Report on the 2nd Meeting of the IAEA's EMRAS* I-131 Working Group

Minutes of the meeting held at the

CIEMAT, Madrid, Spain, 31 May to 2 June 2004

The meeting was hosted by the Centro de Investigaciones Energeticas Medioambientales y Tecnologicas (CIEMAT).

The meeting chaired by Mr. Paweł Krajewski from Central Laboratory for Radiological Protection, POLAND, was attended by 7 participants from 6 Member States and staff member from the IAEA

The purpose of the meeting was to:

- discuss the results of the intercomparison exercise for the Plavsk scenario;
- discuss and agree on methods to evaluate and compare the results obtained by different modelers;
- present and discuss other scenarios;
- plan future work activities.

1 BRIEF RECORD OF THE MEETING[1].

The meeting was opened by Mr. Tiberio Cabianca, Scientific secretary of the IWG.
Mr. Tiberio made his opening remarks and discussed the Preliminary Agenda.
Mr. David Cancio, Director of CIEMAT, welcomed the participants and expressed his expectations for a productive week.

The meeting continued with an overview of the IWG activities, made by Mr. Krajewski[2]. He reminded the background of environmental assessment modeling, which began in the 1970s, i.e., BIOMOVS (initiated in 1985), VAMP (1988–1994), and BIOMASS (1996–2001), the EMRAS.

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[1] The Meeting agenda in given in Appendix A
[2] Detailed information on the presentations can be found in the Minutes of EMRAS* I-131 Working Group on the EMRAS WEB SITE as PDF-documents: http://www-rasanet.iaea.org/projects/emras/emras.asp.

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The major areas of emphasis of IWG activities i.e.:

- identification the most important sources of bias and uncertainty in the model predictions
- improvement of the accuracy of model predictions
- improvement of modeling procedures

During his presentation Mr. Paweł Krajewski described the preparatory activities of the IWG, current status and suggested discussion on both general and specific EMRAS objectives, as well as its expected outputs.

The first Questionnaire[3] of IWG resulted in identification of 9 modelers who agreed to took part in the IWG activities (TABLE 1). Also among the several proposed data set for model testing the Scenario Plavsk has been selected as the most relevant for the first test model comparison.

TABLE 1. Models and participants

Model	Participant Name	Country, Organization
LIETDOS	Ms T. Nedveckaite, Mr V. Flistovic	Lithuania, Institute of Physics
OSCAAR	Mr T. Homma	Japan, Japan Atomic Energy Research Institute
UniVes	Mr B.Kanyár	Hungary, University of Veszprém
CLRP	Mr P. Krajewski	Poland, Central Laboratory for Radiological Protection
ASTRAL	Ms C. Duffa	France, Institut de Radioprotection et de Sûreté Nucléaire (IRSN)
ECOSYS-87	Mr M. Ammann	Finland, Radiation & Nuclear Safety Authority (STUK)
Plavsk Dose Calculator	Mr S. Simon	USA, National Cancer Institute
SPADE V.6	Mr S.Conney, D. Webbe-Wood	UK, Food Standard Agency
CLIMRAD	Mr O. Vlasov	Russian Federation, Medical Radiological Research Center

At the end of January 2003 the Secenario Plavsk was evaluated and distributed among the participants together with prediction formularies (in Excel file). The Scenario is available on the EMRAS WEBSITE: http://www-rasanet.iaea.org/projects/emras/emras.asp.

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[3] prior to the First Meeting of the IAEA's EMRAS I-131 Working Group, held at IAEA Headquarters in Vienna, 1-5 September 2003

This scenario involves the reconstruction of ^{131}I deposition using ^{137}Cs ground contamination data as a tracer and the assessment of ^{131}I thyroid burden and committed inhalation and ingestion dose to thyroid for different age groups in specified locations.

The scenario can be seen as being in two parts:

1. a model test in which predictions of ^{131}I concentration in milk and ^{131}I content in thyroid can be compared with observed values in the test area; and
2. a model comparison in which predictions of the mean ingestion dose to the thyroid of different age groups and inhalation dose are compared and analyzed.

Both urban area and rural settlements are included in the test region and pathways contributing to the dose include terrestrial environment.

The end points considered for model validation:

1. ^{131}I deposition (soil concentration);
2. a time dependent ^{131}I concentration in milk in the period 27 April –30 May 1986;
   for 18 milk farm + Town Plavsk situated at different ^{131}I (^{137}Cs) deposition density;
3. ^{131}I thyroid burden for different age groups:
   new born, 1-2, 3-7, 8-12, 13-17, adult -for urban population (Plavsk town);
   new born, 1-2, 3-7, 8-12, 13-17, adult -for specified rural locations.

The end points considered for model inter-comparison:

1. reconstruction of ^{131}I air concentration for 18 locations and Plavsk town
2. committed doses to thyroid from ingestion
3. (voluntary) inhalation dose contribution to the total dose.

It was agreed to perform preliminary run of prediction and sent results before the 2nd Meeting of the IAEA's EMRAS IWG (31 May 2004).

Eight participants sent results, together with questionnaire summarized assumptions and used parameters.

The meeting continued with an presentation of Plavsk Scenario input data and discussion on credibility of isotopic ratio I-131/Cs-137 and radioiodine plume dynamic over the Plavsk district.

During the afternoon of the first meeting day and following morning session of the second day the several modelers presented their models and results of predictions. For modelers that could not be attended the brief presentation was made by Pawel Krajewski. List of these presentations is given in APPENDIX B .

During the afternoon session Irina Zwonowa presented the observed data for the Plavsk region.

These included ^{131}I concentration in milk and ^{131}I content in thyroids of residences in a settlements.

Method of thyroid dose estimation based on results of direct measurements of 131I in thyroids of local people and in local milk was reported. See appendix APPENDIX C.

In the third day of the meeting the comparison of models predictions against measurements for a number of test points was presented and discussed.

This report is supplemented with full set of predictions and observed data in form of Excel files:

1. SUMMARY OF PREDICTIONS_AIR_DEPOSITION_PASTURE.xls
2. SUMMARY_OF_PREDICTIONS_I_131_in_Milk
3. SUMMARY_OF_PREDICTIONS_I_131_in_Thyroid.xls
4. SUMMARY OF PREDICTIONS_DOSES.xls

These file are available on the EMRAS website

The major topics discussed during the meeting are summarized in the following sections in the next chapter entitled “EVALUATION OF PRELIMINARY PREDICTIONS FOR PLAVSK SCENARIO”.

2 EVALUATION OF PRELIMINARY PREDICTIONS FOR PLAVSK SCENARIO

2.1 Evaluation of ^{131}I deposition (isotopic ratio $^{131}I/^{137}Cs$)

The main activity ratio of gamma-emitters deposited after Chernobyl accident to the surface activity of reference radionuclide ^{137}Cs is presented in Table 4.2.2.2-1 of the Scenario Plavsk description. This ratio for $^{131}I/^{137}Cs$ calculated on 10 May 1986 is equal to 3.34 with standard error of 19%. It was evaluated by Orlov and Pitkevich[4,5] and corresponded to wet deposition. There were four points of soil sampling in May 1986 in Tula region with one point located in the Plavsk district (Town Plavsk with relatively very high ^{137}Cs deposition of 475 kBq m^{-2}). However, remarkably inhomogeneous ^{137}Cs deposition for whole Plavsk district that ranged from 20 to 600 kBq·m^2 indicates that the radioactive fallout can be classified as mixed (dry&wet) and a regional approach should be applied. For these locations where ^{137}Cs deposition is less than 150 kBq·m^2 i.e.: Skorodnoe, Ol'hi, Novo-Nikol'skij, Udarnik, Rossia, Druzhba, Kommunar, Im. K. Marksa, Vpered k kommunizmu, the semi-empirical relationship between ^{131}I and ^{137}Cs content in soil might be used:

$$\sigma_{^{131}I} = a \times (\sigma_{^{137}Cs})^{b}$$

where:

$\sigma_{^{131}I}$ - deposition of ^{131}I on the specified date

$\sigma_{^{137}Cs}$ - deposition of ^{137}Cs

a, b - constants

This approach has been used by Knatko[6] for Bielarus (a= 33.78, b= 0.64) and by Mahonko[7] for Kiev and Tula regions (a= 8.85, b= 0.85)

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[4] Orlov, M.Yu., Snykov, V.P., Khvalensky, Yu. A., Teslenko, V.P., and Korenev, A.I. 1992. Radioactive contamination of the territory of Belorussia and Russia after the Chernobyl accident. Atomnaya Energiya 72(4):371-376. (In Russian)

[5] Pitkevich, V.A., Shershakov, V.M., Duba, V.V., et. al. 1993. Reconsruction of composition of the Chernobyl radionuclide fallout in the territories of Russia. Radiation and Risk 3:62-93. (In Russian)

[6] Knatko, V.A., Dorozhok, I. N., 2001. Reconstruction of 131I deposition density in region of Bielarus with estimation of thyroid doses from inhalation of 131I, Rad. Prot. Dosim.,Vol.,93,No.1, pp. 43-48.

[7] Mahonko, K. P., Kozłowa, E.G., et. al. 1996. Contamination of regions with ^{131}I after the accident at the Chernobyl NPP and assessment of upper doses from ^{131}I. Atomnaya Energiya 80, 466-471 (in Russian).

One can notice that the activity ratios of $^{131}I/^{137}Cs$ evaluated as constant value approach (Orlov 1986) or as a power function approach (Mahonko) differ less than factor 2.5 and decrease with higher ^{137}Cs content in soil (see FIG 1).

Most modelers used constant activity ratio[8] given in Scenario Plavsk (see FIG 2.) and this contributed to almost the same values obtained. The differences in uncertainty ranges evaluated by particular models result from different calculation method of representative mean of ^{137}Cs content in soil for particular areas of milk farm and personal judgment (see FIG 3).

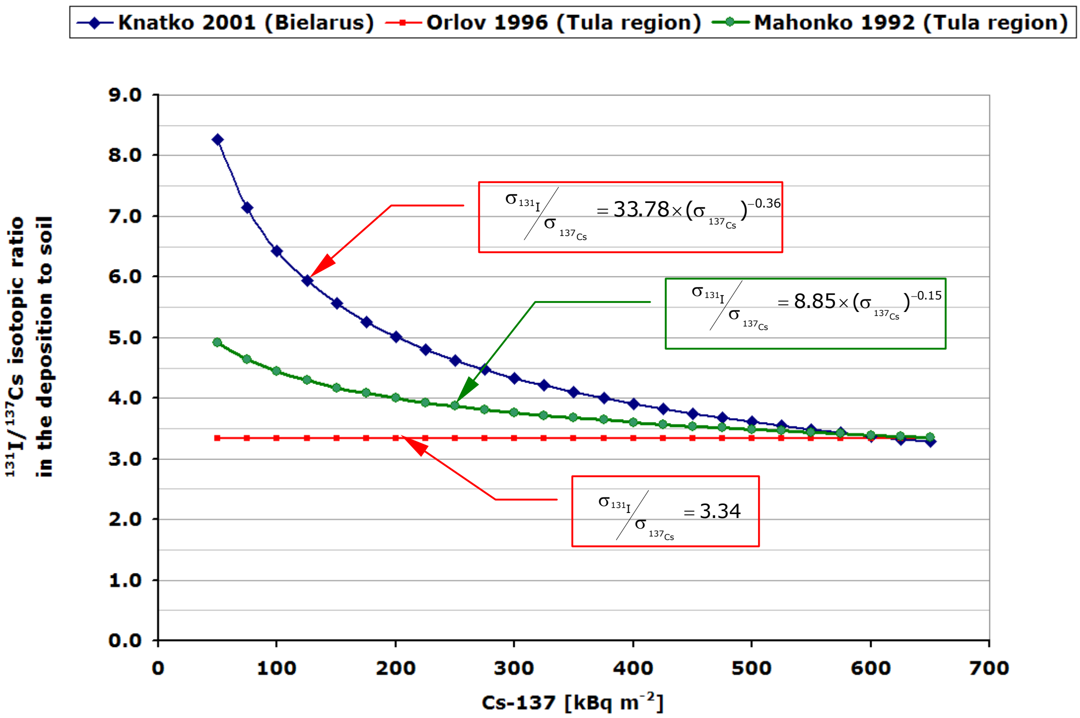

FIG 1. The activity ratio of $^{131}I/^{137}Cs$ deposited after Chernobyl accident calculated on 10 May 1986 as a function of ^{137}Cs content in soil – different approaches of evaluation

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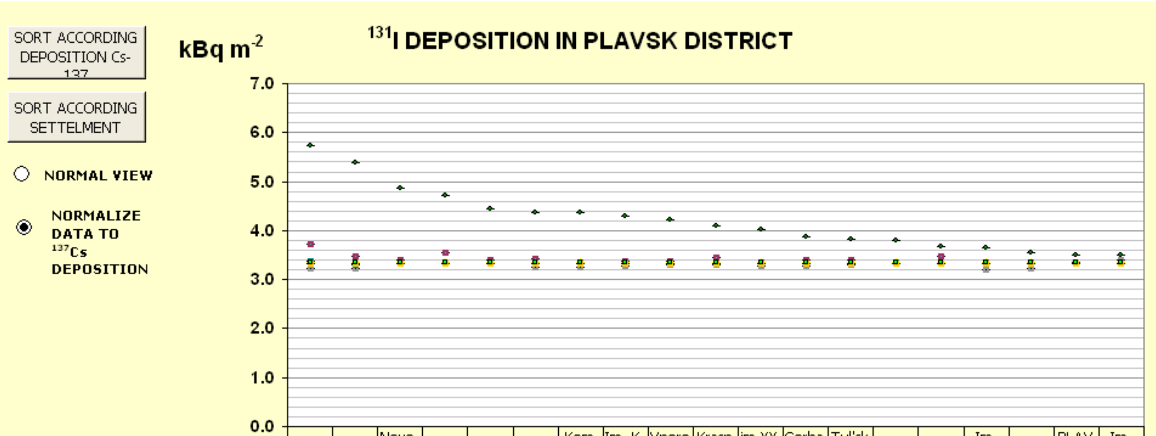
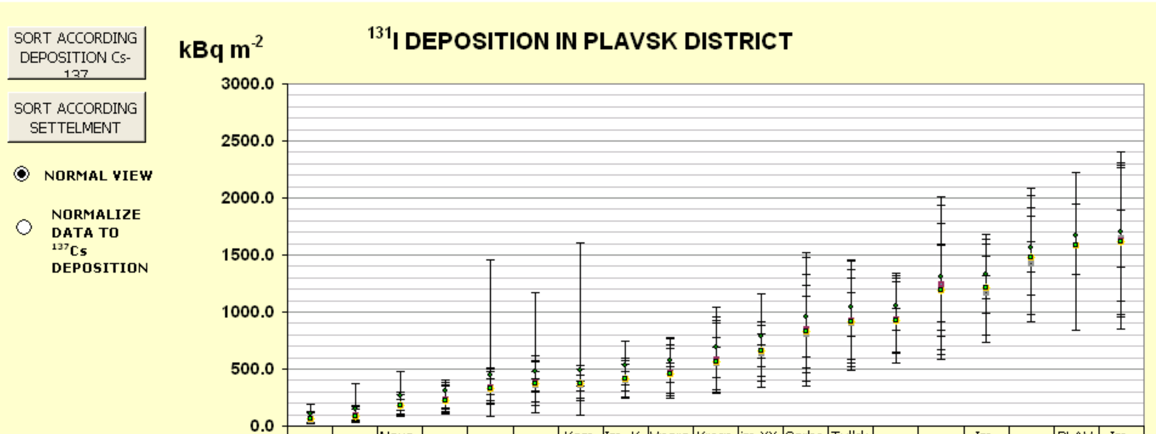
[8] in exception of (CLRP)



	Skorodnoe	Ol'hi	Novo-Nikol'skij	Udarnik	Rossia	Druzhba	Kommunar	Im. K. Marksa	Vpered k komm	Krasnogor'e	im.XXII parts'	Gorbachevskij	Tul'skaja niva	Plavskij	Kollektivist	Im. Luk'janova	Za Mir	PLAVSK Town	Im. Safonova
LIETDOS (T. Nedveckaite)	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3		3.3
MRRC (O.Vlasov)	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
SPADE V.6 D. (Webbe-Wood)	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3		3.3
UniVes (B. Kenyar)	3.2	3.2	3.3	3.3	3.3	3.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2		3.4
ECOSYS - 87 (M. Amman)	3.7	3.5	3.4	3.5	3.4	3.4	3.3	3.4	3.4	3.4	3.3	3.4	3.4	3.4	3.5	3.3	3.4		3.4
CLRP (P. Krajewski)	5.7	5.4	4.9	4.7	4.4	4.4	4.4	4.3	4.2	4.1	4.0	3.9	3.8	3.8	3.7	3.7	3.5	3.5	3.5
ASTRAL (C. Duffa)	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3		3.3
OSCAR (T. Homma)	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
NCI (S. Simon)	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3

MILK FARM NAME

FIG 2. Summary of used activity ratio of $^{131}I/^{137}Cs$ for predictions of ^{131}I deposition in particular areas of milk farm of Plavsk District



	Skorodnoe	Ol'hi	Novo-Nikol'skij	Udarnik	Rossia	Druzhba	Kommunar	Im. K. Marksa	Vpered k komm	Krasnogor'e	im.XXII parts'	Gorbachevskij	Tul'skaja niva	Plavskij	Kollektivist	Im. Luk'janova	Za Mir	PLAVSK Town	Im. Safonova
LIETDOS (T. Nedveckaite)	60.1	90.2	180.4	220.4	334.0	367.4	374.1	410.8	457.6	564.5	654.6	828.3	911.8	928.5	1195.	1215.	1476.		1619.
MRRC (O.Vlasov)	60.9	89.0	179.8	220.3	334.5	368.4	373.9	411.5	458.0	563.7	654.4	827.5	909.7	928.7	1195.	1214.	1476.	1585.	1618.
SPADE V.6 D. (Webbe-Wood)	60.1	90.2	180.4	220.4	334.0	367.4	374.1	410.8	457.6	564.5	654.6	828.3	911.8	928.5	1195.	1215.	1476.		1619.
UniVes (B. Kenyar)	58.2	86.8	180.0	220.0	332.0	357.0	365.0	403.0	453.0	556.0	642.0	810.0	903.0	922.0	1190.	1170.	1430.		1650.
ECOSYS - 87 (M. Amman)	67.0	94.0	184.0	234.0	340.0	378.0	375.0	416.0	463.0	582.0	656.0	846.0	927.0	932.0	1245.	1216.	1481.		1628.
CLRP (P. Krajewski)	103.3	145.7	262.7	311.6	443.6	481.0	488.4	528.9	579.6	692.9	785.9	959.9	1041.	1057.	1311.	1330.	1568.	1667.	1697.
ASTRAL (C. Duffa)	60.9	89.0	179.8	220.3	334.5	368.4	373.9	411.5	458.0	563.7	654.4	827.5	909.7	928.7	1195.	1214.	1476.	1585.	1618.
OSCAR (T. Homma)	60.9	89.0	179.8	220.3	334.5	368.4	373.9	411.5	458.0	563.7	654.4	827.5	909.7	928.7	1195.	1214.	1476.	1585.	1618.
NCI (S. Simon)	60.1	90.2	180.4	220.4	334.0	367.4	374.1	410.8	457.6	564.5	654.6	828.3	911.8	928.5	1195.	1215.	1476.	1586.	1619.

MILK FARM NAME

FIG 3. Summary of predicted ^{131}deposition in particular areas of milk farm of Plavsk District (^{131}I deposition sorted in ascending order)

2.2 ^{131}I concentration in grass

In section 4.3.1 of the Scenario Plavsk is stated that high of the grass in 30 April 1986 was low (about 5 cm-10 cm) what gives yield of the grass about 0.05 kg m^{-2} dry weight. Although, the assumption on low grass yield resulted in lower interception fraction, however it did not affect remarkably the predictions of ^{131}I concentration in grass (no more than 10 %) comparing with assumption on full developed grass (yield 0.2 kg m^{-2} dry weight) as mass interception fraction remained approximately constant.

The ratios of ^{131}I concentration in grass on 1 May 1986[9] to the ^{131}I deposition calculated for particular models fit in a range from 0.3 (UniVes) to 24.2 (CLRP) (see FIG 4) and reflect different assumptions that were made by particular models with respect to grass dry and wet interception fraction, time period and fraction of dry and wet deposition and deposition velocity on grass (see TABLE 4). The interception of airborne and waterborne radionuklides by vegetation especially in a case of unknown fraction of wet and dry deposition yielded discrepancy of predictions by to one order of magnitude (see FIG 5).

Weathering half-life of ^{131}I in grass is suggested in Scenario description (Section 5.5 Spectrometric Measurements of ^{131}I in Milk Samples) where is stated that "the mean effective period of ^{131}I activity reduction in milk in the Tula region is determined as 4.2 days"). One could evaluate the weathering half-time of iodine equal to 8.7 days. The values assumed by models ranged from 8.7 to 13 days base on post Chernobyl knowledge (see TABLE 4) and this parameter had a minor contribution to the discrepancy of predictions (see FIG 5).

[9] Aapproximately the maximum value of I-131 in grass due to deposition on 30 April

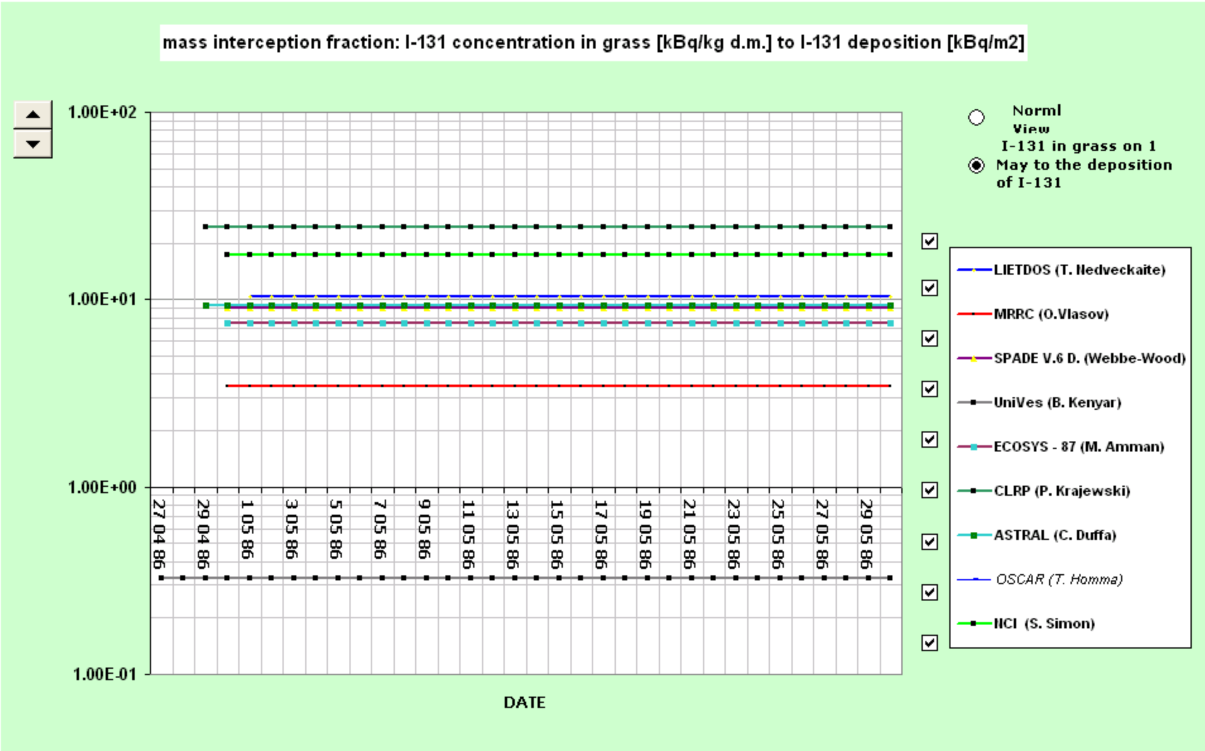


FIG 4. Ratio of ^{131}I concentration in grass on 1 May 1986 to ^{131}I deposition

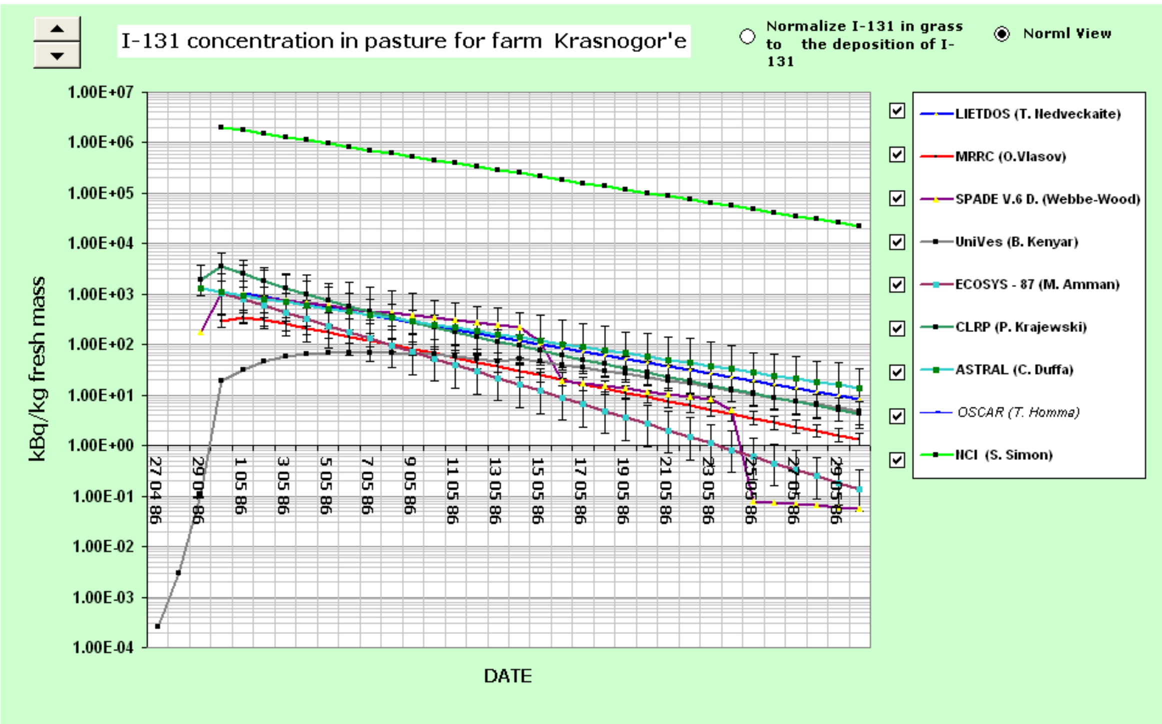


FIG 5. Example for predictions of ^{131}I concentration in grass

2.3 ^{131}I concentration in milk

There are several factors that could have influence on predictions of ^{131}I concentration in milk

2.3.1 Cow consumption rate

The values range of 40-45 kg/day of fresh grass is suggested in Scenario descriptions and were applied by most of models, however information on gradual transfer of cattle in grazing regime[10] after winter period was not been reflected by measurements.

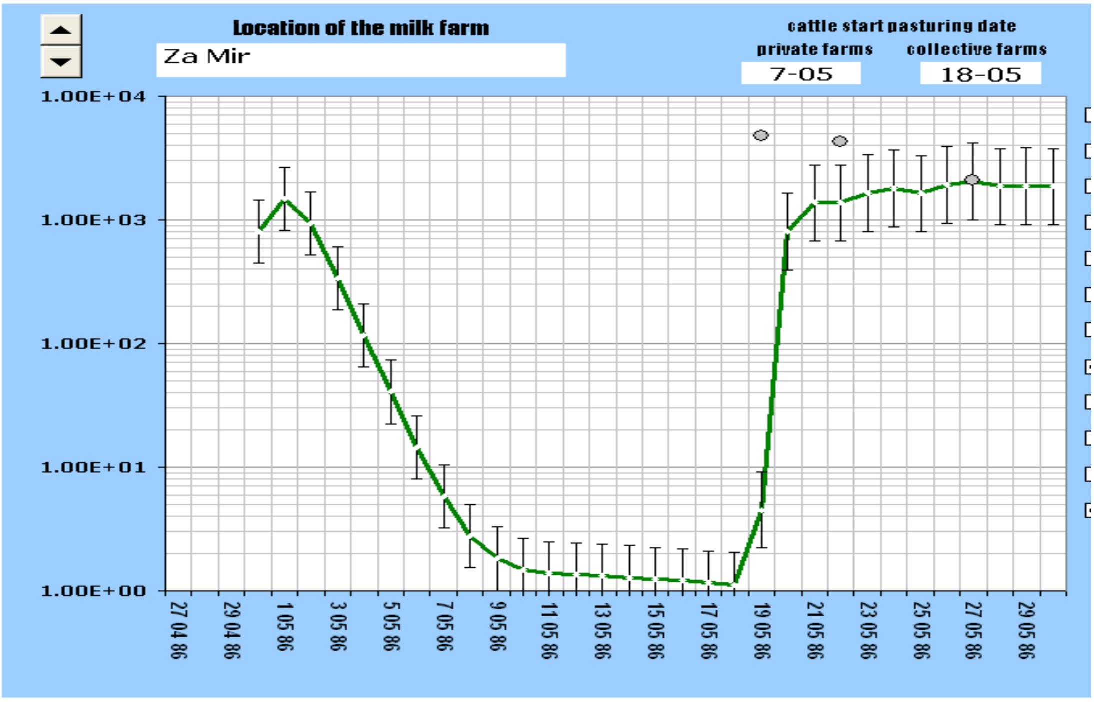


FIG 6. Example of predictions of ^{131}I concentration in milk where assumption about gradual pasturing pattern failed.

[10] beginning from 2 hours in first days, then increasing time of grazing during 7-10 days, it gives approximately daily consumption of 5, 10, 20, 35, 45 kg of fresh grass during following days.

2.3.2 Dates of the beginning of pasturing collective and private cattle

According to the interviews of the collective farms directors (Table 4.3.2-2 in Scenario descriptions) and inhabitants (Table 4.3.2-1 in Scenario Plavsk descriptions) grazing of collective cattle began approximately 10 days later than private cows. This phenomena was not reflected by observed data (see FIG 6). Analysis of available measurements of ^{131}I in milk from collective farms showed that dates of beginning grazing periods of private cows could be more suitable than dates pointed for collective farms. Especially the reported dates after 20 May were not asserted by results of measurements (FIG 7, FIG 8). One could suggest that the date of 12-15 May my be more representative for start grazing in collective farms as the warm weather with a temperature of about 15 °C steeled on the Plavsk district..

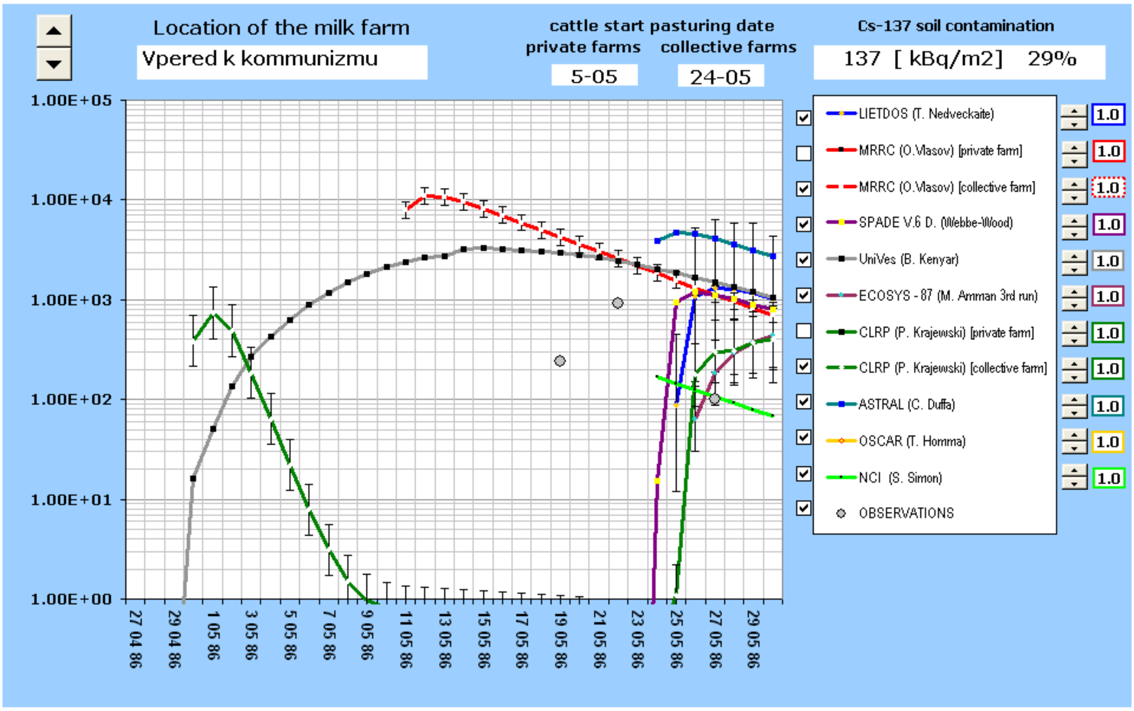


FIG 7. First example of predictions of ^{131}I concentration in milk where assumption on cow pasturing date according to the director of collective farm reports failed

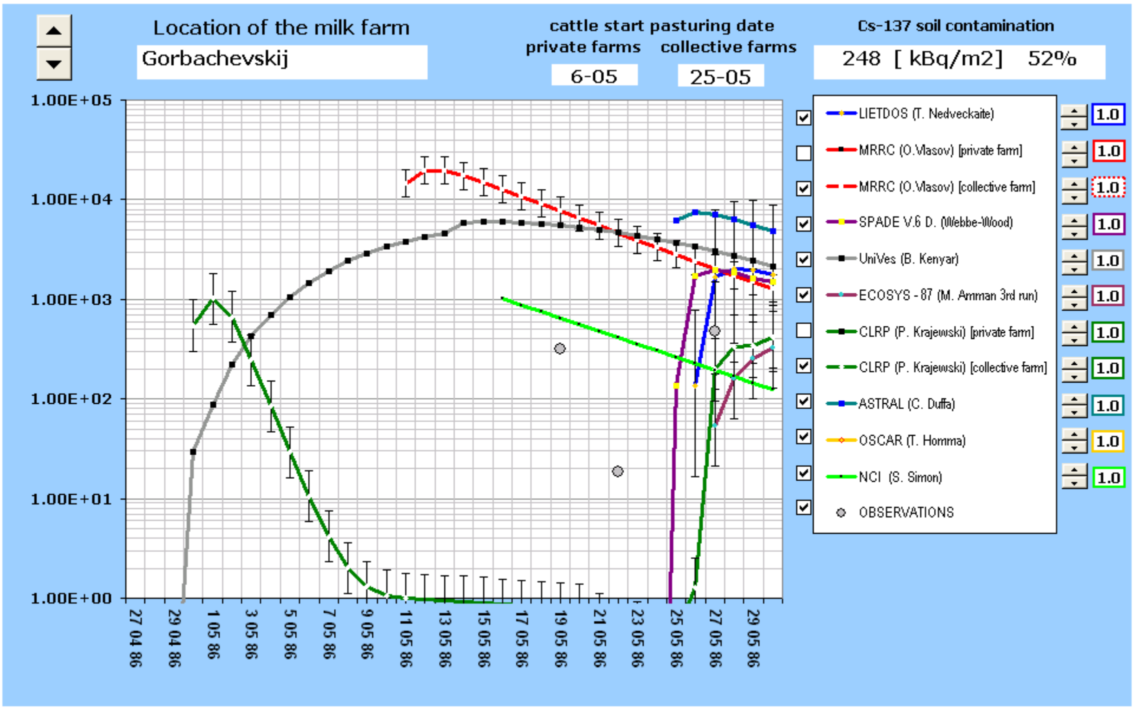


FIG 8. Second example of predictions of ^{131}I concentration in milk where assumption on cow pasturing date according to the director of collective farm report failed.

2.3.3 Representatives ness of milk samples

The main uncertainty was in the form of records in working notebooks. The place of sampling was recorded as the name of a collective farm without a name of a settlement. But there were from 3 to 12 settlements with different level of radioactive contamination in collective farms, so uncertainty of milk sample for verification of the model calculation should be correlated with scattering of surface contamination in settlements included in an examined collective farm. A collective farm could have some milk farms (two or three). A milk sample could be taken from a separate milk farm, from a common container with mixed milk from all milk farms or from small cans in which inhabitants handed over excess milk from their private cows for transportation to a milk factory. These details were not pointed in the working notebooks.

2.3.4 Iodine Metabolic model for cow

The mean milk yield of cows for Plavsk (Tula) region ranges from 5 to 7 L per day what is two fold less then milk yield for highly productive cow. It implies to evaluate iodine metabolic model in cow which could assess iodine transfer factor to milk depending on milk yield. The recent data suggest higher transfer factor in a range of 0.008 to 0.01 [day·L^{-1}].

2.3.5 Comparison of observed and predicted ^{131}I concentration in milk

The predicted versus observed data for ^{131}I concentration in milk for 18 collective farms and Plavsk town are presented on FIG 9. The main reasons of discrepancies are discussed in previous sections.

More then 50% of predicted ^{131}I concentrations in milk fit in a range of (3×observed, 1/3×observed) for most of the models that gives only one order of magnitude uncertainty of predictions. The time when cows were put on a pasture seems to be the most important factor of miss predictions and needs to be carefully considered.

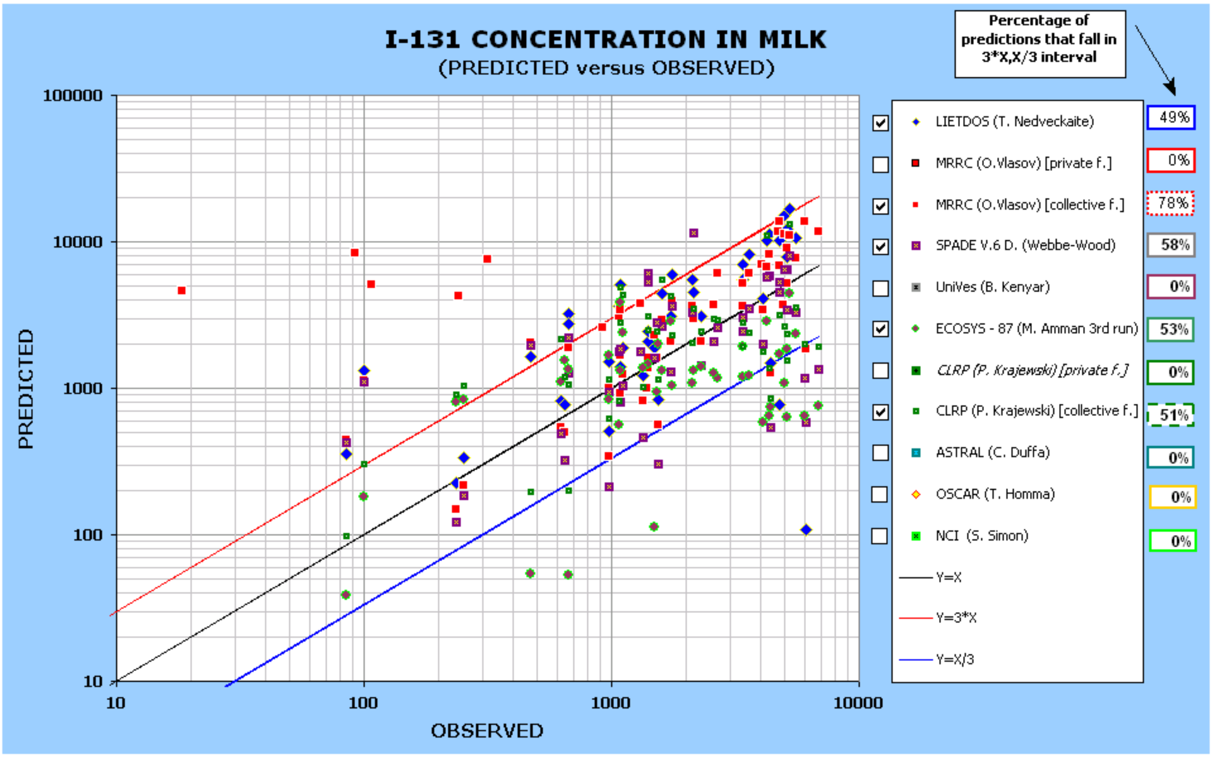


FIG 9. Selected predictions against observed data for Plavsk Scenario. Red and blue line indicate range of (3, 1/3) observation interval. In the square boxes the percentage of predictions that fall in (3,1/3) interval for particular participant are shown.

2.4 ^{131}I thyroid content

This task required models to predict the time dependent average ^{131}I content in thyroid for different ages groups i.e. new born (less then one year old), (2-3 years old), (5-7 years old), (8-12 years old) and adults (20 years old) in 16 settlements situated on 14 different milk farm areas where direct thyroid measurements were conducted (see FIG 10). The settlements can be considered as small villages that belong to the particular milk farm. Participants had to calculate 33 various time series curves together with 95% uncertainty ranges. There were several topics discussed with respect of model capability to predict of ^{131}I content in thyroids.

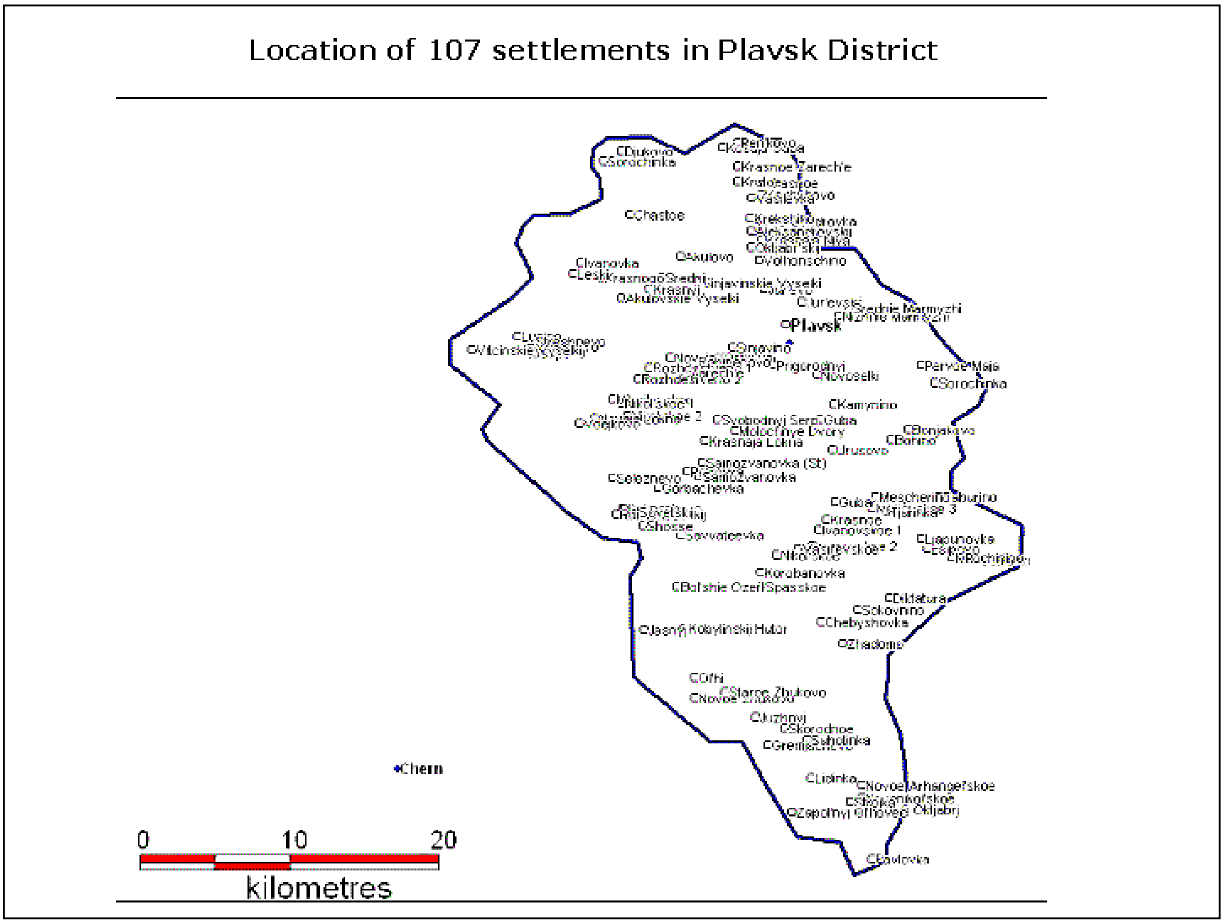


FIG 10. Plavsk district and settlements

2.4.1 Milk consumption rate

The milk consumption rate is reported in section 4.4.2 of Scenario descriptions. One could notice that there is not substantial differences in milk consumption within different ages group in rural and urban population (see TABLE 2). The variation in milk consumption rates for different age groups contributes to the predictions uncertainty no more than approximately 30%. The urban population used to drink about half of milk amount consumed by rural population. The measurements of ^{131}I activity in thyroid present much higher variability than one could expect from reported data about milk consumption rates. However, it needs to remark that statistics of measurements of ^{131}I in thyroids is much less than statistics on consumption habits.

TABLE 2. Milk consumption rates by age for rural and urban inhabitants (L d^{-1}) base on table.

Age (years)	Arithmetic mean	95% confidence interval	
		Lover	Upper
Rural population			
0.25 - < 0.5	0.38	0.26	0.50
0.5 - < 0.75	0.33	0.24	0.42
0.75 - < 1	0.45	0.35	0.55
1-2	0.56	0.53	0.59
3-7	0.6	0.57	0.63
8-12	0.44	0.38	0.50
13-17, male[a]	0.59	0.57	0.61
13-17, female[a]	0.38	0.36	0.40
> 17, male[a]	0.71	0.69	0.73
> 17, female[a]	0.65	0.64	0.66
Urban population			
0.25 - < 0.5	0.08	0.06	0.10
0.5 - < 0.75	0.21	0.17	0.25
0.75 - < 1	0.36	0.32	0.40
1-2	0.4	0.39	0.41
3-7	0.4	0.39	0.41
8-12[a]	0.3	0.29	0.31
13-17, male[a]	0.3	0.28	0.32
13-17, female[a]	0.22	0.20	0.24
> 17, male[a]	0.3	0.29	0.31
> 17, female[a]	0.25	0.24	0.26

2.4.2 Iodine metabolic model for different age groups

The Excel program base on the iodine metabolism model developed by Johnson (1981) was provided for these models that did not have possibility of calculation of ^{131}I content in thyroid (see TABLE 3). Some models used own formulas based on ICRP-56 publication. Although metabolic parameters for particular age groups differ remarkably i.e. mass of thyroid, thyroid uptake of stable iodine and concentrations in particular compartments, the ^{131}I content in thyroid is similar in different ages group (see last row in

TABLE 3 entitled: "I-131 activity in thyroid due to constant intake rate of 1 Bq") and individual age does not contribute more than 20% to the uncertainty of predicted ^{131}I thyroid contents. On the other hand, the individual characteristics and endemic property might have stronger influence on measured ^{131}I level in thyroid but it could not be included in Scenario.

TABLE 3. The iodine metabolism model: Johnson, J.R. (1981). Radioiodine Dosimetry. Journal of Radioanalitycal Chemistry, 65, 223-238

METABOLIC PARAMETERS	Age Groups							
	3 month old	1 year old	2 years old	5 years old	10 years old	15 years old	woman	man
GUT/LUNG fraction	1	1	1	1	1	1	1	1
Body mass M_s [kg]	3.5	7.2	10.9	22	40	58.9	58	70
Thyroid mass M_t [g]	1.63	2.12	2.65	4.39	7.9	12.1	17	20
Daily intake of stable iodine [$\mu g\ d^{-1}$]	10	20.6	31.1	62.8	116	168	166	200
inorganic compartment [μg]:	5	10	16	32	60	85	84	100
thyroid compartment [μg]:	300	300	300	990	3700	8300	10000	12000
organic compartment [μg]:	56	120	170	350	650	940	930	1100
GUT/LUNG iodine uptake rate l_1 [d^{-1}]	192	192	192	192	192	192	192	192
Thyroid uptake rate from inorganic comp. $s_2 = 65 *(M_s/70)$ [$\mu g\ d^{-1}$]	3.3	6.7	10.1	20.4	37.1	54.7	53.9	65.0
iodine release rate by thyroid: $l_3 = s_2 /Mt$ [d^{-1}]	0.0108	0.0223	0.0337	0.0206	0.0100	0.0066	0.0054	0.0054
iodine release from organic comp. to inorganic comp. l_4 [d^{-1}]	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053
iodine release from inorganic comp. to urine l_5 [d^{-1}]	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92
iodine release from organic comp. l_6 [d^{-1}]	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
I-131 activity in thyroid due to constant intake rate of 1 Bq	**2.24**	**2.02**	**1.84**	**2.05**	**2.23**	**2.34**	**2.36**	**2.36**

2.4.3 *^{131}I thyroid burden from inhalation*

Radioiodine uptake due to inhalation of contaminated air was an additional task for Scenario Plavsk as it required models to reconstruct the ^{131}I airborne concentration. However, the expected ^{131}I activity in thyroid due to inhalation becomes remarkably low (less than 10%) comparing with expected ^{131}I activity in thyroid due to ingestion at the date when the thyroids measurements were performed (see FIG 11).

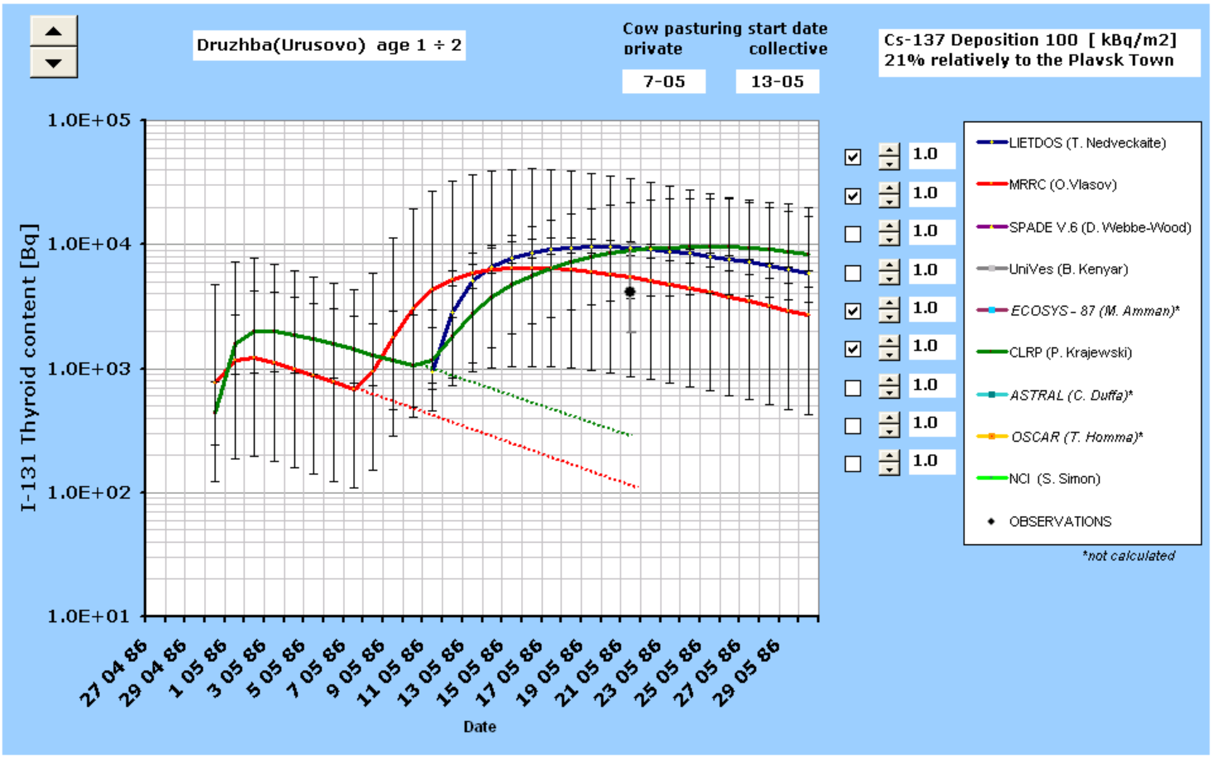


FIG 11. A comparison of the expected activity of ^{131}I in thyroid (dashed lines) due to inhalation to the activity of ^{131}I due to ingestion and inhalation for MRRC (Vlasow) and CLRP (Krajewski) predictions.

2.4.4 *^{131}I burden of new born*

Predictions of the ^{131}I activity in the thyroid of new born was omitted in this preliminary task because of lack proper calculation methodology. Nevertheless in the second run of predictions the suggested methodology should be applied (see APPENDIX E).

2.4.5 Comparison of observed and predicted ^{131}I contents in thyroid

A comparison of measured and predicted values for adults inhabitants of Plavsk Town is presented on FIG 12. Measurements of thyroids in Plavsk district were performed about two weeks later after passing of radioactive cloud i.e. in the period of 13-30 May, but during only one day for each location. The 95% confidence interval of the mean[11] for each age group in particular settlement ranges over two fold of the mean and is presented on graphs. Verification of the ^{131}I in thyroids variation in time base on measurements values is difficult because of very short period of measurements. Moreover the source of contaminated milk (from private or collective farm) is uncertain, nevertheless Scenario description suggests to evaluate radioiodine intakes base on the predictions of ^{131}I concentration in local milk (for settlement) rather than milk from collective farms.

The predicted versus observed data for ^{131}I contents in thyroids of individuals from 15 settlements and Plavsk town are presented on . The main reasons of discrepancies is discussed in previous sections. Generally, for all models, the predicted activity of ^{131}I in thyroids follow previously predicted ^{131}I concentration in consumed milk and reflect assumed time when cows had been put on a pasture. About 70% predictions of one modelers that is closest to the observed data (MRRC, Vlasov) fit in a range of (3×observed, 1/3×observed), therefore the range about one order of magnitude uncertainty was acheved. For remaining models careful consideration of some initial assumptions might be recommended. Especially the dates of the beginning of pasturing collective and private cattle needs to be revised. Simple code errors also were evident for some models.

[11] assuming normal distribution

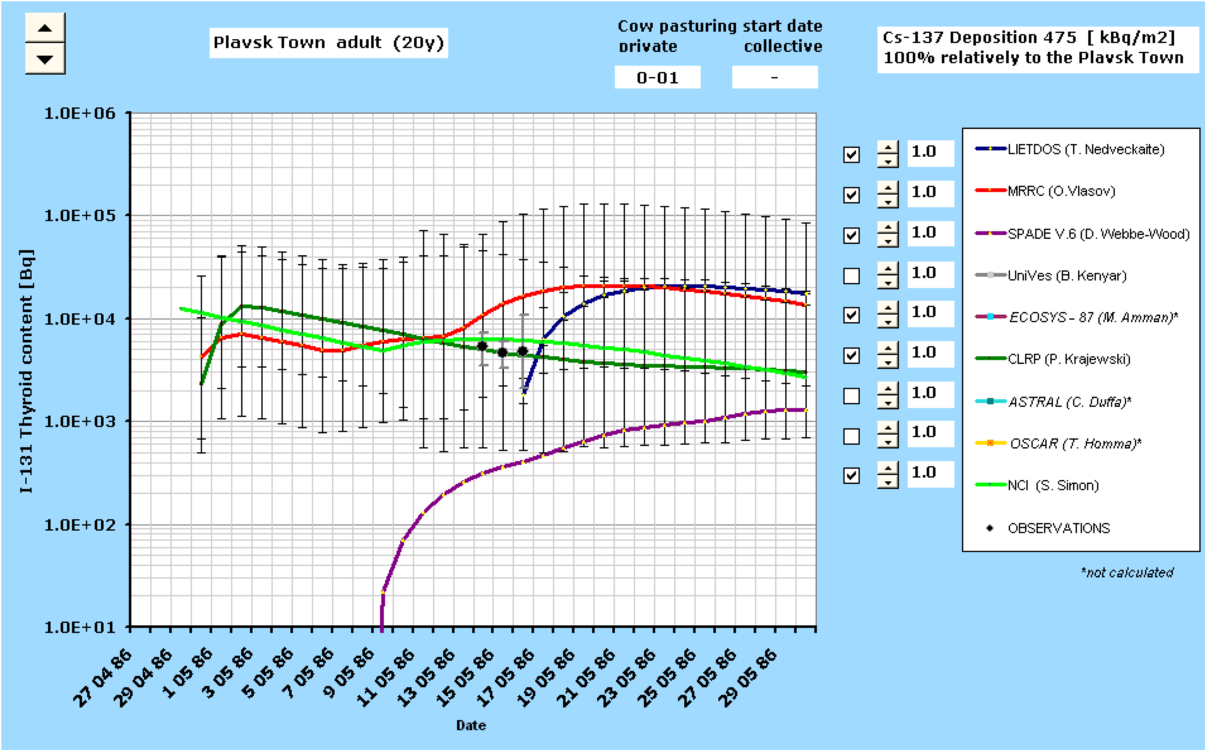


FIG 12. Example of predictions of ^{131}I content in thyroid for inhabitants (adults) of Plavsk Town

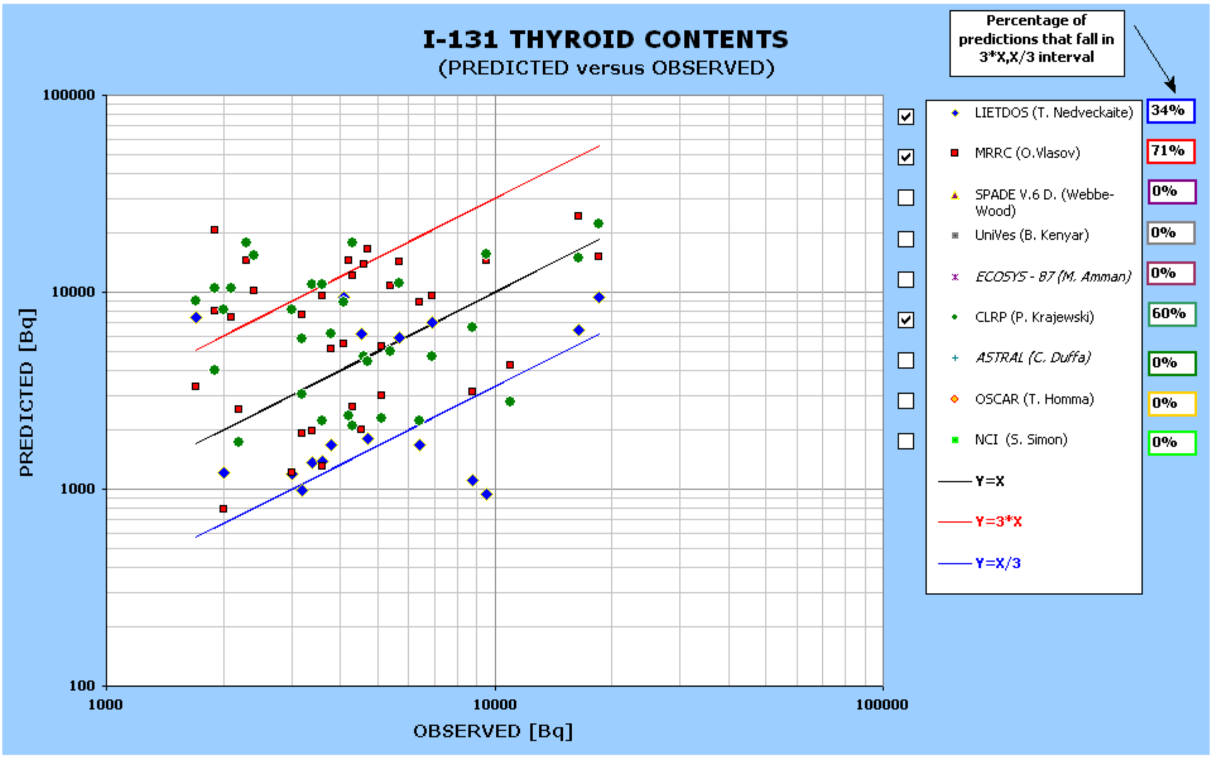
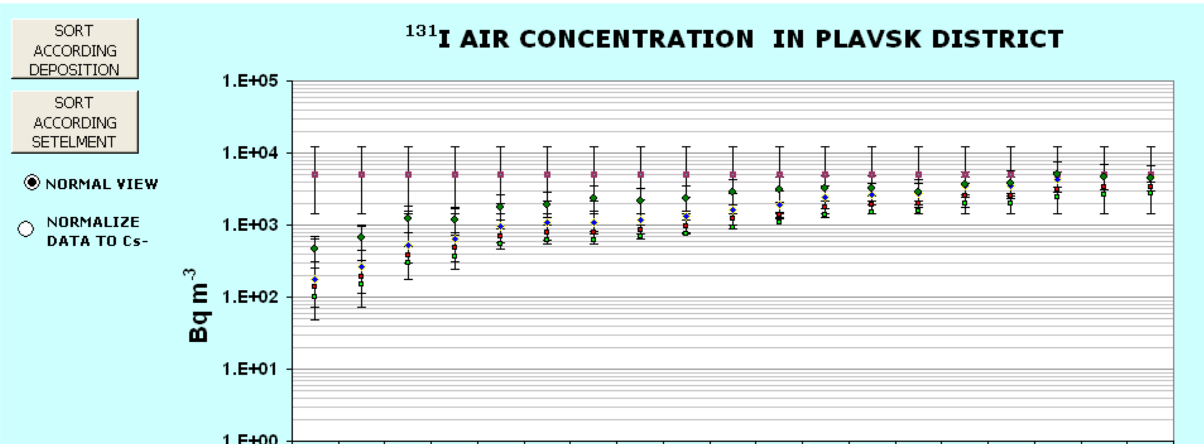


FIG 13. Selected predictions of ^{131}I thyroid content against observed data for Plavsk Scenario. Red and blue line indicate range of (3, 1/3) observation interval. In the squeare boxes the percentage of predictions that fall in (3,1/3) interval for particular participant are shown.

2.5 Reconstruction of ^{131}I concentration in air for Plavsk Scenario

Additional task of Plavsk scenario required participants to reconstruct the ^{131}I concentration in air over Plavsk districts base on evaluated previously ^{131}I deposition. Consequently the contribution of inhalation doses to the total doses could be evaluated. Models needed to assess airborne radioiodine partition (aerosol, elemental, organic), contribution of dry and wet deposition to the total deposition, dry deposition velocity, washout ratio. Made assumption and used parameters are summarized in TABLE 4.

Predicted values fit in a range factor two for particular milk farm (FIG 14). Most participants assumed an inhomogeneous concentration of ^{131}I in air that reflected inhomogeneous pattern of ^{131}I deposition. It implied that average air concentration during cloud passing changed dramatically (by factor 10) over 40 km width Plavsk region. Consequently the parameters that govern deposition level were assumed to be constant for whole Plavsk district. One model (Ecosys-98/Ammand) assumed a constant ^{131}I concentration in air over whole Plavsk district. Some questions aroused about reality of this assumptions. Despite of consistency in predictions, verification of assumptions mentioned above need advanced analysis using plume dispersion models and more detailed information with respect to meteorological condition.



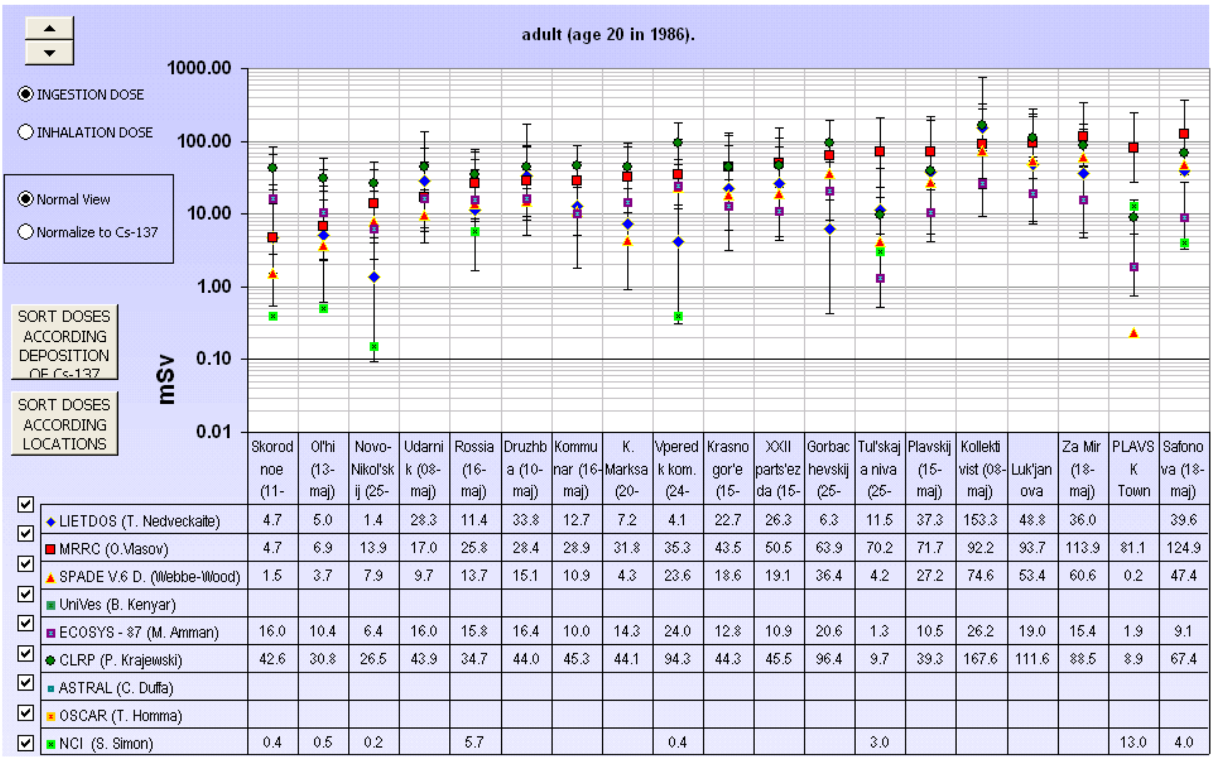
	Skorodnoe	Ol'hi	Novo-Nikol'skij	Udarnik	Rossia	Druzhba	Kommunar	Im. K. Marksa	Vperedk komm	Krasnogor'e	im.XXII parts'ezda	Gorbachevskij	Tul'skaja niva	Plavskij	Kollektivist	Im. Luk'janova	Za Mir	PLAVSK Town	Im. Safonova
LIETDOS (T. Nedveckaite)	175	263	526	643	974	1071	1091	1198	1334	1646	1909	2416	2659	2708	3487	3546	4305		4724
MRRC (O.Vlasov)	136	192	383	477	707	789	785	866	968	1204	1374	1753	1928	1951	2569	2550	3101	3327	3407
SPADE V.6 D. (Webbe-Wood)																			
UniVes (B. Kenyar)																			
ECOSYS - 87 (M. Amman run3)	4970	4970	4970	4970	4970	4970	4970	4970	4970	4970	4970	4970	4970	4970	4970	4970	4970	4970	4970
CLRP (P. Krajewski)	471	676	1200	1186	1756	1900	2315	2135	2364	2825	3128	3251	3271	2866	3659	3765	4992	4577	4469
ASTRAL (C. Duffa)																			
OSCAR (T. Homma)																			
NCI (S. Simon)	100	150	301	367	557	612	623	685	763	941	1091	1381	1520	1548	1993	2026	2460	2644	2700

MILK FARM NAME

FIG 14. Reconstruction of ^{131}I concentration in air for Plavsk Scenario (sorted according ^{137}Cs deposition)

2.6 Dose assessment

The final target of the scenario was to predict mean values of the thyroid dose (committed equivalent dose to thyroid) from ingestion an inhalation for six different age groups i.e. new born, age 1÷3 age, 3÷7, age 8 ÷12 and adult for particular milk farm area and Plavsk Town. The example of predicted doses from ingestion (mainly contaminated milk) are shown on FIG 15. The range of predicted ingestion doses is about one order of magnitude for each locations that reflects differences in predicted ^{131}I concentration in milk by particular participants. It needs to remark that to assess ingestion dose the longer period for ^{131}I concentration in milk had to be produced by model (approx. up to end of July 1986) then it was required by formularies provided with Scenario Plavsk. The example of predicted doses from inhalation are presented on (FIG 16) and item normalized to ^{137}Cs deposition on (FIG 17) . The doses calculated for the same location ranged by factor 7 across different participant and reflect differences in predictions of ^{131}I concentration in air. Generally, inhalation doses are 10% of the total dose that is in agreement with evaluation made by Scenario provider. However, variability of inhalation doses in Plavsk district is determined by range of changeability of ^{131}I concentration in air over 40×60 km area and again it is mater of discussion.



	Skorodnoe (11-	Ol'hi (13-maj)	Novo-Nikol'skij (25-	Udarnik (08-maj)	Rossia (16-maj)	Druzhba (10-maj)	Kommunar (16-maj)	K. Marksa (20-	Vperedk kom. (24-	Krasnogor'e (15-	XXII parts'ezda (15-	Gorbachevskij (25-	Tul'skaja niva (25-	Plavskij (15-maj)	Kollektivist (08-maj)	Luk'janova	Za Mir (18-maj)	PLAVSK Town	Safonova (18-maj)
LIETDOS (T. Nedveckaite)	4.7	5.0	1.4	28.3	11.4	33.8	12.7	7.2	4.1	22.7	26.3	6.3	11.5	37.3	153.3	48.8	36.0		39.6
MRRC (O.Vlasov)	4.7	6.9	13.9	17.0	25.8	28.4	28.9	31.8	35.3	43.5	50.5	63.9	70.2	71.7	92.2	93.7	113.9	81.1	124.9
SPADE V.6 D. (Webbe-Wood)	1.5	3.7	7.9	9.7	13.7	15.1	10.9	4.3	23.6	18.6	19.1	36.4	4.2	27.2	74.6	53.4	60.6	0.2	47.4
UniVes (B. Kenyar)																			
ECOSYS - 87 (M. Amman)	16.0	10.4	6.4	16.0	15.8	16.4	10.0	14.3	24.0	12.8	10.9	20.6	1.3	10.5	26.2	19.0	15.4	1.9	9.1
CLRP (P. Krajewski)	42.6	30.8	26.5	43.9	34.7	44.0	45.3	44.1	94.3	44.3	45.5	96.4	9.7	39.3	167.6	111.6	88.5	8.9	67.4
ASTRAL (C. Duffa)																			
OSCAR (T. Homma)																			
NCI (S. Simon)	0.4	0.5	0.2		5.7				0.4				3.0					13.0	4.0

FIG 15. Example of predictions of thyroid doses from ingestion in Plavsk district (adults) – doses sorted according deposition of ^{137}Cs.

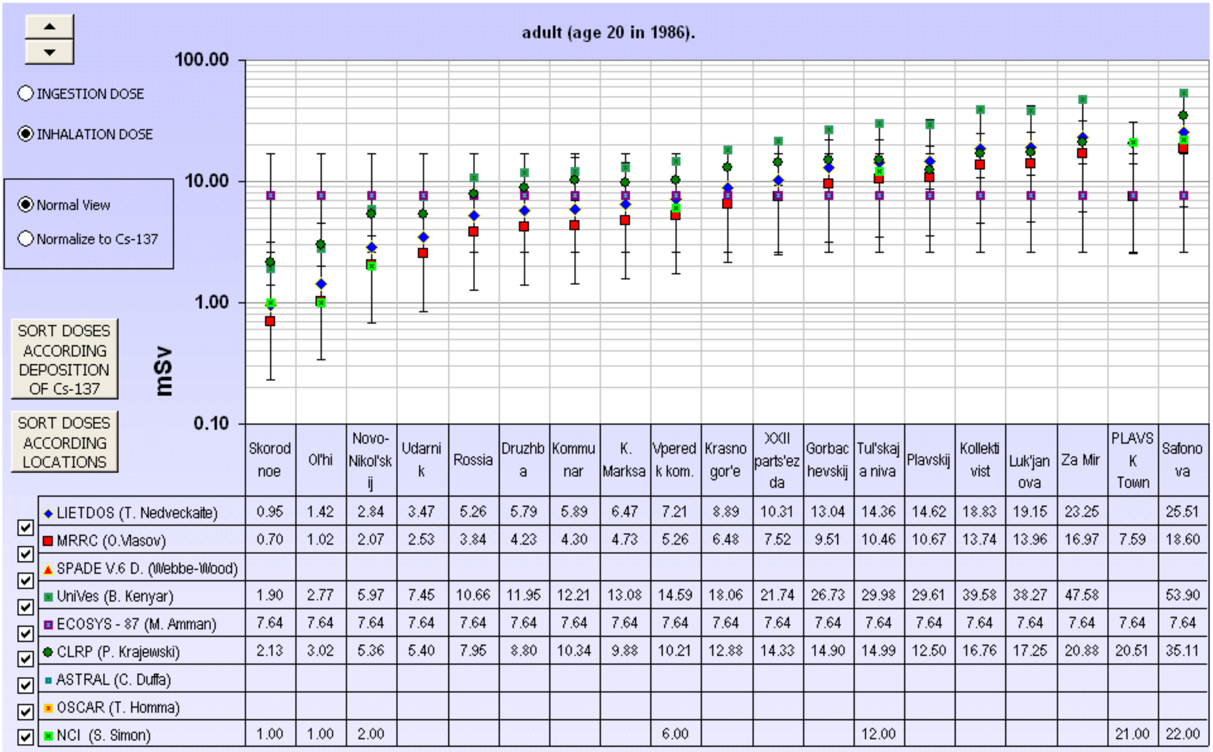


FIG 16. Example of predictions of thyroid doses from inhalation in Plavsk district (adults) – doses sorted according deposition of ^{137}Cs

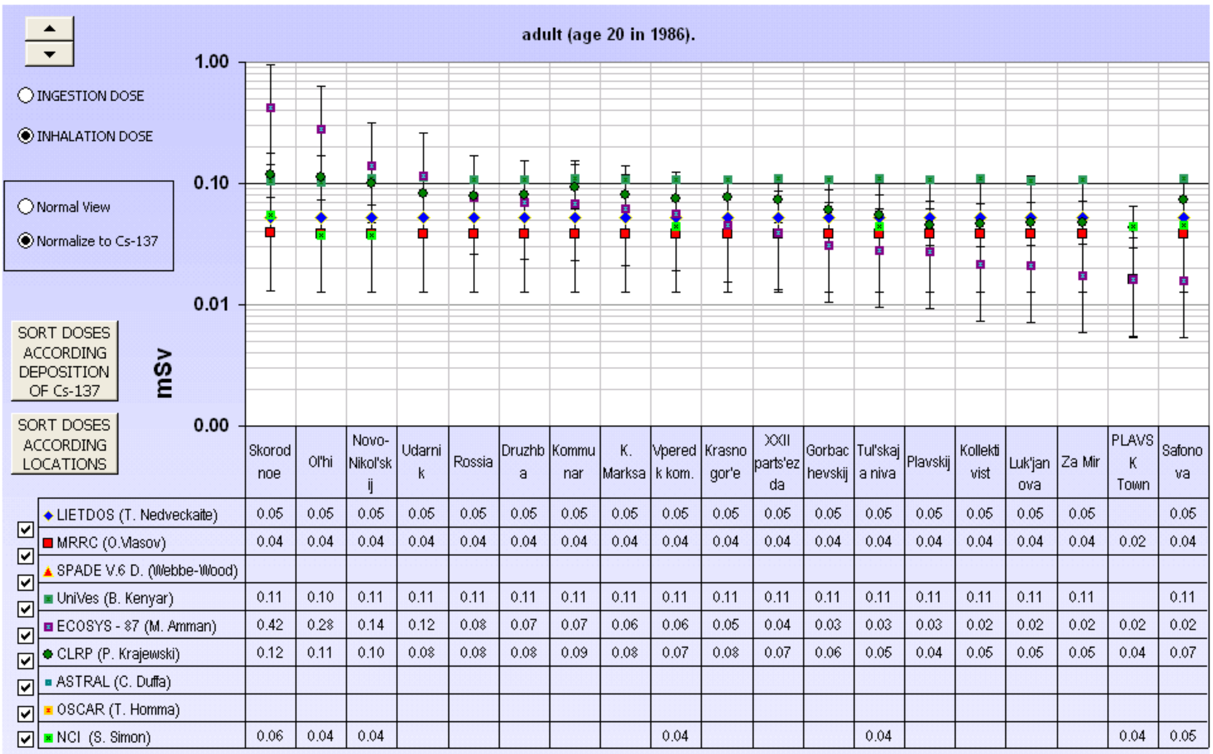


FIG 17. Example of predictions of thyroid doses from inhalation in Plavsk district (adults) – doses sorted and normalized according deposition of ^{137}Cs

TABLE 4. Summary of parameters used by participants

END POINT \ PARTICIPANT	1	2	3	4	5	6	7	8	9
	LIETDOS(T. Nedveckaite)	**CLIMRAD** (O.Vlasov)	**SPADE V.6 (D.** (Webbe-Wood)	**UniVes** (B. Kenyar)	**ECOSYS – 87** (M. Amman)	**CLRP** (P. Krajewski)	**ASTRAL** (C. Duffa)	**OSCAR** (T. Homma)	**NCI** (S. Simon)
^{131}I deposition in Plavsk district									
^{131}I deposition calculation in Plavsk district base on Cs-137 deposition data given in Plavsk scenario (say Yes or No)	YES	YES	YES	YES	YES	YES	YES	YES	YES
Isotopic ratio ^{131}I/^{137}Cs given in scenario **3.34**	YES	YES	YES	Implicitly by reconstruction of air conc. and rate of dep.	YES	$8.85\times(\sigma_{Cs\text{-}137})^{0.85}$	YES	YES	YES
The dynamic of ^{131}I deposition over the Plavsk district: The date when first plume of airborne ^{131}I arrive at Plavsk district ? The date when first plume of airborne ^{131}I depart the Plavsk district ?	30 April 8:00 1 May 8:00	29 April 12:00 30 April 12:00	29 April 18:00 30 April 6:00	Sigmoint distribution with the mean value given by the directors of farms	29 April 13:00 30 April 9:00	29 April 12:00 30 April 9:00	29 April 12:00 30 April 9:00	-	-
If you have assume different period of plume arrival for particular milk farms please specify.	NO	NO	NO	Variation in time	NO	NO	NO		
^{131}I concentration in grass									
grass yield (kg· m^{-2} fresh weight) at the start of ^{131}I deposition at the end of ^{131}I deposition	0.45 0.45	0.2 0.2	0.085 0.085	0.20 0.55	0.16 0.16	0.08 0.08	0.7 0.7		
grass interception fraction (dimensionless for dry deposition for wet deposition formula used: **1-exp(-μY), μ =** weathering H $_{½}$ [d]	0.36 0.36 1 8.7	Own evaluation	 0.7 2.8 13.2	 0.7 - 10	 3% 4	0.13 0.05 7 10	 0.56 5.610-2 11.6		

TABLE 4 (cont). Summary of parameters used by participants

PARTICIPANT / END POINT	1	2	3	4	5	6	7	8	9
	LIETDOS(T. Nedveckaite)	**CLIMRAD** (O.Vlasov)	**SPADE V.6 (D.** (Webbe-Wood)	**UniVes** (B. Kenyar)	**ECOSYS – 87** (M. Amman)	**CLRP** (P. Krajewski)	**ASTRAL** (C. Duffa)	**OSCAR** (T. Homma)	**NCI** (S. Simon)
^{131}I concentration in milk									
Consumption rate									
Cattle consumption rate of fresh grass [$kg \cdot d^{-1}$]	45	40	42.5	45	42	Gradual pasturing 5/10/20/ 35/45	50		
Cattle inhalation rate [$m3 \cdot d^{-1}$] if applied	not applied	not applied	130	120	not applied	100	not applied		
Soil ingestion [$kg \cdot d^{-1}$]	0.25	not applied	not applied	not applied	not applied	not applied	not applied		
Iodine cow metabolic model Milk transfer coefficient for ^{131} I($d \cdot L^{-1}$) if applied Max value of ^{131}I secreted in milk after single intake of 1 Bq [$Bq \cdot L^{-1}$] Equilibrium level of ^{131}I- after chronic intake of 1 Bq per day [$Bq \cdot L^{-1}$]	0.003	0.01	?	0.007	0.003	0.008	0.003		
^{131}I contents in thyroid (thyroid burden)									
Milk consumption rates [$L \cdot d^{-1}$]	urban/rural	urban/rural	urban/rural	urban/rural	urban/rural	urban/rural			
Adult	0.667		0.27/0.68	0.68	0.27/0.68	0.3/0.6			
Child (8 – 12 years old)	0.44		0.3/0.44	0.45	0.3/0.44	0.3/0.4			
Child (3-7 years old)	0.60		0.4/0.6	0.60	0.4/0.6	0.4/0.6			
Babies (1-2 years old)	0.56		0.4/0.56	0.55	0.4/0.56	0.4/0.6			
Newborn	0.293		na	0.40	na	na			
L. vegetables consumption rate(kg· d^{-1}) if applied									
Adult	0.03			0.05					
Child (8 – 12 years old)	0.03			0.05					
Child (3-7 years old)	0.03			0.05					
Babies (1-2 years old)	0.03			0.02					
Newborn	0			0.01					
Inhalation rate (m3·d-1)									
Adult	20			22	22.3	24			
Child (8 – 12 years old)	13.3			15	15.4	15			
Child (3-7 years old)	8.8			10	8.6	10			
Babies (1-2 years old)	5.65			4	5.0	6			
Newborn	2.9			2	na	2			
Iodine metabolic model:				Modifica tions					
Johnson, J.R. (1981) (supplied with Plavsk scenario)			YES	0.24	YES	YES			
ICRP-56 publication	YES	YES		0.089					
Own				0.21[d] 28 [d]					

TABLE 4 (cont). Summary of parameters used by participants

PARTICIPANT / END POINT	1	2	3	4	5	6	7	8	9
	LIETDOS(T. Nedveckaite)	**CLIMRAD** (O.Vlasov)	**SPADE V.6 (D.** (Webbe-Wood)	**UniVes** (B. Kenyar)	**ECOSYS – 87** (M. Amman)	**CLRP** (P. Krajewski)	**ASTRAL** (C. Duffa)	**OSCAR** (T. Homma)	**NCI** (S. Simon)
Reconstruction of ^{131}I concentration in air									
^{131} I iodine speciation (%): reactive gas (I_2) particulate organic	30 40 30	-	Not considered	100		29/30Apr. 25/28 40/55 35/17			
dry deposition velocity ($m\cdot s^{-1}$) if considered ? reactive gas (I_2) particulate organic	9.5×10^{-3} 1.6×10^{-3} 7.0×10^{-5}	1.0×10^{-2}	Not considered	1.8×10^{-3}	1.5×10^{-3}	1.1×10^{-2} 1.2×10^{-3} 1.1×10^{-4}			
washout factor w_r (dimensionless, defined as the ratio of the concentration of radionuclide in surface-level precipitation to the concentration in surface level air during the period of rainfall) W_{wet} deposition ($Bq\cdot m^{-2}$)= $w_r\times C_{concentration\ in\ air}(Bq\cdot m^{-3})\times R_{rainfall}(m)$ reactive gas (I_2) particulate organic	5.0×10^{6} 2.5×10^{6} 8.0×10^{3}			2.0×10^{5}	3.1×10^{5}	2.0×10^{5} 2.0×10^{4} 2.0×10^{5}	500±200		
Doses calculation									
Inhalation dose Time spent indoors [hours per day] Adult Child (8 – 12 years old) Child (3-7 years old) Babies (1-2 years old) Newborn House filtration factor (ratio air concentration indoor to air concentration outdoor) Dose conversion factors if different to those given in scenario	Effective 0.7			17 18 18 18 20 Effective 0.7 1.5×10^{-7}	19.3 0.5 Effective 0.59 ½?	16 20 Effective 0.6			
Ingestion dose Dose conversion factors if different to those given in scenario				$4.5\times10^{-}$	YES				

3 Concluding remarks

Ten experts in environmental modeling participated in the Plavsk Scenario, including four who had not previously been involved in the international model testing programs. The contribution of the participants to the first Scenario Plavsk presumed future success of the launched project.

During the second IWG meeting several aspects of models performance were discussed. The following problems were identified to be most in need of attention:

1. Cnstant isotopic ratio $^{131}I/^{137}Cs$ provided by Scenario Plavsk gives fairly good approximation of ^{131}I deposition, however inhomogeneous ^{137}Cs deposition for whole Plavsk district and relatively short time of rain during the cloud passage (6 hours) indicates that the radioactive fallout can be classified as mixed (dry&wet) and a regional approach might be applied with more complex relationship ^{131}I deposition to ^{137}Cs deposition.
2. Model for grass interception fraction in a case of mixed (dry&wet) radioiodine fallout need to be carefully considered.
3. Uncertainty associated with prediction of ^{131}I concentration in air over the Plavsk district depends on partition of airborne radioiodine in to different forms (particulate, elemental, organic) during the passage of radioactive cloud over the Plavsk district as well as meteorological conditions.
4. Inhomogeneous pattern of ^{131}I fallout not necessary reflects changeability of ^{131}I concentration in air over 40×60 km area. A plume dispersion model are envisaged to verify this assumption.
5. The time when cows from collective farms were put on a pasture seems to be the most important factor of miss predictions of ^{131}I concentration in milk and consequently ingestion doses. It needs to be carefully considered. Analysis of measured data indicate on 12-15 May 1986 as probable period of start grazing in the most of collective farms.
6. There is lack of validated tool to make prediction of ^{131}I thyroid content for new born (age less then one year). This modeling approach needs to be developed and implemented in environmental models and verified base on proper Scenario data set.
7. Measurements data provided for Scenario Plavsk i.e. ^{137}Cs deposition, ^{131}I milk concentration, ^{131}I thyroid content were expressed as a arithmetic mean with standard deviation. The 95% confidence uncertainty ranges of measurements data need to be evaluated base on log-normal distribution.
8. Assessments of ingestion and inhalation dose that had been performed previously by Scenario Plavsk provider need to be included as relevant base for models intercomparison.

In general, although IWG was dealing with areas of assessment modeling for which the capabilities are not yet well established; there is remarkably improvement in models performance comparing with previous radioiodine scenarios. Predictions of the various models were with in a factor of three of the observations, discrepancies between the estimates of average doses to thyroid produced by most participant not exceeded a factor of ten. The process of testing independent model calculations against independent data set also provided useful information to the originators of the test data.

4 Planned schedule of IWG activities:

1. Comments and supplementary files to the "Report on 2nd Meeting of the IAEA's EMRAS* I-131 Working Group – **end of July 2004**

   I would please especially participants of our meeting to send to Tiberio Cabianka their presentations during the meeting to be publish on EMRAS Web-Site.

   I would also please participants of IWG to check and complete their data especially parameters presented in Table 4 and write a few statement comments about their predictions.
2. Revised set of independent observation data (milk, thyroid) – in respect with calculation of 95% uncertainty ranges base on log-normal distribution – **15 August 2004**
3. Final calculation of models predictions for Plavsk Scenario and transmission to the IAEA – **end of September 2004 (possible two week shift but no later than absolute dead line on 10 October 2004**).
4. Distribution of Warsaw scenario draft – **approximately end of October.**
5. Comparison of model predictions, final discussion, conclusion, report preparation: **2nd EMRAS Combined Meetings 8-11 November 2004 in Vienna**

6. Presentation of WARSAW Scenario – **2nd EMRAS Combined Meetings 8-11 November 2004 in Vienna,**

I look forward to working with you over the next three months on this interesting and important topic. Please don't hesitate to contact me with any queries or comments.

Paweł Krajewski
IWG Leader

APPENDIX A: Provisional Agenda of the Second Meeting of the IAEA's EMRAS I-131 Working Group, CIEMAT, Madrid, Spain, 31 May to 2 June 2004

Monday, 31 May 2004		
10:00 – 10:30	Welcome to the participants	T. Cabianca (IAEA)
	Administrative arrangements	A. Aguero (CIEMAT)
	Introduction to the IWG and summary of activities carried out so far a. Results of the first questionnaire b. Summary of the first run predictions of PLAVSK SCENARIO c. Summary of the current activities (results of the second questionnaire) discussion	P Krajewski
10:30 – 11:00	*Coffee break*	
11:00 – 12:30	Presentation of PLAVSK SCENARIO – Discussion on input scenario data a. Credibility of isotopic ratio I-131/Cs-137 b. Contribution of I-131 dry deposition to total deposition c. Metabolic model of iodine for cows d. Default dose conversion factors for different age group e. Availability of additional data	I. Zwonowa, P. Krajewski
12:30 – 14:00	*Lunch break*	
14:00 – 15:30	Presentation of model predictions (first run) – Discussion on modellers assumptions, parameter values used, uncertainty of predictions	
	f. MRRC	O. Vlasov

	g. ASTRAL	C. Duffa
15:30 – 16:00	*Coffee break*	
16:00 – 17:30	Presentation of model predictions (first run) cont.	
	h. Ecosys-87	M. Amman
	i. OSCAAR	T. Homma

Tuesday, 1 June 2004		
10:00 – 10:30	Presentation of model predictions (first run) cont.	
	j. TAM DYNAMIC	B. Kanyar[12]
10:30 – 11:00	*Coffee break*	
11:00 – 12:30	Presentation of model predictions (first run) cont.	
	k. LIETDOS-FILSTEG	T. Nedveckaite[12]
	l. CLRP	P. Krajewski
	m. SPADE V$.6	D. Webbe-Wood[12]
12:30 – 14:00	*Lunch break*	
14:00 – 15:30	Presentation of measurements data n. Deposition o. Milk p. Thyroid	I. Zvonowa
15:30 – 16:00	*Coffee break*	
16:00 – 17:30	Comparison of model predictions and observed data q. Discussion on identification of major sources of discrepancy r. Discussion on uncertainty of predictions	

Wednesday, 2 June 2004		
10:00 – 10:30	Doses calculation (model intercomparison task) s. Discussion on applied methodology t. Discussion on final report of PLAVSK Scenario u. IWG activities before November meeting (second run of predictions of PLAVSC scenario)	P Krajewski

[12] This presentation will be given by P Krajewski

10:30 – 11:00	*Coffee break*
11:00 – 12:30	Future activities of IWG (selection of next scenario) Any other Business Closure of meeting

APPENDIX B : List of presentations of 2nd meeting participants available as PDF file.

1. **CLIMRAD**

   Mr O. Vlasov.
   Russian Federation,
   Medical Radiological Research Cente'r

2. **ASTRAL**

   Ms C. Duffa
   France,
   Institut de Radioprotection et de Sûreté Nucléaire (IRSN)

3. **OSCAAR**
   Mr T. Homma,
   Japan,
   Japan Atomic Energy Research Institute

4. **ECOSYS-87**
   Mr M. Ammann,
   Finland,
   Radiation & Nuclear Safety Authority (STUK)

5. IWG activities Summary
6. Comments to INPUT DATA of Scenario Plavsk
7. Presentation of results of predictions (firs run)

   Mr Paweł Krajewski

   IWG leader

APPENDIX C: Report of Irina Zvonova on participation in the iodine working group meeting, Madrid, 31 May - 2 June, 2004

Preliminary results of model calculations by the "Plavsk" scenario were discussed at the iodine working group meeting in Madrid, 31 May - 2 June, 2004. According to the scenario the modelers calculated dynamics of ^{131}I concentration in milk and ^{131}I content in thyroid of residents of the Plavsk district of Tula region of Russia after the Chernobyl accident. Results of calculations were compared between themselves and with results of direct measurements.

My participation consisted in the presentation of the measurement results for verification the model calculations. Results of spectrometric measurements of milk samples from 18 collective farms and from town of Plavsk collected in May 1986 were presented for discussion. From one to 7 measurements were made in the examined farms from 14 to 30 of May 1986. Results of direct measurements of ^{131}I

thyroid content in inhabitants of 16 settlements of the Plavsk district in May 1986 were also presented for the verification of the calculations. Methods of ^{131}I measurements in milk samples and in human thyroid, local features of inhabitant's lifestyle, grazing of cattle, milk consumption and processing were reported and explained in details. I answered on questions of participants.

Input parameters for calculations and reasons of discrepancy discussed at the meeting. During the discussion on ratio ^{131}I/^{137}Cs in fallout depending on ^{137}Cs surface contamination I presented additional data based on literature and unpublished data that demonstrated the higher ratio ^{131}I/^{137}Cs in fallouts with low ^{137}Cs surface density (dry deposition) in comparison with the value attached to high ^{137}Cs surface density typical for wet deposition on the territory of the Bryansk-Belarus ^{137}Cs spot.

Dates of beginning pasture period were discussed at the meeting. According to the interviews of inhabitants in 1987 and interviews of heads of the collective farms in 1994 grazing of collective cattle began later than private cows. Analysis of available measurements of collective milk showed that dates of beginning grazing periods of private cows are more suitable for collective cattle than dates pointed for collective farms.

Uncertainty of information on milk measurements discussed at the meeting. The main uncertainty was in the form of records in working notebooks. The place of sampling was recorded as the name of a collective farm without a name of a settlement. But there were from 3 to 12 settlements with different level of radioactive contamination in collective farms, so uncertainty of milk sample for verification of the model calculation should be correlated with scattering of surface contamination in settlements included in an examined collective farm. A collective farm could have some milk farms (two or three). A milk sample could be taken from a separate milk farm, from a common container with mixed milk from all milk farms or from small cans in which inhabitants handed over excess milk from their private cows for transportation to a milk factory. These details were not pointed in the working notebooks.

Information on I-131 measurements in thyroid of inhabitants of the Plavsk district was presented for comparison with calculated results. Parameters of generalized distribution of I-131 content in thyroids of residences in a settlement in one date of measurements was presented.

Method of thyroid dose estimation based on results of direct measurements of I-131 in thyroids of local people and in local milk was reported at the meeting. This method was used for thyroid dose reconstruction in Russia.

APPENDIX D: Milk measurements

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Spectrometric measurements of ^{131}I content in milk samples and other foods in Tula region were carried out from May 14 till June 12, 1986 on the base of the regional sanitary-and-epidemiological station. For this purpose there was used a spectrometer on the base of the crystal of NaI(Tl) ∅40 x 40 mm, used to define the function of the thyroid gland. The detector was put inside the cylindrical leaden collimator in vertical position. The sample, which volume was 100 millilitres, in a thin glass was positioned on the butt of the detector. The measurement lasted for 100 seconds. Measurements were done in the energetic channel of gamma-radiation of ^{131}I: 150-450 keV. Minimally detected activity (MDA) of ^{131}I in sample with 100 seconds of measurement and 95 % of confidence probability was equal to 0.2 kBq/l. Totally there were performed 1744 measurements of milk samples.

When elaborating the measurement results it happened to be necessary to exclude those samples that arrived from the settlements, for which the soil contamination with caesium-137 has not been defined yet. Besides, measurements done in June 1986 were not used either, as in this period the number of measurements with sample's activity lower than the MDA increased so much, that it affected the results of averaging-outs. Thus, the operative data range counted 867 spectrometric measurements performed from May 14 till May 30.

All the measurements of ^{131}I concentration in milk got normalized for 1 kBq/m^2 of soil contamination with ^{137}Cs on the territory where the sample has been taken. When a collective farm was noted as the place of the sample's origin, the average contamination value for this collective farm was taken into consideration. Measurements distribution of normalized ^{131}I concentration in milk for one day of sample selection had an asymmetric nature, which can be described well with a logarithmically normal distribution. Therefore when calculating the average values of the relative concentrations for each day of measurements a logarithmically normal distribution was always used. On fig. 13 the logarithm dynamics is shown for the relative ^{131}I concentrations in milk in the Tula region, basing on the elaboration results of all the measurements performed within May 14 and May 30 1986. The average values of logarithms of the relative concentrations for each day of measurements are performed in table 30. The effective period of milk decontamination from iodine-131 in the Tula region s defined as 4,2 days.

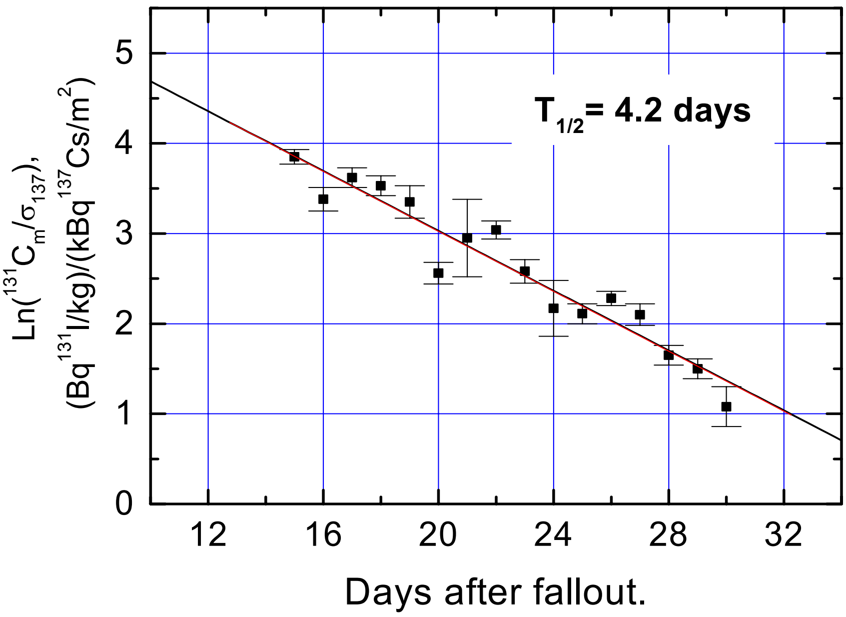

Fig.1. Dynamics of 131I concentration in milk samples from the Tula region.

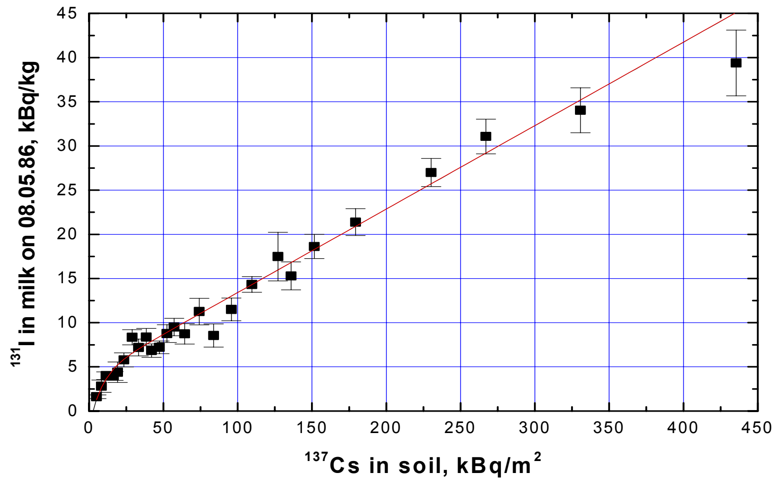

Fig. 2. Dependence of the referent 131I concentration in milk on soil contamination with ^{137}Cs in Tula region

Having the received meaning of the effective period, all the milk measurements were recalculated for a conventional date May 8, 1986. Concentration values reconstructed for this date were called the reference ^{131}I concentration in milk. All the reference concentrations in milk samples were consequently classified by the range of soil contamination with 137Cs in the place of the sample's origin. The average values of soil contamination and reference concentration were calculated from these data. Averaging results are reported in table 31, and on fig. 14 – a graphics of the reference ^{131}I concentration in milk depending on soil contamination with ^{137}Cs can be seen [20, 21]. Every point on the graphics represents an averaging of 16 to 69 measurements of milk samples from villages, which contamination with caesium-137 remains within the indicated range. Most of villages have had a relatively low radioactive contamination, so in the range of the contamination less than 74 kBq/m^2 the graphics' points are very close to each other and represent a higher number of measurements (about 60 each). There are fewer measurements from villages with a relatively high contamination level; they are classified by a wider range of soil contamination with ^{137}Cs.

The relation between the reference ^{131}I concentration in milk and the territory's contamination for rural settlements is described by the equation:

$$\mathbf{C^r_m} = (4.0 + 0{,}094 \cdot \boldsymbol{\sigma_{137}}) \cdot [1-\exp(-0.693 \cdot (\boldsymbol{\sigma_{137}}-2.5)/5)], \qquad (2)$$

where $\boldsymbol{\sigma_{137}}$ – density of soil contamination with caesium-137, kBq/m^2.

Transfer factor for 08.05.86: 0,094 kBq/l of ^{131}I per 1 kBq/m^2 of ^{137}Cs in soil

For 30.05.86: 0,0025 - " -

Reference ^{131}I concentration in milk of a town, $\boldsymbol{C^r_m(town)}$, is connected with the average reference iodine-131 concentration in milk of the district that provides this town with milk, $\mathbf{{}^rC_m}$, kBq/kg by the equation:

$$\boldsymbol{C^r_m(town)} = (0{,}75 \pm 0{,}05) \cdot \boldsymbol{C^r_m}, \quad \text{kBq/l}, \quad R=0.93. \qquad (3)$$

Iodine-131 measurements in thyroids of inhabitants

The ^{131}I content in the thyroid of people in the districts of the Tula region, which were contaminated by radioactive fallouts, was being measured in the radioisotope laboratory of Tula regional hospital from May, 13 till June 6, 1986. The measurements were done on the standard Russian-made equipment for radio diagnostics GTRM used for the functional diagnostics of the thyroid gland with ^{131}I. Thyroid measurements were done with collimated scintillation detector with a NaI(Tl) crystal ∅40 x 40 mm in the energetic channel of ^{131}I: 300-450 keV [21, 29, 30]. The equipment was calibrated according to the methods of diagnostic observation of patient's thyroid, using radioactive ^{131}I in solution $Na^{131}I$, prepared and certified by the national corporation "Isotope". When calibrating, the distance between the detector and the radioactive source was of 13,5 cm, the same as during the diagnostic measurements of patients.

People from the contaminated areas got measured in the position with the neck straight against the collimator. As soon as the detector was deepened inside the collimator, the distance between the neck of a measured person and the detector was 8 cm. This correction was introduced when estimating ^{131}I activity in the thyroid by measurement results. The minimal detectable activity of the apparatus is 0.5 kBq with the measurement time 60 seconds [29, 30].

Totally 643 people were measured from 40 settlements of the Tula region, where 385 persons were from rural settlements and 258 from urban settlements. Most of the measured people (459 persons) were living in the Plavsk district. The age distribution of measured urban and rural inhabitants is shown in table 58.

The results of iodine-131 activity measurements in the thyroid of people living in the district of interest for some measurements dates are reported in table 1.

APPENDIX E: Proposed methodology to calculate 131I activity in the thyroid of newborn

DOSES TO THE EMBRYO, FETUS AND NEWBORN CHILD FOLLOWING INTAKES OF RADIONUCLIDES AT WORK BY THE MOTHER

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Abstract

Estimates have been made of *in utero* and postnatal doses to the child after intakes of radionuclides by the mother during pregnancy and doses from the ingestion of radionuclides in breast milk. Results show that working conditions for pregnant women potentially exposed to tritiated water (HTO), ^{90}Sr or ^{131}I should take account of the possibility that doses to the child could be greater than reference adult values. Preliminary estimates suggest that exposures of women during breastfeeding to HTO, ^{90}Sr, ^{131}I or ^{137}Cs may result in doses to the child that are similar to reference adult values.

Introduction

The European Union Basic Safety Standards Directive[1] requires the working conditions for pregnant women to be such that the dose to the child will be as low as reasonably achievable and unlikely to exceed 1 mSv before birth. The directive also prohibits the employment of women who are breastfeeding in areas of work involving a significant risk of bodily radioactive contamination. The relationships between maternal intakes of radionuclides and doses to the child during pregnancy and breastfeeding are not straightforward. This paper presents preliminary estimates of doses to the embryo, fetus and newborn child, following intakes of radionuclides by the mother before conception, during pregnancy and during breastfeeding. The radionuclides considered here are ^{3}H, ^{90}Sr, ^{131}I, ^{137}Cs, and ^{239}Pu. The aim of this work is to provide guidance to employers to help identify types of work where these considerations are important.

Modelling approaches

Limited information is available on changes during pregnancy in factors such as placental transfer of radionuclides, distribution within the fetus, geometric relationship of the fetus to maternal organs, and tissue radiosensitivity. The calculation of doses to the embryo and fetus therefore requires a number of assumptions. The approaches adopted here, summarised below, are as developed for an International Commission on Radiological Protection (ICRP) report due for publication in 1999.

Dose to the embryo to the end of week 8 of gestation is taken to be the same as the dose to the uterine wall.

Photon doses to the whole fetus from week 9 to term (38 weeks) from radionuclides in maternal tissues and the placenta are calculated using mathematical phantoms representing the pregnant female at the end of the 1st, 2nd & 3rd trimesters[2].

Because of the small mass of fetal tissues, the calculations take account of both self dose and irradiation of other fetal tissues (so called cross-fire).

For most radionuclides, transfer to the fetus is calculated from the ratio of the concentration in the body of the fetus (C_F) relative to the mother (C_M). These $C_F{:}C_M$ ratios, based mainly on animal data, are assumed constant after intake. In some cases (e.g. Pu) different values are specified for different times of intake. A similar ratio, $C_{Pl}{:}C_M$, is used to calculate activity in the placenta.

The distribution of elements between fetal tissues is based on that defined for the 3 month old infant[3].

Where better data are available, it is possible to develop specific dynamic models. Such models have been developed for iodine and the alkaline earth elements.

ICRP[(4)] tissue weighting factors are used to calculate an *in utero* effective dose.

Radionuclides present in the fetus at term are distributed to corresponding tissues of postnatal models for the newborn infant in order to calculate committed doses.

Methods for the calculation of doses to newborn children from radionuclides transferred in breast milk have yet to be agreed by ICRP. The provisional approach adopted here takes account of limited human and animal data. Transfer to milk from maternal blood and tissues is considered on an element-specific basis. Milk consumption is taken to average 850 ml d^{-1} throughout breastfeeding. Increased intestinal absorption in infants is taken into account in estimates of radionuclide absorption from milk.

Biokinetic data

Tritium

Tritiated water (HTO) in the body of the fetus and mother are assumed to be in equilibrium at all times after intake. The water concentration is about 60% higher in the fetus than in the mother, so a $C_F:C_M$ ratio of 1.6 is adopted. The concentration of ^3H in the placenta is taken to be the same as in maternal tissues ($C_{Pl}:C_M$ = 1). For breast milk it is assumed that the HTO content is in equilibrium with maternal body water.

Iodine

A dynamic model developed by Berkovski[(5)] has been used for the transfer of I to the embryo and fetus. The model includes bidirectional fetomaternal transport and retention in the thyroid and other tissues of the fetus. For breast milk, based on an estimated average I secretion into milk of 45 µg d^{-1}, it is assumed that 20% of the activity in maternal blood is transferred to milk.

Caesium

On the basis of the available human data, $C_F:C_M$ and $C_{Pl}:C_M$ ratios of 1 are adopted for Cs. For breast milk, it is assumed that there is an initial transfer to milk of 13% of Cs entering maternal blood and that subsequent daily transfer is 0.2% of the maternal body content[(6)].

Strontium

A biokinetic model developed by Fell et al.[(7)] has been used for the transfer of alkaline earths to the human fetus. The model takes account of changes during pregnancy in maternal bone turnover and urinary excretion and relates fetal transfer to requirements for skeletal calcification. Daily transfer of Sr to the fetus is taken to be lower than for Ca by a factor of 0.6. For breast milk, daily secretion of Ca is taken to average 280 µg and Sr secretion to be 0.6 times that of Ca. The fractional absorption of ingested Sr by the child is assumed to be 0.8 at birth, 0.6 from 2 weeks to 2 months of age and 0.4 to 6 months.

Plutonium

Based on animal data, the C_F:C_M ratios adopted are 0.03, 0.1, 0.3 and 1 for intakes prior to pregnancy and during the 1st, 2nd & 3rd trimesters, respectively. The ratio C_{Pl}:C_M is taken to be 0.1 for intakes before conception and 5.0 for intakes during pregnancy. The distribution of Pu in the fetus is taken to be the same as the short-term distribution in the 3 month old infant(3). The concentration of Pu in milk is taken to be about 10% of that in maternal blood. Fractional absorption of ingested Pu by the child is assumed to be 5 x 10^{-3} to 6 months of age.

Results and Discussion

Table 1 gives preliminary estimates of doses following inhalation of radionuclides at the beginning of the 15th week of pregnancy and compares total doses to the child, *in utero* and after birth, with corresponding reference doses for workers(3). For ^{3}H, ^{137}Cs and ^{90}Sr, doses for intakes later in pregnancy are lower than for intakes at 15 weeks, primarily because of the shorter duration of fetal exposure, although this is counteracted to some extent by increases in postnatal doses. For ^{131}I and ^{239}Pu, doses for intakes later in pregnancy are higher than intakes at 15 weeks by factors of up to about 10 and 2 - 3, respectively. The dominating effect for ^{131}I is the increasing I requirement of the fetal thyroid. For ^{239}Pu, doses resulting from greater transfer to the fetus in late pregnancy (3rd trimester) are largely delivered postnatally as a result of long-term retention in the child. For each radionuclide, doses to the child following intakes by the mother prior to conception are substantially lower than for intakes during pregnancy.

The dose estimates in Table 1 show that working conditions for pregnant women exposed to HTO, ^{90}Sr and ^{131}I should take account of the possibility that doses to the child will be greater than reference adult values. This will be true of other radionuclides as well, and we are continuing to look for important ones to which women may be occupationally exposed.

Preliminary calculations of doses to children from the ingestion of radionuclides in breast milk have been made, assuming maternal intake by inhalation (5 µm particles or vapour; as Table 1) shortly after giving birth. Committed effective doses are estimated to be similar to reference doses to workers for HTO, ^{137}Cs, ^{90}Sr and ^{131}I and a small fraction (< 10^{-4}) of worker dose for ^{239}Pu.

Radionuclide	**e (*in utero*)**	**e (total)[b]**	**e (total)/ e(adult)[c]**
HTO (vapour)	3.2×10^{-11}	3.2×10^{-11}	1.8
^{137}Cs (Type F[d])	2.8×10^{-9}	2.9×10^{-9}	0.4
^{90}Sr (Type F)	7.1×10^{-8}	7.4×10^{-8}	2.5
^{131}I (Type F)	3.4×10^{-9}	3.4×10^{-9}	0.3
^{239}Pu (Type S)	2.2×10^{-10}	7.7×10^{-9}	0.1

Table 1: Doses ($SvBq^{-1}$) to the child following maternal inhalation of a 5µm AMAD [a] aerosol or vapour at the start of the 15th week of pregnancy.

Note a: AMAD = activity median aerodynamic diameter.

Note b: e(total) is the sum of dose e(*in utero*) and committed effective dose from activity remaining in the newborn infant at birth.

Note c: e(adult) is the reference dose coefficient for workers[(3)].

Note d: ICRP respiratory tract model inhalation categories: F = fast absorption to blood; S = slow absorption.

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