \Delta_{\text{rd}} \] random error;
\[ \Delta_{\text{src}} \] uncertainty due to the preparation of the radioactive sample;
\[ \Delta_{\text{sol}} \] uncertainty due to the preparation of certified solution;
\[ \Delta_{\text{count}} \] uncertainty due to the variability of the counter efficiency.

Excluding random error, the overall uncertainty of the calibration coefficients listed in Table I was about 0.2–0.3.
3. Database of results related to the total beta-activity measurements

Original notebooks with records of total beta activity measurements are being collected in the Institute of Biophysics and the data are being entered into a computer database according to a standard methodological approach. Each record related to the radiometric result in the database has a detailed structure. The most important and crucial information that is available in the original notebooks relates to the name of the settlement (including Oblast and raion), type of sample, date of measurement, count rate from the sample, background count rate, and specific activity of the sample. Unfortunately, the information is not always complete. Also, it is worth noting that the conduct of measurements, recording the results, the calculation of the specific activity, and recoding the results of calculation were provided by many people of different qualification from various institutions. All such records need to be carefully verified and checked.

The numbers of total beta-activity measurements in milk that were carried out by sanitary and veterinary departments of Gomel Oblast during the first two months after the accident are shown in Fig.2.

FIG. 2. Monitoring of total beta-activity in foodstuffs provided in Gomel Oblast in May-June 1986 by sanitary (numerator) and veterinary (denominator) departments.

The overall number of total beta-activity measurements for Gomel Oblast was 22,834, [MS: is it 22834 for all raions, or only for 17 out of 21, as indicated in the abstract?] including 18,494 in milk (81%), 1,945 in milk products (8.5%), and 2,395 in leafy vegetables (10.5%). About 40,000 radiometric measurements were registered for Belarus.

4. Analysis of total beta-activities in milk

Taking into account that radioecological conditions (the day of main fallout, dry or wet deposition, beginning of pasture season etc) may have differed in various parts of Belarus, the analysis of the total beta activities varies to some extent from one area to another. This paper contains the analysis of original data on total beta-activity measurements related to two neighboring raions of Gomel Oblast, namely, Dobrush and Vetka raions. There were 43 collective farms of milk in these raions.

These raions are located 120–190 km north-east of the Chernobyl Nuclear Power Plant (Fig. 2). The fallout of radionuclides occurred mainly on April 27-28, 1986. Table II shows the distribution of the number of settlements in Dobrush and Vetka raions according to $^{137}\text{Cs}$ deposition density. The high
variability of the deposition density of $^{137}$Cs over the territory of the raions is an indirect evidence of the extent of wet depositions over certain areas.

Table II. Number of settlements in Dobrush and Vetka raions according to $^{137}$Cs deposition density.

<table>
<thead>
<tr>
<th>$^{137}$Cs deposition density, kBq m$^{-2}$</th>
<th>Total</th>
<th>&lt;37</th>
<th>37-185</th>
<th>185-555</th>
<th>555-1480</th>
<th>≥1480</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of settlements</td>
<td>Dobrush</td>
<td>105</td>
<td>46</td>
<td>24</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Vetka</td>
<td>141</td>
<td>–</td>
<td>11</td>
<td>64</td>
<td>57</td>
</tr>
</tbody>
</table>

The first total beta-activity measurements of samples were conducted by the raion veterinary department on May 4, 1986. Each sample was measured once or twice during 5 minutes. Background was measured over 10 minutes, once or twice a day. The average background was 17.6 (14.3 – 24.6) counts min$^{-1}$ in May and 16.2 (12.9 – 22.6) counts min$^{-1}$ in June. With such background level, the values of minimum detectable count rate (MDCR) were 7.8 and 7.1 counts min$^{-1}$ in May and June, respectively. Those values of MDCR correspond to values of minimum detectable activity (MDA) of 0.77 kBq kg$^{-1}$ and 0.70 kBq kg$^{-1}$, respectively.

In Dobrush raion, about 95% of the measurements conducted were of milk samples. Out of a total number of 1,017 milk measurements, 170 were of milk samples from private cows.

In Vetka raion, the percentage of milk samples is 62% (737 measurements), while the percentages of samples of milk products and of leafy vegetables are 21% and 17%, respectively. In that raion, about 50% of the milk samples, 64% of the samples of milk products, and 78% of the samples of leafy vegetables measured in May exceeded the MDA, while in Dobrush raion only one third of the milk samples exceeded the MDA.

The distribution of the percentage of milk samples, stratified according to total beta-activity, $^{137}$Cs deposition density $\sigma_{Cs-137}$, and date of measurement, is given in Table III.

Table III. Distribution of the percentage (%) of milk samples according to total beta-activity, $^{137}$Cs deposition density $\sigma_{Cs-137}$, and date of measurement.

<table>
<thead>
<tr>
<th>$\sigma_{Cs-137}$, kBq m$^{-2}$</th>
<th>Date of measurement</th>
<th># of samples</th>
<th>&lt; 7.4</th>
<th>7.4–18.5</th>
<th>18.5–37</th>
<th>≥37</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;110</td>
<td>≤15 May</td>
<td>123</td>
<td>21.1</td>
<td>34.1</td>
<td>35.0</td>
<td>9.8</td>
</tr>
<tr>
<td></td>
<td>16-31 May</td>
<td>232</td>
<td>98.3</td>
<td>1.3</td>
<td>0.4</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>299</td>
<td>99.0</td>
<td>0.3</td>
<td>-</td>
<td>0.7</td>
</tr>
<tr>
<td>110 - 369</td>
<td>≤15 May</td>
<td>67</td>
<td>3.0</td>
<td>6.0</td>
<td>10.4</td>
<td>80.6</td>
</tr>
<tr>
<td></td>
<td>16-31 May</td>
<td>95</td>
<td>91.6</td>
<td>7.4</td>
<td>1.0</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>112</td>
<td>93.8</td>
<td>5.4</td>
<td>0.8</td>
<td>-</td>
</tr>
<tr>
<td>≥370</td>
<td>≤15 May</td>
<td>96</td>
<td>2.1</td>
<td>5.2</td>
<td>10.4</td>
<td>82.3</td>
</tr>
<tr>
<td></td>
<td>16-31 May</td>
<td>275</td>
<td>29.1</td>
<td>46.5</td>
<td>24.4</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>454</td>
<td>60.1</td>
<td>36.1</td>
<td>3.8</td>
<td>-</td>
</tr>
</tbody>
</table>

In a first stage of the analysis, the total beta activities in milk were considered, and the issue arose on whether the milk samples from private cows should be separated from the milk samples from collective farms. Two questions are discussed here:

1. Was there any difference in the radionuclide concentrations in milk taken from private cows and from collective farms?
2. What was the distribution of the total beta activity in milk at some fixed periods of time after the accident in specific settlements and in collective farms?

In order to answer those questions, the total beta activity in milk samples was related to the total deposition density of the five most important radionuclides that contribute to the contamination of milk ($^{89}$Sr, $^{90}$Sr, $^{131}$I, $^{134}$Cs, and $^{137}$Cs).
The deposition densities of $^{137}$Cs and $^{90}$Sr were taken from a database of measured values [2]. [MS: is this the correct reference?] For private cows, the average values for the settlement were used, whereas, for collective farms, the geometric means of the deposition densities of $^{137}$Cs and $^{90}$Sr in the settlements included into given collective farm were used in the analysis.

The ratio of $^{89}$Sr to $^{90}$Sr in fallout was assumed to be equal to 11.5, while the ratio of $^{134}$Cs to $^{137}$Cs was taken to be 0.5. [MS: is 0.5 the value you used? It was not given in your text.] The ratio of $^{131}$I to $^{137}$Cs, decay-corrected to April 26, 1986, was derived from the results of spectrometric measurements of 27 soil samples in Dobrush raion and of 67 samples in Vetka raion, carried out in May-June by the Minsk Research Institute of Nuclear Energy (RINE) and the Moscow Institute of Biophysics (IBP). The variation of the $^{131}$I/$^{137}$Cs ratio with the $^{137}$Cs deposition density is shown in Figure 3.

![Image of Figure 3](image)

**FIG. 3. Variation of the ratio of $^{131}$I/$^{137}$Cs, decay-corrected to April 26, 1986, in soil samples from Vetka and Dobrush raions, as a function of the $^{137}$Cs deposition density.**

A power function with free term was found to provide the best fit of the data in Figure 3, with a correlation coefficient, $r^2=0.33$:

$$\sigma_{I-131} / \sigma_{Cs-137} = 9.5 + 155/(\sigma_{Cs-137})^{0.5}$$

(3)
The procedure to compare the total beta activity levels in milk samples taken from private cows and from collective farms was as follows:

(1) For all measurements of milk in the two raions, the ratio of the total beta-activity in milk, \(q(t)\) in Bq L\(^{-1}\), and of the total deposition density, \(\sigma(t)\), of the five most important radionuclides (\(^{131}\)I, \(^{134}\)Cs, \(^{137}\)Cs, \(^{89}\)Sr, and \(^{90}\)Sr), decay corrected to the time \(t\) of measurement of the milk sample, was calculated.

(2) The ratios of \(q(t)/\sigma(t)\), plotted in Figure 4 as a function of \(t\), were found to fit the following function with a correlation coefficient \(r^2 = 0.38\):

\[
q(t)/\sigma(t) = f(t) = 4.5 + 38e^{-0.093t} \quad \text{[Bq L}^{-1} \text{ per kBq m}^{-2}] \quad (4)
\]

(3) The ratios of \(q(t)/\sigma(t)\) were decay corrected to \(D+15\) (on May 10, 1986) according to formula (4).

(4) For each area, the sets of decay corrected ratios for cows’ milk taken from private and collective farms were formed. Those sets were compared by using two-samples analysis method to check a hypothesis about equality of samples.

Table IV shows the results of the comparison of the statistical characteristics for those samples. It follows from Table IV that the average and median estimates in the samples related to milk taken from collective farms are greater than those in milk taken from private cows by a factor of (1.2-1.7).
Table IV. Comparison of the total beta activity levels in cows’ milk taken from private and collective farms using two-samples analysis method.

<table>
<thead>
<tr>
<th>Raion</th>
<th>Sample Statistics</th>
<th>Private</th>
<th>Collective</th>
<th>Pooled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dobrush</td>
<td>Number of elements</td>
<td>117</td>
<td>542</td>
<td>654</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>9.2</td>
<td>15.8</td>
<td>14.7</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>7.3</td>
<td>9.0</td>
<td>8.7</td>
</tr>
<tr>
<td></td>
<td>Standard deviation</td>
<td>6.3</td>
<td>17.7</td>
<td>16.3</td>
</tr>
<tr>
<td>Vetka</td>
<td>Number of elements</td>
<td>226</td>
<td>453</td>
<td>679</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>6.4</td>
<td>7.8</td>
<td>7.3</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>5.4</td>
<td>7.0</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>Standard deviation</td>
<td>4.4</td>
<td>4.8</td>
<td>4.6</td>
</tr>
</tbody>
</table>

Stochastic radioecological models of milk contamination and dosimetric models of exposure to thyroid suppose to account for the parameters of distribution of milk activity at a given time within a settlement (cows’ milk taken from private farms) or a collective farm (cows’ milk taken from a collective farm). To assess the parameters of such distribution all ratios of \( \frac{q(t)}{\sigma_\Sigma(t)} \) were decay-corrected to May 10, 1986 and were normalized to a geometric mean value of a given set of data. The same approach was used for total beta-activity measurements of private milk in Vetka town. Type and the characteristics of the distributions are presented in Figure 5.

\[
\left[ \frac{q(15)}{\sigma_\Sigma(15)} \right] / \left[ \frac{q(15)}{\sigma_\Sigma(15)} \right]_{geom} \quad \left[ \frac{q(15)}{\sigma_\Sigma(15)} \right] / \left[ \frac{q(15)}{\sigma_\Sigma(15)} \right]_{geom}
\]

FIG. 5. Distributions of the ratios of \( \frac{q(15)}{\sigma_\Sigma(15)} \) / \( \frac{q(15)}{\sigma_\Sigma(15)} \)_{geom}.

The distributions are satisfactorily fitted by lognormal functions with geometric standard deviations of 2.05 and 2.2. This is close to the distribution of the \(^{137}\)Cs activity in milk obtained using good statistics of measurements in settlements for late periods of time after the accident (geometric standard deviation in the range from 1.8 to 2.0). It appears that the variability of the radionuclide concentration in milk, averaged over a specific area (settlement or collective farm), does not depend substantially on the type of grass contamination (aerial or root). This preliminary, but important conclusion needs to be checked using measurement data from other raions.

Despite the differences between cows’ milk from private and from collective farms, it was considered reasonable in the investigation of the influence of the deposition process (dry or wet) on the total beta
activity level in milk. For that purpose, two sets of ratios of \( q(t)/\sigma_\Sigma(t) \) were selected according to the range of \(^{137}\text{Cs} \) deposition density, \( \sigma_{\text{Cs-137}} \), namely one set of ratios was assumed to be associated with dry deposition for which \( \sigma_{\text{Cs-137}} < 110 \) kBq m\(^{-2} \) and the other set of ratios was assumed to be associated with wet deposition for which \( \sigma_{\text{Cs-137}} \geq 370 \) kBq m\(^{-2} \). All measurements of milk samples conducted on May 4-6 and from May 25 to June 5 in the two raions were considered; for the first range of dates, \( \text{[MS: is dates OK? You had Cs-137 deposition density in your version.]} \) the total beta-activity in milk is expected to be mainly determined by \(^{131}\text{I} \), while for the second range of dates, the total beta-activity in milk is expected to be mainly determined by \(^{134}\text{Cs} \) and \(^{137}\text{Cs} \).

Results of comparison of the ratios of \( q(t)/\sigma_\Sigma(t) \) for various periods of time and ranges of the \(^{137}\text{Cs} \) deposition density are presented in Table V.

Table V. Results of comparison of the ratios of \( q(t)/\sigma_\Sigma(t) \) for various periods of time and ranges of the \(^{137}\text{Cs} \) deposition density.

<table>
<thead>
<tr>
<th>Date of measurement</th>
<th>( \sigma_{\text{Cs-137}}, ) kBq m(^{-2} )</th>
<th># of milk samples</th>
<th>( q(t)/\sigma_\Sigma(t), ) Bq L(^{-1} ) per kBq m(^{-2} )</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 4-6</td>
<td>&lt;110</td>
<td>74</td>
<td>21.4</td>
<td>12.3</td>
</tr>
<tr>
<td></td>
<td>\geq 370</td>
<td>77</td>
<td>17.1</td>
<td>27.6</td>
</tr>
<tr>
<td>May 25 – June 5</td>
<td>&lt;110</td>
<td>109</td>
<td>15.6</td>
<td>15.1</td>
</tr>
<tr>
<td></td>
<td>\geq 370</td>
<td>229</td>
<td>5.2</td>
<td>3.1</td>
</tr>
</tbody>
</table>

It follows from Table V that for the beginning of May the values of the ratio of \( q(t)/\sigma_\Sigma(t) \) are close to each other for the two sets of data, whereas for the end of May there is a factor of 3 between the two sets. It is rather difficult to explain this result; a possibility is that grass was very sparse during the first period of time so that a substantial part of the \(^{131}\text{I} \) intake by cow was due to the contamination of soil, which is largely independent of the type of deposition. By the end of May, grass had had time to grow, so that the contamination of grass, which is more important for dry than for wet deposition, played a predominant role. It is noteworthy that the results obtained for the end of May agree with the empirical relationship between the \(^{134}\text{Cs} \) + \(^{137}\text{Cs} \) concentration in milk (\( q_{\text{cs}} \)) and the \(^{137}\text{Cs} \) deposition density: \( q_{\text{cs}} \sim (\sigma_{\text{Cs-137}})^{0.5} \), established in [3].

It is clear that it will be important to pursue the investigation on the role of the type of deposition using measurement data from other raions.

Though possible peculiarities related to (1) radionuclide contamination of cows’ milk taken from private and collective farms, (2) dependency of milk contamination on the type of deposition, (3) cows’ feeding in private and collective farms were not taken into account, the general view of the distribution is close to the distribution of the \(^{137}\text{Cs} \) activity in milk received using good statistics of measurements in settlements for the late periods of time after the accident (a geometric standard deviation was in the range from 1.8 to 2.0). It appears to be that the variation of radionuclide concentration in milk with respect to average estimate characterizing specific area (settlement, collective farm) does depend insignificantly on the way of grass contamination (aerial or root).

5. Preliminary estimates of \(^{131}\text{I} \) concentration in milk

The variation with time of the specific activity of the main radionuclides in milk in contaminated areas in Belarus was shown to be satisfactorily described with the following empirical ratios [3, 4]:

\[
q_{\text{milk,137}}(t) = 0.07 \times \sqrt{\sigma_{137}} \times [2.9 \times \exp(-1.84 \times t) - 5.6 \times \exp(-0.69 \times t) - 12.5 \times \exp(-0.17 \times t) + 13.5 \times \exp(-0.05 \times t) + 1.5 \times \exp(-0.023 \times t)]
\]

\[
q_{\text{milk,131}}(t) = \sigma_{131} \times 9 \times 10^{-3} \times [0.86 \times \exp(-7 \times t) - 6.33 \times \exp(-1.03 \times t) + 5.47 \times \exp(-0.15 \times t)]
\]
where:

\[ q_{\text{milk},137}(t) \] is the \(^{137}\text{Cs}\) specific activity in milk at the time \(t\), Bq L\(^{-1}\);
\[ \sigma^{137} \] is the \(^{137}\text{Cs}\) ground deposition density in the vicinity of the settlement considered, Bq m\(^{-2}\);
\[ q_{\text{milk},131}(t) \] is the \(^{131}\text{I}\) specific activity in milk at the time \(t\), Bq L\(^{-1}\);
\[ \sigma^{131} \] is the \(^{131}\text{I}\) ground deposition density in the vicinity of the settlement considered, Bq m\(^{-2}\);
\[ q_{\text{milk},90}(t) \] is the \(^{90}\text{Sr}\) specific activity in milk at the time \(t\), Bq L\(^{-1}\).
\[ \sigma^{90} \] is the \(^{90}\text{Sr}\) ground deposition density in the vicinity of the settlement considered, Bq m\(^{-2}\).

[MS: what did you do for \(^{134}\text{Cs}\) and \(^{89}\text{Sr}\)?]

Using equations 5 to 7, the \(^{131}\text{I}\) specific activity in milk can be derived from the results of the total beta-activity measurements according to:

\[ q_{\text{milk},131}(t) = K_I(t) \times N(t) \]  \hspace{1cm} (8)

where

\[ K_I(t) = k_{131} \times f(\sigma^{131}) \times f_{131}(t)/\sum_i (k_i \times f(\sigma_i) \times f_i(t))/K_i \]  \hspace{1cm} (9)

[MS : what are \(K_I, N, k_{131}, f, f_{131}, \text{and} f_i\)?]

Results of calculation of \(K_I(t)\) for two settlements with different contamination levels are presented in Figure 6.

**FIG. 6.** Calculated values of conversion coefficient for the \(^{131}\text{I}\) activity.

Figure 7 presents the dependency of the count rate from \(^{131}\text{I}\) in milk (proportional to the \(^{131}\text{I}\) concentration in milk) [MS: why did you not use the \(^{131}\text{I}\) concentration in milk instead of the count rate?] versus the \(^{131}\text{I}\) deposition density in the area considered. The samples, taken from areas in Vetka and Dobrush raions with different types of deposition (wet and dry), were measured on May 4-5, 1986. The count rate from \(^{131}\text{I}\) in milk was calculated by subtracting the contribution from isotopes of cesium and strontium according to ratio (4) [MS: what is (4)?] and was estimated to be about 80% of the total. The dependency is satisfactorily fitted by a relationship of \(N_i = (0.37 \pm 0.06) \times \sigma^{131}\). According to the model for \(^{131}\text{I}\), the value of the proportional coefficient is equal to 0.34 counts min\(^{-1}\) per Ci km\(^{-2}\). [MS: I do not understand this sentence; what model is that? + replace Ci km\(^{-2}\) with kBq m\(^{-2}\) here and in Figure 7.] The linear dependency of the count rate related to \(^{131}\text{I}\) activity in the sample versus
the $^{131}$I deposition density, as well as satisfactory agreement of model estimates and measured values of total count rates, seems to indicate that the type of deposition (dry or wet) does not influence the $^{131}$I concentration in milk.

A few spectrometric measurements of milk samples were made in Vetka raion. The average ratio of the spectrometry data to the estimates of $^{131}$I activity in milk derived from total beta-activity measurements is equal to $0.77\pm0.35$.

CONCLUSIONS

1. An analysis of possible differences in the levels of radionuclide contamination in cows’ milk taken from private and from collective farms in Vetka and Dobrush raions of Gomel Oblast was not conclusive. A continuation of this analysis, using data from other raions of Gomel Oblast is warranted.
2. The data from Dobrush and Vetka raions do not show an important influence of the type of deposition (dry or wet) on the level of radionuclide contamination in cows’ milk. This result may be due to poor statistics and large measuring errors in the total beta-activity measurements.
3. The distribution of the measured samples of milk with respect to average value at a given time is well fitted by a lognormal function with a geometric standard deviation of 2.
4. The comparison of the estimates of $^{131}$I concentrations in milk derived from total beta-activity measurements and from spectrometric measurements shows a satisfactory agreement.

REFERENCES

1. Instruction on the express methods of estimation of radioactive contamination in foodstuffs and drinking water. Adopted by the Chief of the Main Sanitary and Epidemiological Agency of the Ministry of Public Health of the USSR P. Lyarsky on 8 May 1966. (in Russian).