The Chernobyl I-131 Release: Model Validation and Assessment of the Countermeasure Effectiveness

Report of the Chernobyl ^{131}I Release Working Group of EMRAS Theme 1

Environmental Modelling for RAdiation Safety (EMRAS) Programme

FOREWORD

Environmental assessment models are used for evaluating the radiological impact of actual and potential releases of radionuclides to the environment. They are essential tools for use in the regulatory control of routine discharges to the environment and also in planning measures to be taken in the event of accidental releases; they are also used for predicting the impact of releases which may occur far into the future, for example, from underground radioactive waste repositories. It is important to check, to the extent possible, the reliability of the predictions of such models by comparison with measured values in the environment or by comparing with the predictions of other models.

The International Atomic Energy Agency (IAEA) has been organizing programmes of international model testing since the 1980s. The programmes have contributed to a general improvement in models, in transfer data and in the capabilities of modellers in Member States. The documents published by the IAEA on this subject in the last two decades demonstrate the comprehensive nature of the programmes and record the associated advances which have been made.

From 2003 to 2007, the IAEA organised a programme titled “Environmental Modelling for RAdiation Safety” (EMRAS). The programme comprised three themes:

Theme 1: Radioactive Release Assessment

- Working Group 1: Revision of IAEA Technical Report Series No. 364 “Handbook of parameter values for the prediction of radionuclide transfer in temperate environments (TRS-364) working group;
- Working Group 2: Modelling of tritium and carbon-14 transfer to biota and man working group;
- Working Group 3: the Chernobyl I-131 release: model validation and assessment of the countermeasure effectiveness working group;
- Working Group 4: Model validation for radionuclide transport in the aquatic system “Watershed-River” and in estuaries working group.

Theme 2: Remediation of Sites with Radioactive Residues

- Working Group 1: Modelling of naturally occurring radioactive materials (NORM) releases and the remediation benefits for sites contaminated by extractive industries (U/Th mining and milling, oil and gas industry, phosphate industry, etc.) working group;
- Working Group 2: Remediation assessment for urban areas contaminated with dispersed radionuclides working group.

Theme 3: Protection of the Environment

- Working Group 1: Model validation for biota dose assessment working group.

This report describes the work of the Chernobyl ^{131}I Release Working Group under Theme 1. The IAEA wishes to acknowledge the contribution of the Working Group Leader, P. Krajewski of Poland to the preparation of this report. The IAEA Scientific Secretary for this publication was initially M. Balonov and subsequently V. Berkovskyy both of the Division of Radiation, Transport and Waste Safety.

ACKNOWLEDGEMENT

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SUMMARY

The Chernobyl ^{131}I Release Working Group (IWG) which was established within the framework of the EMRAS Programme continues some of the more traditional work of previous international programmes that were aimed at increasing confidence in methods and models for the assessment of radiation exposure related to the environmental releases.

There is still very little information regarding the quantitative relationship between radiation dose to the thyroid from Chernobyl and the risk of thyroid cancer.

The uncertainty combined with individual estimates of radiation dose constitutes a crucial point in establishing this relationship, since, any release of radioiodine into environment creates wide range of uncertainty for internal dose assessments.

The ^{131}I scenarios provide an excellent opportunity to compare a number of modelling approaches to a single assessment problem, in a dose reconstruction context.

Nine experts in environmental modelling participated in the Plavsk Scenario dealing with areas of assessment modelling for which the capabilities are not yet well established. One could observes the remarkably improvement in models performance comparing with previous radioiodine scenarios. Predictions of the various models were within 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.

CHAPTER 1. INTRODUCTION

1.1. Background

The Chernobyl ^{131}I Release Working Group (IWG), which was established within the framework of the EMRAS Programme continues some of the more traditional work of previous international programmes (VAMP -Validation of Model Predictions; BIOMOVS - BIOospheric Model Validation Study, BIOMOVS II, BIOMASS – BIOsphere Modelling and ASSessment) that were aimed at increasing confidence in methods and models for the assessment of radiation exposure related to the environmental releases.

Following the explosion at the Chernobyl Power Station in Ukraine on 26 April 1986, large quantities of radionuclides were released into the atmosphere, resulting in the contamination of a large geographic area. Initially elevated exposures of populations in Ukraine, Belarus and Russia were due to thyroid-gland irradiation by radioisotopes of iodine, primarily ^{131}I and subsequently to radiocesiums, primarily ^{137}Cs from both external exposure and the consumption of contaminated milk and other foods.

An increase in the incidence of thyroid cancer first was reported in Ukraine for 1990 [1] and in Belarus for the time period 1990–1992 [2, 3]. The questions appeared whether such increases were related directly to radiation exposure from Chernobyl [4, 5] due to the unexpectedly short latency period (only 4 years), uncertain background rates of thyroid cancer, the influence of widespread population screening and the rightness of the pathological diagnoses [2]. Numerous reports [6, 7] have confirmed an increasing number of cases of thyroid cancer, particularly in the most heavily contaminated regions of Ukraine and Belarus, but also in Russia [8]. There is still very little information regarding the quantitative relationship between radiation dose to the thyroid from Chernobyl and the risk of thyroid cancer. Few published population-based case-control studies of thyroid cancer indicates on a firm relationship between estimated radiation dose and thyroid cancer [9, 10].

However, in both studies the uncertainty combined with individual estimates of radiation dose constitutes a crucial point in establishing this relationship, since; any release of radioiodine into environment creates wide range of uncertainty for internal dose assessments. The major sources of the uncertainty include the small number and poor quality of thyroid measurements performed after Chernobyl accident, difficulties in evaluation and validation of the dynamic of the ^{131}I intakes function into a human body based on sparse (single point) individual thyroid measurements and milk samples (in early periods of accident). Also large variety in inhabitants' behavior and agricultural practices (e.g. the time when cows had been put on a fresh pasture) has considerable impact on doses variability [11].

The ^{131}I scenarios provide an excellent opportunity to compare a number of modelling approaches to a single assessment problem, in a dose reconstruction context. The importance of the confident reconstruction of the average and personal thyroid dose in affected areas results from its purposes including: confirmation of special medical aid to the population and measures of social protection, providing information for the public and the authorities and ensuring epidemiological investigations.

As previously concluded by other model-testing exercises critical assessments should be performed by more than one assessor or modelling group. Multiple independent assessments are effective in disclosing discrepancies in expert judgment and interpretation of input data. In these cases, resources should be allocated to resolving these differences before drawing final conclusions.

1.2. Objectives

The main activity of the EMRAS IWG will be to carry out environmental modelling exercises on radioiodine to test and compare model predictions with actual measurements data and to compare modelling approaches and model predictions among several assessors. This exercise provides an opportunity for comparison of assessment methods and conceptual approaches, for testing models for the specified level of the assessment, and for identifying the most important sources of uncertainty with respect both to that part of the assessment and to the overall assessment.

The main objectives of the exercises to be carried out by the EMRAS IWG are:

(1) To evaluate the performance of the participating models in dose reconstruction exercises in cases when ^{137}Cs is used as a tracer to estimate the deposition of ^{131}I;
(2) To assess the applicability of the models to identify countermeasure; such measures include evacuation, sheltering, feed and food controls as well as iodine prophylaxis.
(3) To assess the uncertainties of the participating models, their limitations, and the input data required to run the model.

The most important areas of the work of the group are:

(1) Improvement of the accuracy of model predictions through the identification of the most important sources of bias and uncertainty;
(2) Implementation of new modelling procedures supported by current state of knowledge about processes and phenomena.

1.3. Scope

The modellers who participated in IWG exercise are from different parts of the world, such as Europe, the U.S., and Japan, and represent various geographic and climatic zones. Some of the models used by participants were commercial or official models used by national authorities for assessment and decision making for radiological situations: SPADE, ASTRAL, ECOSYS-87-Finland version, OSCAAR; other models were developed for research purposes: LIETDOS, TAM-DYNAMIC, IRH-model, CLIMRAD, CLRP. The great diversity of models, as well as the specific individual or national judgment of specialists participating, provided a unique opportunity to discuss the problems of radioecological assessment from many points of view.

This IWG has developed and used model-testing scenarios to examine one or more aspects of the dose reconstruction assessment process. This process includes the following elements:

(1) Evaluation of the environmental transport of the contaminants, including dispersion, chemical transformation, persistence, and time-dependent concentrations of the contaminants in various environmental media;
(2) Description and evaluation of potential pathways for human exposure to the contaminants;
(3) Estimation of the internal and external doses to humans.

Before the First Combined Meeting a questionnaire had been sent to the people who had expressed an interest in participating to the work of the Iodine Working Group requesting information on the models which they intended to use in the project and on data sets which could be made available to all experts participating in the activities of the group. The purpose of the questionnaire was to identify potential participants to the Group. Ten responses were received with details of models and/or data sets.

Two groups of possible calculation endpoints were identified: quantities for which measurement data exist and quantities that can only be predicted (such as radiation dose). Usually, in a case of real situations, the amount of data available was rather limited and the modellers used their own experiences to interpret the data.

A unique feature common for the each scenario has been a detailed description of countermeasures applied to decrease doses to the local population.

The authors of the particular scenarios also performed independent model estimations for each of the scenario endpoints; the purposes of such calculations were to check the completeness of the input information provided in the scenario and to select optimal values of model parameters.

The IWG activities are focused on several main tasks:

(1) collection of measurement data sets,
(2) quality check of input and measurement data and evaluation of appropriate standard scenario for model validation purposes,
(3) model runs and comparison of outputs with the independent data sets, once carrying out blind test models calculations (without disclosing observed data) then perform evaluation of predictions discrepancies and identification of the most important sources of bias and uncertainty.

All the data sets were presented and discussed during the meeting of the Working Group. The availability and suitability of the data to be used as scenarios were discussed.

1.4. Structure

This report provides a summary of the activities of the IWG based on the above objectives, between 2004 and August 2007.

Chapter 2 gives short descriptions of evaluated 3 scenarios, Chapter 3 introduces participating models and model parameters, Chapter 4 describes models performances in particular scenarios, Chapter 5 presents summary and conclusions and Chapter 6 provides recommendations and suggestions for future work.

The main report is supplemented by four Appendices, i.e., Appendices I, II and III contain detailed descriptions of three scenarios (PLAVSK, MAZOWIA and PRAGUE) respectively, including both the input and observed data. A detailed description of each participating models and individual evaluations of model predictions prepared by each participant is included in Appendix IV.

Detailed documentation of numerical values of model predictions is provided in the form of an electronic database in EXCEL format and are available on the EMRAS website: http://www-ns.iaea.org/projects/emras/emras-iodine-131-wg.asp?s=8.

CHAPTER 2. THE CHERNOBYL ^{131}I RELEASE SCENARIOS

2.1. Plavsk Scenario

2.1.1. Purpose

The Plavsk Scenario initially prepared by SENES and revised for IWG purposes by Ms I. Zvonova, Institute of Radiation Hygiene, Russia and Mr P. Krajewski, Central Laboratory for Radiological Protection, Poland.

The Scenario considered the Plavsk highly contaminated agricultural area and it provided an excellent opportunity to perform an approximation of ^{131}I contamination of food-chain and evaluate thyroid doses for urban and rural population in area on the basis of isotopic ratio ^{131}I/^{137}Cs.

2.1.2. Scenario descriptions

The Plavsk district, in the Tula region of Russia, was chosen as the scenario area (see Figure 2.1). The Plavsk district is located about 200 km south of Moscow. The population under consideration consists of about 30 000 people, working mainly in agricultural production. The area was significantly contaminated with radionuclides on 29–30 April 1986 from the same Chernobyl cloud which contaminated the Bryansk region one day before. The district belongs to the Tula-Kaluga-Orel radioactive spot created during the Chernobyl accident on the Russian territory. The dynamics of the cloud movement, meteorological conditions of the fallout, isotopic composition, and soil contamination levels with deposited radionuclides are reviewed in this scenario description. In the research works analyzing the transport of air masses during the Chernobyl accident, it was concluded that radionuclides that were released from the reactor on 27 April first were carried to the north and northeast, and then they turned to the east, northeast and southeast, where they fell out with precipitation, forming the Bryansk-Byelorussia-Kaluga-Tula spot [12–14]. In the official methodical indications for calculating the effective doses and thyroid radiation doses for the Russian population, it was accepted, based on the available information that, the contamination of the Plavsk district started 3.5 ± 0.2 days after the accident, and it reached the maximal level 4.3 ± 0.2 days later [15]. Thus the radioactive cloud passed through the Tula region from the second half of the day on 29 April, until 07:00–10:00 of 30 April. The maximum ^{137}Cs soil contamination density of 0.5 MBq km^2 is located directly in the town of Plavsk, at the center of the Plavsk district. Data for precipitation, which was recorded 4 times a day: at 06:00, 09:00, 18:00 and 21:00 indicated that on 29 April, during the transit of the radioactive cloud, there were rains of different intensity in most of the Tula region. It is known that ratio ^{131}I/^{137}Cs in depositions depend on type of fallout – wet or dry. The spots of high contamination with ^{137}Cs were found after wet deposition. But the ratio ^{131}I/^{137}Cs decreases with the amount of rain during deposition [16, 17]. Rain occurred in all districts that were later nominated as contaminated areas on 29 April 1986. One can assume that wet fallout took place in the whole Plavsk district. The surface contamination levels by ^{137}Cs were evaluated based on measurements of soil contamination in the 110 particular settlements of the Plavsk district and the average levels of contamination on the territories of the collective farms in the study area were calculated. The 95% confidence intervals for each collective farm were included. Figure 2.2 shows a scheme of the territory's contamination with radioactive fallout of ^{137}Cs in the Plavsk district, counted for 26 April 1986.

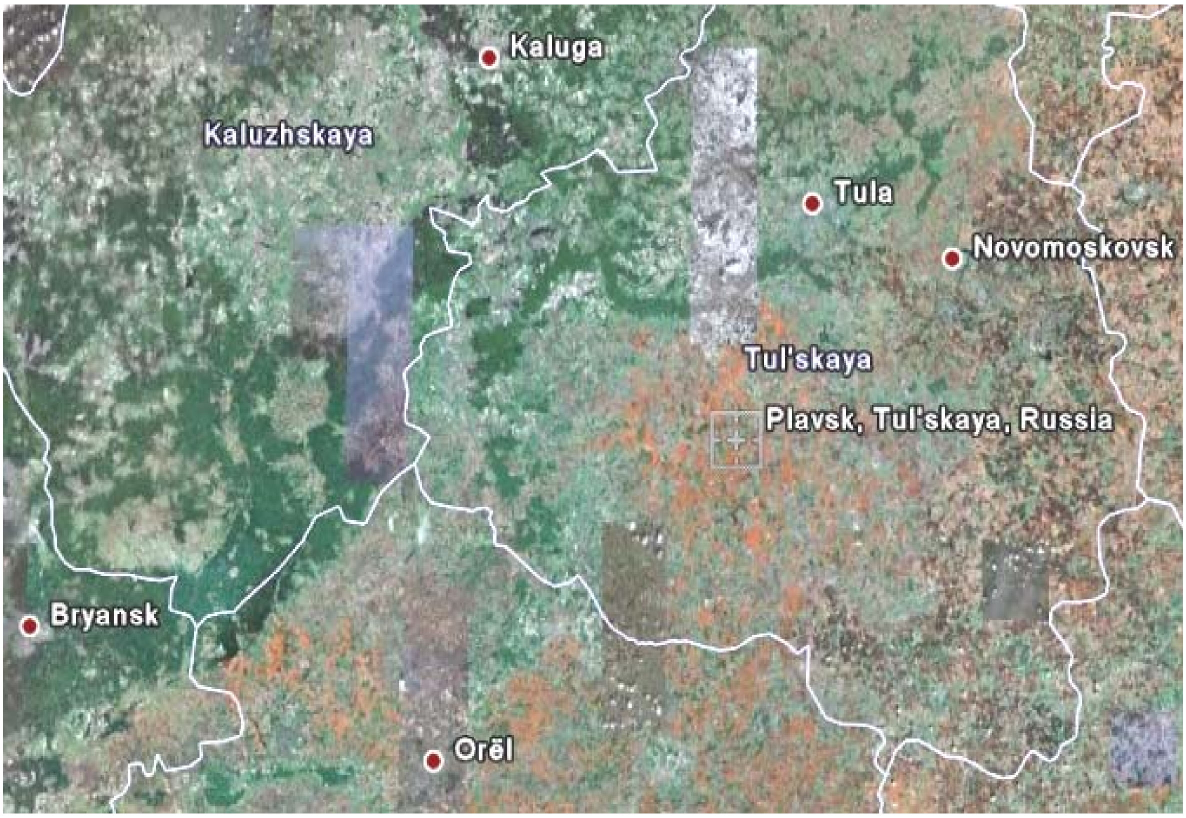

Fig. 2.1. Location of the Plavsk district.

The Plavsk area received less attention in Russia with regard to population radiation protection than the with the Bryansk region, because the contamination levels were lower (maximum in Novozybkov district of the Bryansk region is above 2 MBq km^2) and the dominating soil (chernozem) fixed cesium radionuclides, which diminished internal exposure from 1987 onwards. No protective measures were applied in this area in the early period after the accident. About ninety thyroid cancers in former children and teenagers (at the time of the accident) were registered in 1991–2000 in the Tula region [18]. Measurements of local people on ^{131}I content in thyroid glands and spectrometric measurements of ^{131}I concentration in local milk began on 14 May 1986 [19, 20]. Data of these measurements together with some meteorological data and results of inhabitant's interviews about their life style and food habits are available for test scenario.

A complete description of the Plavsk Scenario and the input information are provided in the Appendix I.

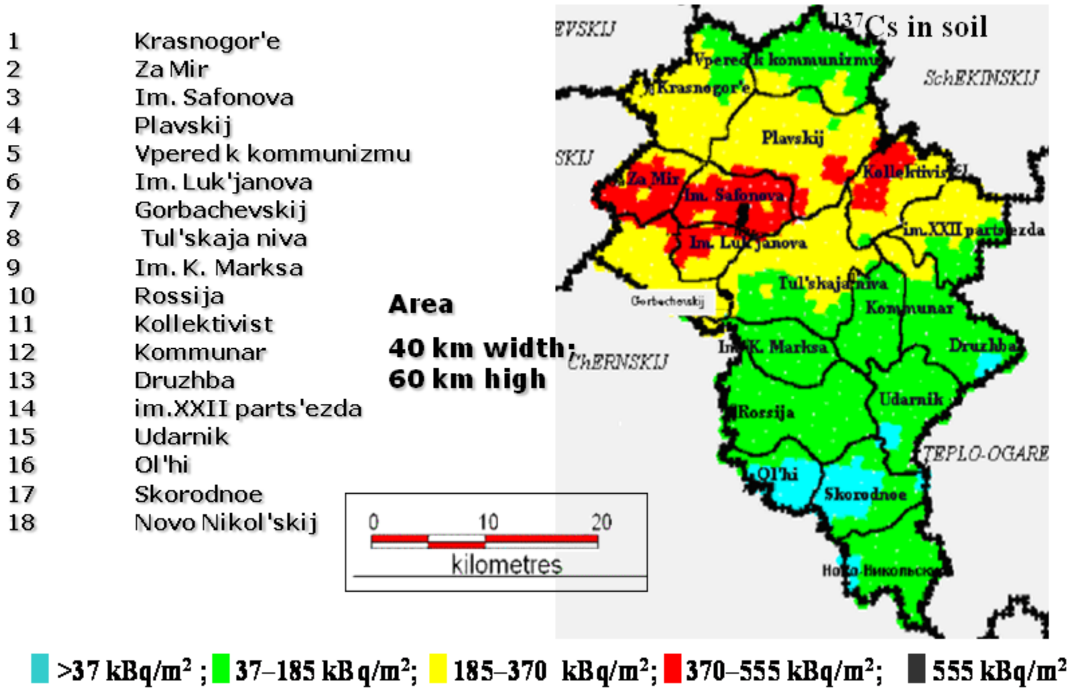

Fig. 2.2. Scheme of soil contamination with ^{137}Cs in the Plavsk district.

2.1.3. Assessment tasks

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

The scenario can be seen as being in two parts:

(1) Model validation 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) 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 the urban area of Plavsk and 19 rural settlements are included in the test region.

The endpoints considered for model validation are:

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

Table 2.1. Scheme of soil contamination with ^{137}Cs in the Plavsk district.

Model*	Country	Participant Name	Organization	Models validation				Models inter comparison			
				^{131}I deposition	^{131}I milk concentration 27 April – 30 May 1986; 18 milk farm + Plavsk	^{131}I thyroid burden: urban population (Plavsk town)	^{131}I thyroid burden: specified rural locations	^{131}I air concentration for 18 locations and Plavsk town	^{131}I grass concentration 27 April – 30 May 1986	Committed doses to thyroid due to inhalation	Committed doses to thyroid due to ingestion
ASTRAL	France	C. Duffa	Institut de Radioprotection et de Sûreté Nucléaire (IRSN)	×	×				×		×
CLIMRAD	Russian Federation	O. Vlasov	Medical Radiological Research Center	×	×	×	×	×	×	×	×
CLRP	Poland	P. Krajewski	Central Laboratory for Radiological Protection	×	×	×	×	×	×	×	×
ECOSYS-87	Finland	M. Ammann	Radiation & Nuclear Safety Authority (STUK)	×	×			×	×	×	×
LIETDOS	Lithuania	T. Nedveckaite V. Flistovic	Institute of Physics	×	×	×	×	×	×	×	×
OSCAAR	Japan	T. Homma	Japan Atomic Energy Research Institute	×	×	×	×	×	×	×	×
Plavsk Dose Calculator	USA	S. Simon	National Cancer Institute	×	×	×	×	×	×	×	×
UNIVES	Hungary	B. Kanyár	University of Veszprém	×	×	×	×	×		×	
SPADE V.6	UK	D. Webbe-Wood, S.Conney,	Food Standard Agency	×	×	×	×	×	×		×

* In the alphabetic order of the model name.

The endpoints considered for models comparison:

(1) Reconstruction of the ^{131}I air concentrations for 18 locations and Plavsk town;
(2) The time dependent ^{131}I concentration in fresh pasture (grass) for the period 27 April – 30 May 1986;
(3) Committed doses to thyroid from ingestion; and
(4) Inhalation dose contribution to the total dose (not done by all participants).

2.1.4. Participants and models

The first Questionnaire[1] of IWG resulted in identification of 9 modellers who agreed to take part in the IWG activities (Table 2.1). 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.

[1] Prior to the First Meeting of the IAEA's EMRAS ^{131}I Working Group, held during the First Plenary and Working Group Meeting of the EMRAS Programme, IAEA Headquarters in Vienna, 1–5 September 2003.

2.2. Mazovia Scenario

2.2.1. Purpose

The Mazovia test scenario was proposed by Mr P. Krajewski, Central Laboratory for Radiological Protection, Poland.

The proposed Warsaw test scenario encompassed an area of MAZOVIA province (35.6×10^3 km^2) with Warsaw as the province capital (see Figure 2.3). The main goal of the scenario was to perform an assessment of the effectiveness of short-term protective measures that were applied in this province to reduce the radioiodine uptake by the thyroid of inhabitants. In particular, the ability and accuracy of models to calculate the reduction of the ^{131}I content in thyroids when stable iodine dose is applied as a countermeasure was considered.

The pathways contributing to dose are primarily through inhalation and ingestion of contaminated milk.

2.2.2. Scenario descriptions

The Mazovia Province (Polish: Wojewodztwo Mazowieckie) MAZOVIA, in Poland, is the largest and most populated of the 16 Polish administrative provinces (voivodships). It covers an area of 35 598 km² in eastern-central Poland, equal to about 11% of Poland's territory, with a population of 5.1 million; it consists of 42 counties. Most Mazovians are urban residents (64%), greater Warsaw being the largest urban centre (over 2.8 million) [21].

Its principal cities are Warsaw in the centre, Radom (230 000) in the south, Plock (130 000) in the west, Siedlce (75 000) in the east, and Ostroleka (55 000) in the north.

The region's main river is the Vistula with its right-bank tributaries: the Narew and the Bug. Mazovia has a rural population of1.8 million. As much as 67% of the area of the province is used for agriculture, accounting for 13% of Poland's agricultural land. Mazovia is a horticultural and orchards' centre. The expansion of agriculture is encouraged by the closeness of Warsaw's vast market. The region's agricultural production is the basis for the food-processing sector. Even so, much of Mazovia's agricultural potential remains unused. Small farms continue to operate.

Initially, the origin of contaminated air, which probably moved to Poland on 28 April 1986 at 00:00 GMT[2], was unknown. However, just preliminary spectrometric measurements (performed in CLOR 28 April 10:00–13:15) of particulates collected on filters indicated that there were fission products and following analysis suggested that it was caused by a reactor accident [22]. It was confirmed by presence of ^{134}Cs and small contribution of the elements with a boiling point above 1500 °K, which usually occur in a greater amount in fallout after nuclear weapons explosions. The gamma spectrometric measurements of airborne particulates activity collected on filters allowed the identification of above 20 artificial radionuclides, the presence of ^{133}Xe in air was also evident. In addition, investigations of physic-chemical phases of ^{131}I were carried out by filtration of air throughout the filter set with fiber medium,

[2] 28 April 1986 at 07:00 monitoring station Mikolajki reported 700 fold higher global beta activity in air.

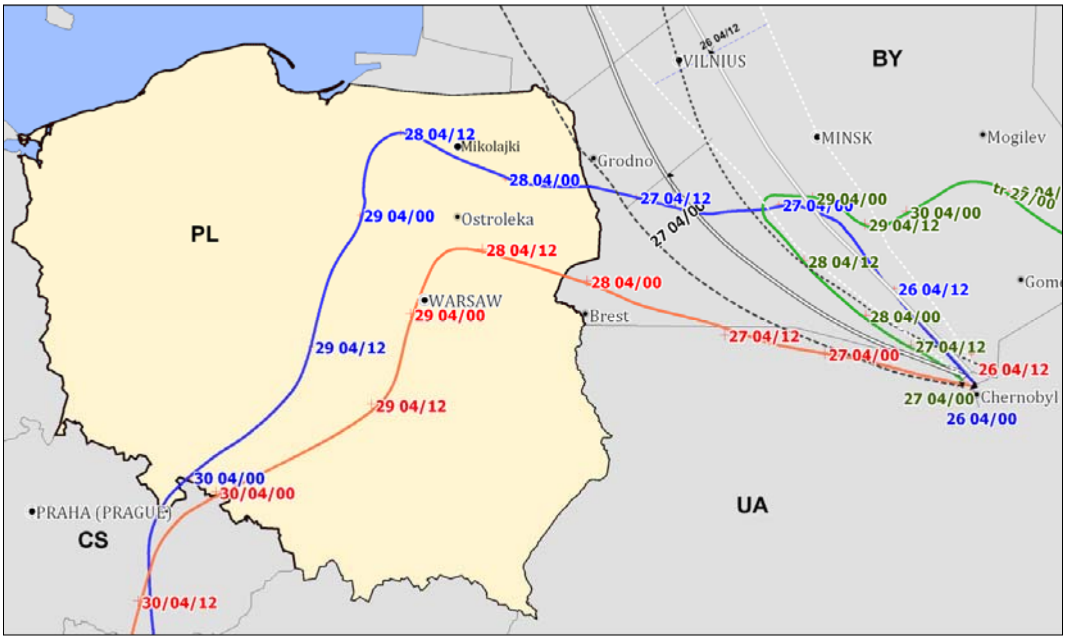

Fig. 2.3. A passage of contaminated air over Poland after Chernobyl accident. Trajectories blue, red and green correspond to: surface winds originating from Chernobyl on 26 April 00:00 GMT, 26 April 12:00 GMT, 27 April 00:00 GMT respectively. Trajectories grey and white correspond to 925 mb – 800 m altitude, 850 mb – 1500 m altitude respectively originating from Chernobyl on 26 April 12:00 GMT. (Reconstruction by Polish Institute of Meteorology and Water Management).

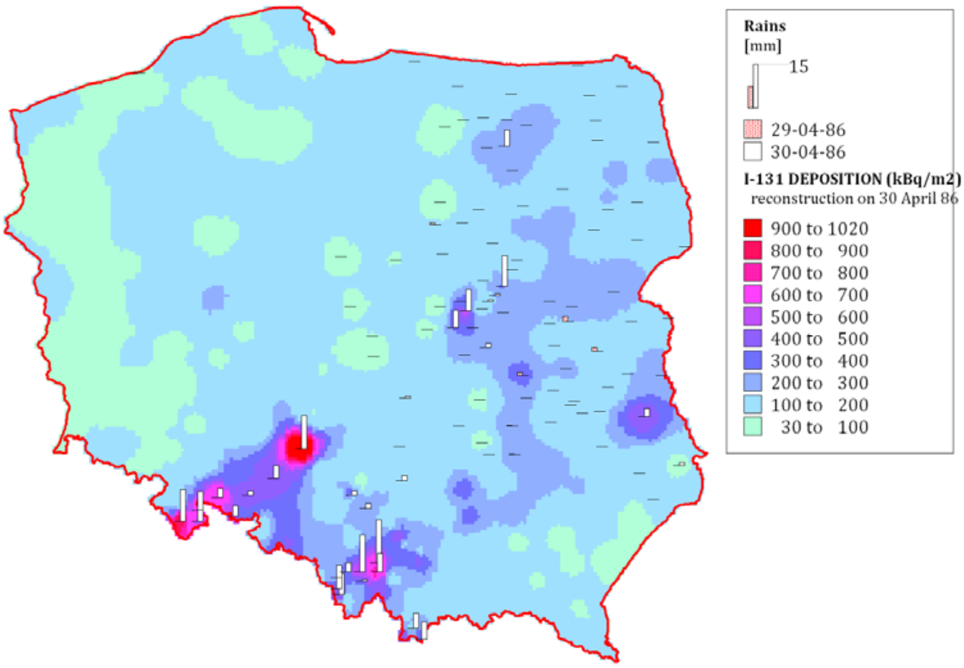

Fig. 2.4. Reconstruction of ^{131}I deposition (calculated on 30 April 1986) from ^{137}Cs surface contamination.

charcoal and charcoal impregnated paper. About 59 ± 12% of the particulate radioactive iodine was collected during the first few days of measurement, later the percentage of airborne particulate decreased. A radioactive plume reached Warsaw probably on 28 April 1986 and the highest air concentration of ^{131}I lasted from 29 to 30 April 1986. Due to the weather conditions, ^{131}I deposition was almost dry and relatively homogeneous (see Figure 2.4). One could expect that the major source of variability of ^{131}I thyroid contents and consequently ingestion doses would have been the different ^{131}I activity concentration in milk as result of various storage of uncontaminated feedstuff in the affected regions. In particular the elevated levels of airborne ^{131}I during the first hours of 28 April (above 100 Bq m^3) indicated that thyroid doses to children could exceed 50 mSv. In the late afternoon of 28 April 1986, the message about Chernobyl nuclear power plant accident was revealed by western media. On 29 April 1986 about 06:00 the Governmental Commission for Assessment of Nuclear Radiation and Prophylactic Measures was created which recommended (on 29 April 1986 11:00) to introduce countermeasures in order to reduce children's thyroid exposure to radioodine [23]. These countermeasures mainly included administration of stable iodine in form of solution-so called "Lugol liquid") to children and teenagers up to 16 years of age. The distribution of stable iodine started in the evening hours of 29 April 1986 and continued on 30 April 1986 (when 75% of the child population had received stable iodine) as well as in the first days of May, depending on resources in particular districts. Generally, in the distribution of stable iodine to kindergartens and schools, pharmacies and medical centers were involved. Additionally, the Commission recommended feeding animals on stored feed, followed by the banning of potentially contaminated milk, milk products and leafy vegetables. The recommendations were given to avoid the intake of milk, milk products and leafy vegetables and to avoid the use of fresh grass for feeding cows, however there were no mains to make them obligatory but only to encourage voluntary action.

It can be seen from the meteorological data that on 29 and 30 April 1986, during the peak of the transit of the radioiodine cloud, there were only sparse and local rains of different intensity in a few locations of the Mazovia province. It resulted in elevated level of ^{131}I and ^{137}Cs deposition in small spots but it did not result in high contamination of pasture grass and milk as these rains not affected pasture land. The ratio ^{131}I/^{137}Cs in this spots ranged for 8 to 15 (calculated on 27 April 1986). However, intensive rains occurred in the most districts of Mazovia province a week later, on 8 and 9 May 1986, resulted in washout of airborne radioiodine from the next cloud from Chernobyl on 5 May 1986, but with an order of magnitude lower contamination. The influence of intensive rains 10–15 May 1986 was only of short weathering half-time on the grass.

2.2.3. Assessment tasks

The Mazovia 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 for various countermeasures; and

(2) A model comparison in which calculation of integrated air concentration, predictions of the mean inhalation and ingestion dose to the thyroid for different age groups are compared and analyzed.

Both urban areas (Warsaw) and rural settlements are included in the test region.

The suggested starting point of the calculation is the estimation of deposition of ^{131}I over the Mazovia province from the ^{131}I airborne concentrations. The models that would not be able to use air data could reconstruct ^{131}I deposition from the ^{137}Cs content in soil (provided in Section II.5.2 of Appendix II) although with awareness of higher uncertainty.

Calculations for model testing included:

(1) Arithmetic mean of daily activities of ^{131}I concentration in milk (Bq L^{-1}) in milk in three variants:
  (a) Cows grazing limitation – for collective farm (named Falenty) situated near Warsaw where it was reported that cows had been kept indoors during the whole period;
  (b) Average milk from big dairy – composite milk samples taken daily from the Warsaw Town dairy shops;
  (c) No pasture limitation – composite milk samples taken daily from the Ostroleka dairy. It was reported that most of the private farms in this area suffer from shortage of uncontaminated hay.

(2) Arithmetic mean of ^{131}I thyroid content (Bq) for test age groups of urban population (Warsaw town) and rural population (Ostroleka area) during the period 27–31 May 1986. The proposed age's groups were selected to provide good statistics for model validation purposes as follow:
  (a) Warsaw inhabitants:
    (i) children at the age from 3 to 10, who had been given a stable iodine dose of 30 mg on 29 April 1986 12:00;
    (ii) children at the age from 3 to 10 who had been given a stable iodine dose of 30 mg on 30 April 1986 12:00;
    (iii) teenagers at the age from 10 to 17 who had been given a stable iodine dose of 60 mg on 29 April 1986 12:00;
    (iv) teenagers at the age from 10 to 17 who had been given a stable iodine dose of 60 mg on April 1986 12:00;
    (v) adults at the age 20 who had not taken any stable iodine dose;
    (vi) adults at the age 20 who had voluntarily taken a stable iodine dose of 60 mg on 29 April 1986 12:00;
    (vii) adults at the age 20 who had voluntarily taken a stable iodine dose of 60 mg on 30 April 1986 12:00.
  (b) Ostroleka area inhabitants:
    (i) children at the age from 3 to 10, who had been given a stable iodine dose of 30 mg on 29 April 1986 12:00;
    (ii) children at the age from 3 to 10 who had been given a stable iodine dose of 30 mg on 30 April 1986 12:00;
    (iii) teenagers at the age from 10 to 17 who had been given a stable iodine dose of 60 mg on 29 April 1986 12:00;
    (iv) teenagers at the age from 10 to 17 who had been given a stable iodine dose of 60 mg on April 1986 12:00;
    (v) adults at the age 20 who had not taken any stable iodine dose;
    (vi) adults at the age 20 who had voluntarily taken a stable iodine dose of 60 mg on 29 April 1986 12:00;
    (vii) adults at the age 20 who had voluntarily taken a stable iodine dose of 60 mg on 30 April 1986 12:00.

Calculations for model comparison included:

(1) Integrated air concentration of ^{131}I based on original measurements from two air sampling stations (A and B);
(2) Arithmetic mean of ^{131}I concentration in grass in two test location (Warsaw town, Ostroleka area) from 27 April – 25 May 1986. Note that initially there was no rain in places the where grass samples had been taken;
(3) Inhalation dose – this point provided an opportunity for the dose assessment professionals, to examine their skills, methods and conceptual approaches for the specified level of the assessment, when applied countermeasures need to be evaluated with respect of their real practicability;
(4) Ingestion dose – committed equivalent dose to thyroid for the specified age groups for various countermeasures applied in two locations, i.e., Warsaw town and rural Ostroleka area. In this case, the countermeasures involve a combination of grazing limitation as well as administration of stable iodine at different times. The most probable dates of putting cows on a pasture has been selected. For the sake of model comparison transparency, participants were asked to make assumption, that whole milk is consumed by representatives of the particular age groups.

2.2.4. Participants and models

The first Questionnaire of IWG resulted in identification of 9 modellers who agreed to take part in the IWG activities (see Table 2.1). 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 2.2. Summary of participants, models and endpoints modelled in the model validation study.

Model*	Country	Participant Name	Organization	Models validation: Daily ^{131}I milk concentration in the period 27 April – 30 May 1986			Models validation: ^{131}I thyroid content in the period 27 April – 30 May 1986	
				Falenty dairy (cows kept in cowsheds and fed by uncontaminated fodder)	Warsaw dairy	Ostroleka dairy	Warsaw inhabitants:Adults age >= 20 y in 1986Teenagers age between 10 to 17 y in 1986Children age between 3 to 10 y in 1986	Ostroleka inhabitants:Adults age >= 20 y in 1986 Teenagers age between 10 to 17 y in 1986 Children age between 3 to 10 y in 1986
CLIMRAD	Russian Federation	O. Vlasov	Medical Radiological Research Center	×	×	×	×	×
CLRP	Poland	P. Krajewski	Central Laboratory for Radiological Protection	×	×	×	×	×
ECOSYS-87	Finland	M. Ammann	Radiation & Nuclear Safety Authority (STUK)	×	×	×	×	×
LIETDOS	Lithuania	T. Nedveckaite V. Flistovic	Institute of Physics		×	×	×	×
OSCAAR	Japan	T. Homma	Japan Atomic Energy Research Institute	×		×	×	×
UNIVES	Hungary	B. Kanyár	University of Veszprém	×	×	×	×	×
IRH-model	Russian Federation	I. Zvonowa	Institute of Radiation Hygiene of the Ministry of Public Health, St. Petersburg	×	×	×	×	×

* In the alphabetic order of the model name.

Table 2.3. Summary of participants, models and endpoints modelled in the model inter-comparison study.

Model*	Country	Participant Name	Organization	Models inter-comparison			
				The total integrated ^{131}I air concentration in ground level air over MAZOVIA area, contribution of the radioiodine phases, i.e., particulate, reactive gaseous and organic	Average ^{131}I concentration in grass for Warsaw and Ostroleka area in the period 27 April – 30 May 1986	Committed doses to thyroid due to inhalation for specified age groups: age 1, 5, 10, 20 (adult) in 1986 for following variant of countermeasures: No stable iodine 28 April 12:00 29 April 12:00 30 April 12:00 1 May 12:00	Committed doses to thyroid due to ingestion for specified age groups: age 1, 5, 10, 20 (adult) in 1986 for following variant of countermeasures: No stable iodine 28 April 12:00 29 April 12:00 30 April 12:00 1 May 12:00 Cows on pasture from 28 April 1986 from 1 May 1986 from 15 May 1986 from 1 June 1986
CLIMRAD	Russian Federation	O. Vlasov	Medical Radiological Research Center	×	×	×	×
CLRP	Poland	P. Krajewski	Central Laboratory for Radiological Protection	×	×	×	×
ECOSYS-87	Finland	M. Ammann	Radiation & Nuclear Safety Authority (STUK)	×	×	×	×
LIETDOS	Lithuania	T. Nedveckaite V. Flistovic	Institute of Physics	×	×	×	×
OSCAAR	Japan	T. Homma	Japan Atomic Energy Research Institute	×	×	×	
UNIVES	Hungary	B. Kanyár	University of Veszprém	×	×	×	×
IRH-model	Russian Federation	I. Zvonowa	Institute of Radiation Hygiene of the Ministry of Public Health, St. Petersburg	×	×	×	×

* In the alphabetic order of the model name.

2.3. Prague Scenario

2.3.1. Purpose

The Prague Scenario was proposed by Ms I. Malátová, National Radiation Protection Institute, Czech Republic. The third Prague Scenario has been focused on several aspects of the internal ^{131}I dose evaluation for a case when a special cow feeding regime is applied, i.e., to keep dairy cows on winter fodder – if available. Data available included concentrations of ^{131}I in air, precipitation, vegetation, animal feed, water, milk, human thyroid measured in the area near Prague in the weeks following the accident. The critical groups of exposure e.g., children 5 and 10 years old were considered with special attention.

2.3.2. *Scenario descriptions*

Prague covers an area of 496 km^2, and the first signals about the arrival of a contaminated plume on the territory were detected during the night from 29 to 30 April 1986. Three passages of contaminated air through the territory were detected. The first during the night from 29 to 30 April 1986, the second on 3 and 4 May and the third on 7 May 1986. It resulted in locally elevated levels of ^{137}Cs content in soil and expected higher ^{131}I deposition in the same locations (see Figure 2.5).

Between 6–8 May 1986 it was recommended to keep dairy cows on winter fodder – if available. Consumption of milk with activity of $^{131}I > 1000$ $Bq.L^{-1}$ was banned. As these countermeasures were not announced publicly, it is most probable that people voluntarily decreased consumption of milk and vegetable. Therefore, to assess the effectiveness of such countermeasures, the participants have been asked to estimate the ^{131}I concentration in milk for a hypothetical situation when cows were grazing near Prague. This calculation is useful to compare ingestion doses to estimate the dose reduction factor.

The first step consisted of the reconstruction of ^{131}I concentration in air on the basis of ^{137}Cs measurements in soil as well as on several data of ^{131}I deposition. The participant could validate ^{131}I air concentrations predictions with sparse data of measurements. The ^{131}I milk concentration has been chosen as second target of predictions. Three dairies i.e.: Praha-Troja, Praha-Kyje and Benesov were selected for model validation study (see Figure 2.6).

The dairies were located in differently contaminated areas. The several variants of countermeasures have been considered including prevention of milk contamination by feeding cows without fresh grass contaminated by ^{131}I.

2.3.3. *Assessment tasks*

The Prague 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; for various countermeasures variants; and
(2) A model comparison in which calculations of integrated air concentration and predictions of the mean inhalation and ingestion dose to the thyroid for different age groups are compared and analyzed.

Both urban areas (Prague town) and rural settlements, are included in the test region.

The models that would not be able to use ^{131}I air data for deposition calculations could reconstruct ^{131}I deposition using ^{137}Cs in soil as a tracer (provided in the scenario) although with associated higher uncertainty.

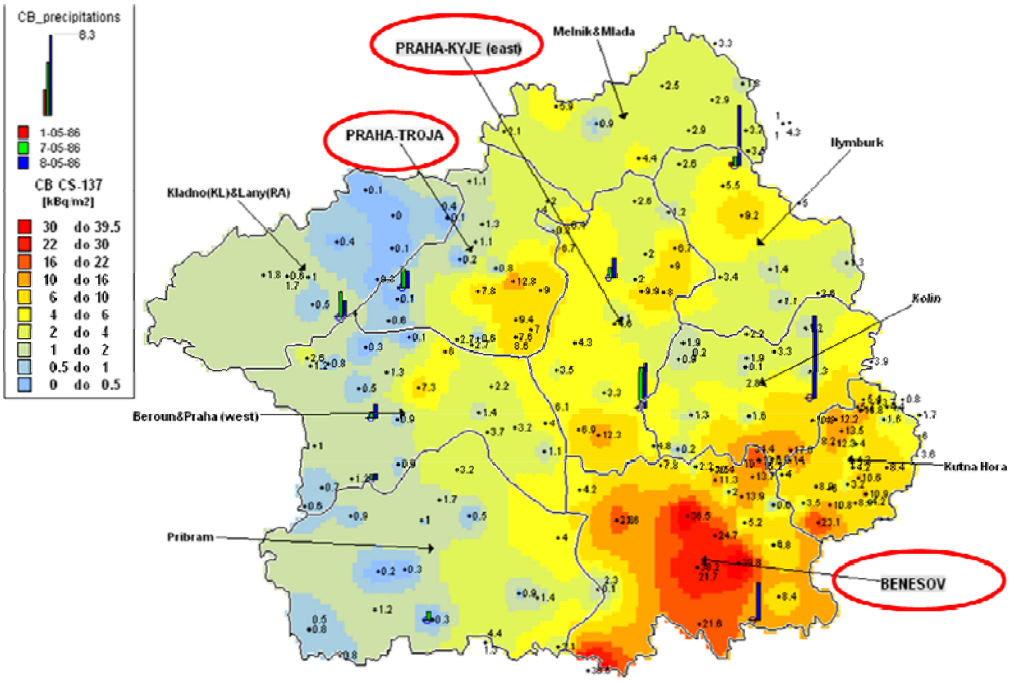

Fig. 2.5. Inhomogeneous spatial distribution of ^{137}Cs in Central Bohemia.

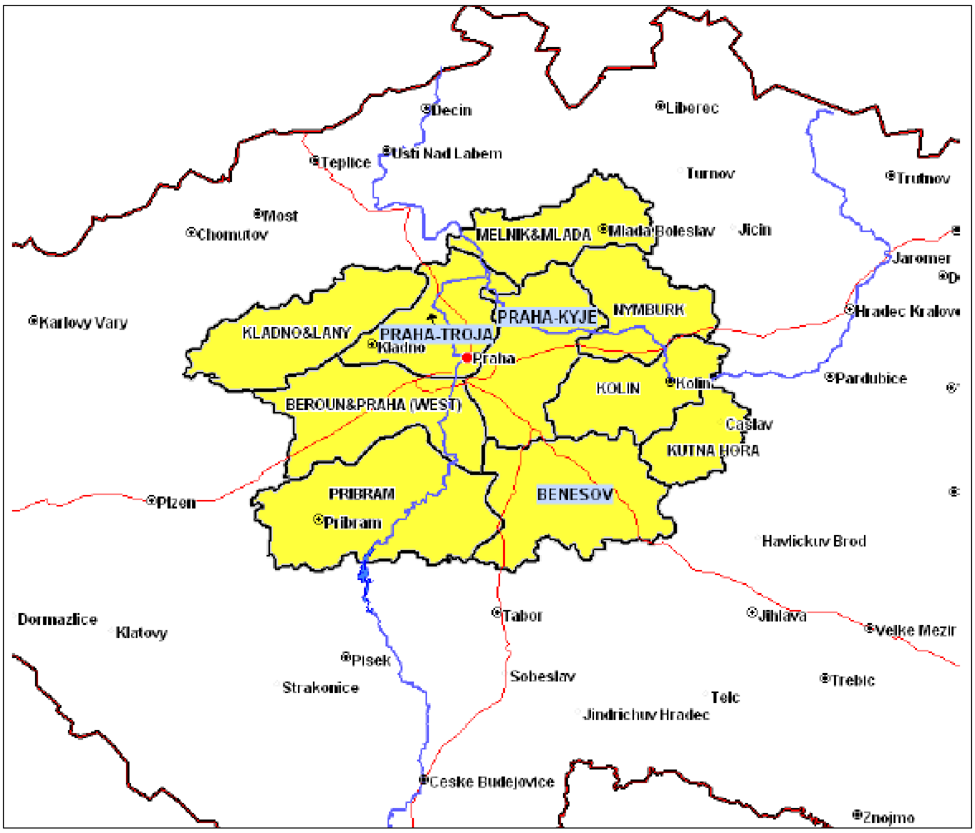

Fig. 2.6. Location of dairies in Central Bohemia and their gathering regions.

The several end points for model validation purposes were considered:

(1) ^{131}I deposition (soil concentration);
(2) a time dependent ^{131}I concentration in milk for the period 27 April – 30 May 1986; for different dairies both situated in agricultural areas and Prague;
(3) ^{131}I thyroid burden for different age groups.

The end points considered for model inter-comparison:

(1) reconstruction of ^{131}I air concentration based on isotopic ratio ^{131}I/^{137}Cs;
(2) a time dependent ^{131}I concentration in fresh pasture (grass) for the period of 27 April – 30 May 1986;
(3) committed doses to thyroid from inhalation;
(4) committed doses to thyroid from ingestion.

During the 4th EMRAS Combined Meeting (held 6–10 November 2006, IAEA Headquarters, Vienna), participants pointed out difficulties in interpretation of the scenario because of lack of information about cows feeding practices in the transitional period (winter-summer) and spatio-temporal monitoring data on: air concentrations, iodine forms and deposition. The discussion concluded that during the early period of emergency the monitoring data on air concentration, iodine form, deposition density as well as comprehensive data on milk contamination are required for improvement of reliability of thyroid exposures model predictions. Therefore the Prague Scenario has been split into two parts, where the second part focused on thyroid exposure on the basis of previously revealed ^{131}I milk concentrations observed data. Seven modellers will participants in this task and the extended version of the Scenario.

2.3.4. Participants and models

Table 2.4. Summary of participants, models and endpoints modelled in the model validation study.

Model	Country	Participant Name	Organization	Models validation				
				daily ^{131}I concentration in grass in Prague in the period 27 April –30 May 1986	daily ^{131}I milk concentration in the period 27 April – 30 May 1986			^{131}I thyroid content in the period 27 April – 30 May 1986
					Praga-Kye	Praga-Troja	Benesow	Prague inhabitants Adults age >= 20 y in 1986
CLIMRAD	Russian Federation	O. Vlasov	Medical Radiological Research Center	×		×		×
CLRP	Poland	P. Krajewski	Central Laboratory for Radiological Protection	×		×		×
ECOSYS-87	Finland	M. Ammann	Radiation & Nuclear Safety Authority (STUK)	×		×		×
LIETDOS	Lithuania	T. Nedveckaite V. Flistovic	Institute of Physics	×		×		×
OSCAAR	Japan	T. Homma	Japan Atomic Energy Research Institute	×		×		×
UNIVES	Hungary	B. Kanyár	University of Veszprém	×		×		×
IRH-model	Russian Federation	I. Zvonowa	Institute of Radiation Hygiene of the Ministry of Public Health,St. Petersburg	×		×		×

Table 2.5. Summary of participants, models and endpoints modelled in the model comparison study.

Model	Country	Participant Name	Organization	Models comparison				
				Committed doses to thyroid due to inhalation for specified age groups: age 1, 5, 10, 20 (adult) in 1986			Committed doses to thyroid due to ingestion for specified age groups: age 1, 5, 10, 20 (adult) in 1986	
				8 h in building	16 h in building	24 h in building	Cows on pasture from 29 April 1986	Cows fed with uncontaminated fodder
CLIMRAD	Russian Federation	O. Vlasov	Medical Radiological Research Center	×		×	×	
CLRP	Poland	P. Krajewski	Central Laboratory for Radiological Protection	×		×	×	
ECOSYS-87	Finland	M. Ammann	Radiation & Nuclear Safety Authority (STUK)	×		×	×	
LIETDOS	Lithuania	T. Nedveckaite V. Flistovic	Institute of Physics	×		×	×	
OSCAAR	Japan	T. Homma	Japan Atomic Energy Research Institute	×		×	×	
UNIVES	Hungary	B. Kanyár	University of Veszprém	×		×	×	
IRH-model	Russian Federation	I. Zvonowa	Institute of Radiation Hygiene of the Ministry of Public Health, St. Petersburg	×		×	×	

CHAPTER 3. MODELS CHARACTERIZATION

3.1. Plavsk Scenario

Table 3.1. Summary of parameters and approaches used by participants for ^{131}I deposition assessment.

END POINT \ PARTICIPANT	1 ASTRAL	2 CLIMRAD	3 CLRP	4 ECOSYS	5 LIETDOS	6 OSCAAR	7 Plavsk Dose Calculator	8 UniVes	9 SPADE V.6
^{131}I deposition in Plavsk district									
^{131}I deposition calculation in Plavsk district base on ^{137}Cs deposition data given in Plavsk scenario	YES	YES	YES	YES	YES	YES	YES	YES	YES
Isotopic ratio $^{131}I/^{137}Cs$ given in scenario equal to **3.34**	YES	YES	$8.85\times(\sigma^{137}Cs)^{0.85}$	YES	YES	YES	YES	Implicitly by reconstruction of air concentration and rate of deposition	YES
The dynamic of ^{131}I deposition over the Plavsk district: The date when first plume of airborne ^{131}I arrive at Plavsk district ?	29 04 (12:00)	29 04 (12:00)	29 04 (12:00)	29 04 (13:00)	30 04 (8:00)	29 04 (12:00)	29 04 (12:00)	Sigmoint distribution with the mean value given by the directors of farms	29 04 (18:00)
The date when first plume of airborne ^{131}I depart the Plavsk district ?	30 04 (1 9:00)	30 04 (12:00)	30 04 (09:00)	30 04 (19:00)	1 05 (08:00)	30 04 (10:00)	30 04 (12:00)		30 April (06:00)
If you have assume different period of plume arrival for particular milk farms please specify.	NO	NO	NO	NO	NO	NO	NO	Variation in time	NO

Table 3.2. Summary of parameters and approaches used by participants for predictions of ^{131}I concentration in grass.

PARTICIPANT / END POINT	1 ASTRAL	2 CLIMRAD	3 CLRP	4 ECOSYS	5 LIETDOS	6 OSCAAR	7 Plavsk Dose Calculator	8 UniVes	9 SPADE V.6
^{131}I concentration in grass									
grass yield (kg· m^{-2} fresh weight)									
at the period of ^{131}I deposition	0.7	0.2	0.08	0.16	0.45	0.15	0.05*	0.20	0.425
at the end of ^{131}I deposition	0.7	0.2	0.08	0.16	0.45	0.15	0.05	0.55	0.425
grass interception fraction (dimensionless				–					
for dry deposition	0.56	Own evaluation	0.13	≈3%	0.36	0.074	0.21	0.7	0.7
for wet deposition			0.05		0.36	0.074	0.21	0.7	0.7
formula used:				1			(0.021)**		
1-exp(-μY), μ =					1.0(?)	2.8		–	2.8
			7	4		10			
weathering H ½ [d] (none effective)	11.6		≈ 6	(1st run) 25 (2nd, 3rd run)	8.7		≈11	10	13.2

* Readout from worksheet.

** Chamberlain formula gives 0.021.

Table 3.3. Summary of parameters and approaches used by participants for reconstruction of ^{131}I concentration in air.

END POINT \ PARTICIPANT	1 ASTRAL	2 CLIMRAD	3 CLRP	4 ECOSYS	5 LIETDOS	6 OSCAAR	7 Plavsk Dose Calculator	8 UniVes	9 SPADE V.6
Reconstruction of ^{131}I concentration in air									
^{131}I iodine speciation (%):		-	29/30Apr.						
particulate	100		25/28	100	40	23	100	100	Not considered
reactive gas (I_2)			40/55	-	30	26			
organic			35/17	-	30	51			
dry deposition velocity ($m \cdot s^{-1}$)			1.2×10^{-3}						
particulate		1.0×10^{-2}	1.1×10^{-2}	1.5×10^{-3}	1.6×10^{-3}	2.0×10^{-3}	1.7×10^{-3}	1.8×10^{-3}	Not considered
reactive gas (I_2)		–	1.1×10^{-4}	–	9.5×10^{-3}	1.0×10^{-2}			
organic		–		–	7.0×10^{-5}	1.0×10^{-4}			
washout factor w_r ♣ particulate									
particulate									
reactive gas (I_2)	$(5\pm2)\times10^{5}$	Not considered	2.0×10^{4}	3.1×10^{5}	2.5×10^{6}	3.0×10^{5}	Not considered	2.0×10^{5}	Not considered
organic			2.0×10^{5}		5.0×10^{6}	2.0×10^{5}			
			2.0×10^{5}		8.0×10^{3}	2.0×10^{3}			

♣ 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: $W_{wet} = C\times \mathbf{w_r}\times R$; where: W_{wet} –wet deposition ($Bq\cdot m^{-2}$), C- concentration in air ($Bq\cdot m^{-3}$), R- rainfall (m)

Table 3.4. Summary of parameters and approaches used by participants for calculation of ^{131}I concentration in milk.

END POINT \ PARTICIPANT	1 ASTRAL	2 CLIMRAD	3 CLRP	4 ECOSYS	5 LIETDOS	6 OSCAAR	7 Plavsk Dose Calculator	8 UniVes	9 SPADE V.6
^{131}I concentration in milk									
Consumption rate:									
Cow consumption rate of fresh grass [$kg \cdot d^{-1}$]	50	40	5/10/20/35/ 45, 100	42	45	42.5	40	45	42.5
Cow inhalation rate [$m^3 \cdot d^{-1}$] (if applied)	Not applied	Not applied		Not applied	Not applied	130	130	120	130
Soil ingestion rate [$kg \cdot d^{-1}$] (if applied)	Not applied	1	Not applied	Not applied	0.25	0.5	Not applied	Not applied	Not applied
Iodine cow metabolic model Milk transfer coefficient for ^{131}I [$d \cdot L^{-1}$]	0.003	0.01	0.008	0.003	0.003	0.0044	0.004	0.007	0.003
^{131}I contents in thyroid									
Milk consumption rates [$L \cdot d^{-1}$]	urban/rural	urban/rural	urban/rural	urban/rural	urban/rural	urban/rural	urban/rural	urban/rural	urban/rural
Adult	0.27/0.68	0.27/0.68	0.30/060	0.27/0.68	0.67	0.27/0.68	0.27/0.68	0.27/0.68	0.27/0.68
Child (8-12 years old)	0.30/0.44	0.30/0.44	0.30/040	0.30/0.44	0.44	0.30/0.44	0.30/0.44	0.30/0.44	0.30/0.44
Child (3-7 years old)	0.40/0.60	0.40/0.60	0.40/0.60	0.40/0.60	0.60	0.40/0.60	0.40/0.60	0.40/0.60	0.40/0.60
Babies (1-2 years old)	0.40/0.56	0.40/0.56 0.8 (mother milk)	0.40/0.60	0.40/0.56	0.56 (0.3 newborn)	0.40/0.56	0.40/0.56	0.40/0.56	0.40/0.56
Leafy vegetables consumption rate [$kg \cdot d^{-1}$]									
Adult	Not applied	0.03	Not applied	Not applied	0.03	Not applied	Not applied	0.05	Not applied
Child (8-12 years old)		0.02			0.03			0.05	
Child (3-7 years old)		0.01			0.03			0.05	
Babies (1-2 years old)		0.00			0.03			0.02	
Inhalation rate [$m^3 \cdot d^{-1}$]									
Adult	Not applied	20.0	24	22.3	20.0	23	23	22	Not applied
Child (8-12 years old)		13.3	15	15.4	13.3	15	15	15	
Child (3-7 years old)		11.0	10	8.6	8.8	10	10	10	
Babies (1-2 years old)		6.0 (2.9 new born)	6	5.0	5.6 (2.9 new born)	6	6	4	
Iodine metabolic model [24, 25]	Not applied	[25]	[24]	[24]	[25]	[24]	[25]	[24] (modified)	[25]

3.2. Mazovia Scenario

Table 3.5. Summary of parameters and approaches used by participants for ^{131}I deposition assessment.

PARTICIPANT / END POINT	1	2	3	4	5	6	7
	ECOSYS-87	LIETDOS	OSCAAR	UniVes	CLRP	CLIMRAD	IRH-model
^{131}I concentration in air							
Integrated air concentration (Bq d)	391.6	380	380	380	390.3	380	390
^{131} I iodine speciation (%): average on 28,29,30 April 1986							
particulate	59	40	60	57/57/68	60	60	50
reactive gas (I_2)	37	30	37	41/41/30	37	37	40
organic	4	30	3	2/2/2	3	3	10
^{131}I deposition in MAZOVIA district							
^{131}I deposition calculation in MAZOVIA district base on ^{137}Cs deposition data given in the scenario			NO	NO	NO		NO
^{131}I deposition calculation in MAZOVIA district base on ^{131}I concentration air data given in the scenario	YES	YES	YES	YES	YES	YES	YES
If you have assumed different period of plume arrival for particular milk farms (WARSAW, OSTROLEA) please specify	NO	NO	NO	NO	NO	NO	NO
dry deposition velocity ($m\times s^{-1}$) if considered ?							
particulate	1.5×10^{-3}	1.6×10^{-3}	2.0×10^{-3}	1.9×10^{-3}	3.1×10^{-3}		1.0×10^{-3}
reactive gas (I_2)	1.5×10^{-2}	9.5×10^{-3}	1.0×10^{-2}	1.9×10^{-2}	1.3×10^{-2}		2.0×10^{-2}
organic	1.5×10^{-4}	7.0×10^{-5}	1.0×10^{-4}	2.3×10^{-4}	1.3×10^{-4}		1.0×10^{-4}
washout factor w_r §*							
particulate		2.5×10^{6}	3.0×10^{5}	2.0×10^{5}	2.0×10^{4}	Not considered	Not considered
reactive gas (I_2)		5.0×10^{6}	2.0×10^{5}	8.0×10^{5}	1.3×10^{5}		Not considered
organic		8.0×10^{3}	2.0×10^{3}	2.0×10^{4}	1.3×10^{5}		Not considered
dry deposition ($kBq\times m^{-2}$)	72				230.6		270
wet deposition ($kBq\times m^{-2}$)					150.0		
total deposition ($kBq\times m^{-2}$)	72				380.6		270

*♣ 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: $W_{wet} = C\times \mathbf{w_r} \times R$; where: W_{wet} –wet deposition ($Bq\cdot m^{-2}$), C- concentration in air ($Bq\cdot m^{-3}$), R- rainfall (m)

Table 3.6. Summary of parameters and approaches used by participants for predictions of ^{131}I concentration in grass.

END POINT \ PARTICIPANT	1	2	3	4	5	6	7
	ECOSYS-97	**LIETDOS**	**OSCAAR**	**UniVes**	**CLRP**	**CLIMRAD**	**IRH-model**
	^{131}I concentration in grass						
grass yield (kg· m^{-2} fresh weight)							
at the period of start ^{131}I deposition	0.4	0.45	0.40	1.5(0.3dry)	0.48	0.2	0.4
at the end of ^{131}I deposition	0.4	0.45	0.59	1.5(0.3dry)	0.5	0.2	0.4
grass interception fraction (dimensionless) (μ)							
for dry deposition	0.33	0.36	1-exp(-Y(t))	0.45	0.11		0.25
for wet deposition	-	0.36	another formula	0.7	0.2		0.1
formula used: 1-exp(-μY)	LAI		2	2	2.4		3.6
weathering H ½ [d]	25	10.0	10	11	4.7		Not used
weathering H ½ [d] (effective)	4.65	8.7	4.5	4.65	3		3.5

Table 3.7. Summary of parameters and approaches used by participants for predictions of ^{131}I concentration in milk.

END POINT \ PARTICIPANT	1	2	3	4	5	6	7
	ECOSYS-97	**LIETDOS**	**OSCAAR**	**UniVes**	**CLRP**	**CLIMRAD**	**IRH-model**
			^{131}I concentration in milk				
Cattle consumption rate of fresh grass [kg·d^{-1}]	45		50	40	50	45	40
Falenty	uncontaminated grass	uncontaminated grass			0.3(0.67%)		0
WARSAW			5 kg/d dry				
28/04 - 6/05;					2		40
7/05-18/05;					10		40
19/05- 31/05					50		40
PERCENGE			depends on farm		87%		83%
OSTROLEA			9 kg/d dry				
28/04 - 5/05;					10		40
6/05-15/05;					30		40
16/05- 30/05					50		40
PERCENGE			depends on farm		59%		59%
Cattle inhalation rate [m^3· d^{-1}]	120		130	not applied	100	not applied	112.5
Soil ingestion [kg ·d^{-1}]]	not applied	0.52	1	not applied	0.25		not applied, but assume that box for cow's food (0,2 sq.m.) is also contaminated with fallout
Milk transfer coefficient for ^{131} I(d·L^{-1})	3.0×10^{-3}		4.4×10^{-3}	1.0×10^{-2}	2.97×10^{-3}	3×10^{-3}	3×10^{-3}

Table 3.8. Summary of parameters used by participants for predictions of ^{131}I intakes of particular age groups.

END POINT \ PARTICIPANT	1	2	3	4	5	6	7
	ECOSYS-97	LIETDOS	OSCAAR	UniVes	CLRP	CLIMRAD	IRH-model
^{131}I contents in thyroid (thyroid burden)							
	WARSAW/ OSTROLEKA	WARSAW/ OSTROLEKA	WARSAW/ OSTROLEKA	WARSAW/ OSTROLEKA	WARSAW/ OSTROLEKA	WARSAW/ OSTROLEKA	WARSAW/ OSTROLEKA
Milk consumption rates [L× d^{-1}]							
Adult	0.16/0.29		0.26/0.37	0.4/0.6	0.26/0.37	0.67	0.26/0.37
15 Years Old	0.26/0.48		0.34/0.55	0.28/0.4.	0.34/0.55	0.44	0.34/0.57
10 Years Old	0.286/0.53		0.34/0.58	0.33/0.37	0.34/0.58	0.60	0.34/0.57
5 Years Old	0.29/0.54		0.32/0.57	0.44/0.50	0.32/0.58	0.56	0.32/0.57
1 Years Old	0.34/0.64		0.35/0.65	0.8 (mother milk)	0.35/0.65	0.29	0.35/0.57
L. vegetables consumption rate(kg× d^{-1})							
Adult	Not considered		Not considered		-/0.036	–	
15 Years Old	Not considered		Not considered	0.03	-/0.031	0.03	
10 Years Old	Not considered		Not considered	0.02	-/0.023	0.03	
5 Years Old	Not considered		Not considered	0.01	/0.014	0.03	
1 Years Old	Not considered		Not considered	0	-/0.007	0.03	
Inhalation rate (m^3× d^{-1})							
Adult		22.32	22.2	20			22
15 Years Old		20.16	20.1	13.3			18
10 Years Old		15.36	15.3	11			13.5
5 Years Old		8.64	8.72	6			7.7
1 Years Old		5.04	5.16	2.9			3.7

Table 3.9. Summary of parameters used by participants for predictions of ^{131}I thyroid burden of particular age groups.

PARTICIPANT / END POINT	1 ECOSYS-97	2 LIETDOS	3 OSCAAR	4 UniVes	5 CLRP	6 CLIMRAD	7 IRH-model
Iodine metabolic model:							
[24]	YES				YES	YES	exponential function*
[25]						YES	
remained fraction of committed dose to thyroid after acute intake							
after 6 hours			0.49		0.44		0.54
after 12 hours			0.74		0.71		0.77
after 18 hours			0.87		0.85		0.89
after 24 hours			0.94		0.93		0.95
Inhalation dose Time spent indoors [hours per day]							WARSAW/ OSTROLEKA
Adult	0.8		16.8				18 / 13
15 Years Old	0.8		16.8				16 / 14
10 Years Old	0.8		16.8				17 / 14
5 Years Old	0.8		16.8				19 /17
1 Years Old	0.8		16.8				20 /18
House filtration factor	0.5		0.5				0.5
Effective factor	0.6						

* Exponential function of ^{131}I retention in thyroid.

3.3. Prague Scenario

Table 3.10. Summary of parameters and approaches used by participants for ^{131}I deposition assessment.

PARTICIPANT / END POINT	1 ECOSYS-97	2 LIETDOS	3 OSCAAR	4 UniVes	5 CLRP	6 CLIMRAD	7 IRH-model
^{131}I concentration in air							
Integrated air concentration (Bq d)					240		193
^{131}I iodine speciation (%): average on 28–30 April 1986							
particulate					40%		33
reactive gas (I_2)					50%		33
organic					10%		34
^{131}I deposition in PRAGUE district							
^{131}I deposition calculation in PRAGUE district base on ^{137}Cs deposition data given in the scenario					NO		YES
^{131}I deposition calculation in PRAGUE district base on ^{131}I concentration air data given in the scenario					YES	YES	YES
dry deposition velocity ($m\times s^{-1}$) if considered ?							
particulate	1.5×10^{-3}	1.6×10^{-3}	2.0×10^{-3}	1.9×10^{-3}	3.1×10^{-3}		1.0×10^{-3}
reactive gas (I_2)	1.5×10^{-2}	9.5×10^{-3}	1.0×10^{-2}	1.9×10^{-2}	1.3×10^{-2}		1.0×10^{-2}
organic	1.5×10^{-4}	7.0×10^{-5}	1.0×10^{-4}	2.3×10^{-4}	1.3×10^{-4}		1.0×10^{-4}
washout factor w_r §*							
particulate		2.5×10^{6}	3.0×10^{5}	2.0×10^{5}	2.0×10^{4}	Not considered	Not considered
reactive gas (I_2)		5.0×10^{6}	2.0×10^{5}	8.0×10^{5}	1.3×10^{5}		Not considered
organic		8.0×10^{3}	2.0×10^{3}	2.0×10^{4}	1.3×10^{5}		Not considered
dry deposition ($kBq\times m^{-2}$) ?	72				230.6		59
wet deposition ($kBq\times m^{-2}$) ?					150.0		
total deposition ($kBq\times m^{-2}$) ?	72				380.6		

♣ 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: $W_{wet} = C\times\mathbf{w_r}\times R$; where: W_{wet} –wet deposition ($Bq\cdot m^{-2}$), C- concentration in air ($Bq\cdot m^{-3}$), R- rainfall (m)

Table 3.11. Summary of parameters and approaches used by participants for predictions of ^{131}I concentration in grass.

END POINT \ PARTICIPANT	1 ECOSYS-97	2 LIETDOS	3 OSCAAR	4 UniVes	5 CLRP	6 CLIMRAD	7 IRH-model
^{131}I concentration in grass							
grass yield (kg· m^{-2} fresh weight)							
at the period of start ^{131}I deposition	0.4	0.45	0.40	1.5(0.5dry)	0.5	0.2	0.5
at the end of ^{131}I deposition	0.4	0.45	0.59	1.5(0.5dry)	0.5	0.2	0.5
grass interception fraction (dimensionless) (μ)							
for dry deposition	0.33	0.36	1-exp(-Y(t))	0.45	0.1		0.25
for wet deposition	-	0.36	another formula	0.7	0.2		0.1
formula used: 1-exp(-μY)	LAI		2	2	2.4		3.6
weathering H ½ [d]	25	10.0	10	11	8		8
weathering H ½ [d] (effective)	4.65	8.7	4.5	4.65	4		4

Table 3.12. Summary of parameters and approaches used by participants for predictions of ^{131}I concentration in milk.

PARTICIPANT / END POINT	1 ECOSYS-97	2 LIETDOS	3 OSCAAR	4 UniVes	5 CLRP	6 CLIMRAD	7 IRH-model
^{131}I concentration in milk							
Cattle consumption rate of fresh grass [kg·d^{-1}]	45		50	40	30.04-2.05 (5) 3.05-13.05 (15) 14.05-20.10 (35)	45	40
PRAGA-TROJA	uncontaminated grass	uncontaminated grass					0
PRAGA-KYE			5 kg/d dry				
BENESOW							40
Cattle inhalation rate [m^3· d^{-1}]	120		130	not applied	100	not applied	112.5
Soil ingestion [kg ·d^{-1}]]	not applied	0.52	1	not applied	not applied		not applied, but assume that box for cow's food (0,2 sq.m.) is also contaminated with fallout
Milk transfer coefficient for ^{131} I(d·L^{-1})	3.0×10^{-3}		4.4×10^{-3}	1.0×10^{-2}	2.97×10^{-3}	3×10^{-3}	3×10^{-3}

Table 3.13. Summary of parameters used by participants for predictions of ^{131}I intakes of particular age groups.

END POINT \ PARTICIPANT	1 ECOSYS-97	2 LIETDOS	3 OSCAAR	4 UniVes	5 CLRP	6 CLIMRAD	7 IRH-model
^{131}I contents in thyroid (thyroid burden)							
Milk consumption rates [L× d^{-1}]							
Adult	0.16/0.29		0.26/0.37	0.4/0.6	0.26/0.37	0.67	0.5
15 Years Old	0.26/0.48		0.34/0.55	0.28/0.4.	0.34/0.55	0.44	0.7
10 Years Old	0.286/0.53		0.34/0.58	0.33/.37	0.34/0.58	0.60	1
5 Years Old	0.29/0.54		0.32/0.57	0.44/0.50	0.32/0.58	0.56	1
1 Years Old	0.34/0.64		0.35/0.65	0.8 (mother milk)	0.35/0.65	0.29	0.1
L. vegetables consumption rate(kg× d^{-1})							
Adult	Not considered		Not considered		-/0.036	–	
15 Years Old	Not considered		Not considered	0.03	-/0.031	0.03	
10 Years Old	Not considered		Not considered	0.02	-/0.023	0.03	
5 Years Old	Not considered		Not considered	0.01	/0.014	0.03	
1 Years Old	Not considered		Not considered	0	-/0.007	0.03	
Inhalation rate (m^3× d^{-1})							
Adult		22.32	22.2	20			22
15 Years Old		20.16	20.1	13.3			18
10 Years Old		15.36	15.3	11			13.5
5 Years Old		8.64	8.72	6			7.7
1 Years Old		5.04	5.16	2.9			3.7

Table 3.14. Summary of parameters used by participants for predictions of ^{131}I thyroid burden of particular age groups.

END POINT \ PARTICIPANT	1 ECOSYS-97	2 LIETDOS	3 OSCAAR	4 UniVes	5 CLRP	6 CLIMRAD	7 IRH-model
Iodine metabolic model:							
[24]	YES				YES	YES	exponential function*
[25]						YES	
Inhalation dose Time spent indoors [hours per day]							
Adult	0.8		16.8				18
15 Years Old	0.8		16.8				16
10 Years Old	0.8		16.8				16
5 Years Old	0.8		16.8				19
1 Years Old	0.8		16.8				20
House filtration factor	0.5		0.5				0.5
Effective factor	0.6						

* Exponential function of ^{131}I retention in thyroid.

CHAPTER 4. RESULTS AND DISCUSSION

4.1. Plavsk Scenario

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

The mean activity ratio of gamma-emitters deposited after Chernobyl accident to the surface activity of ^{137}Cs is presented in Table 4.1. This ratio for $^{131}I/^{137}Cs$, calculated on 10 May 1986, is equal to 3.34 with a standard error of 19%. It was evaluated by Orlov [13] and Pitkevich [26] and corresponds 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, the 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 and 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:

$$\sigma_{^{131}I} = a \times (\sigma_{^{137}Cs})^b \qquad (4.1)$$

where:

$\sigma_{^{131}I}$ is the deposition of ^{131}I on the specified date;
$\sigma_{^{137}Cs}$ is the deposition of ^{137}Cs; and
a, b are the constants.

This approach has been used by Knatko [27] for Belarus (a= 33.78, b= 0.64) and by Mahonko [28] for Kiev and Tula regions (a= 8.85, b= 0.85)

One can notice that the activity ratios of $^{131}I/^{137}Cs$ evaluated as constant value approach [29] or as a power function approach [28] differ by less than a factor 2.5 and decrease with higher ^{137}Cs content in soil (see Figure 4.1). Most modellers used constant activity ratios (with the exception of CLRP) given in Scenario Plavsk and this resulted in almost the same values. The differences in uncertainty ranges estimated by particular models result from different calculation method of the representative mean of ^{137}Cs content in soil for particular areas of milk farm and personal judgment (see Figure 4.2).

Table 4.1. Mean activity ratios* of gamma-emitting radionuclides deposited after the Chernobyl accident for the “northeast trace” [13, 26].

Radionuclides*	Mean	Standard error (%)
$^{134}Cs / ^{137}Cs$	0.51	4.3
$^{131}I / ^{137}Cs$	3.34	19.5
$(^{140}Ba + ^{140}La) / ^{137}Cs$	0.64	24.0
$(^{95}Zr + ^{95}Nb) / ^{137}Cs$	0.13	27.0
$^{103}Ru / ^{137}Cs$	1.39	29.0
$^{106}Ru / ^{137}Cs$	0.47	15.7
$^{133}I / ^{131}I$	2.0	5.0
$^{136}Cs / ^{137}Cs$	0.26	8.0
$^{132}Te / ^{137}Cs$	15.8	30.0

* In general, the ratios apply to 10 May 1986; for the short-lived radionuclides ^{136}Cs, ^{133}I, and ^{132}Te they apply to 26 April 1986.

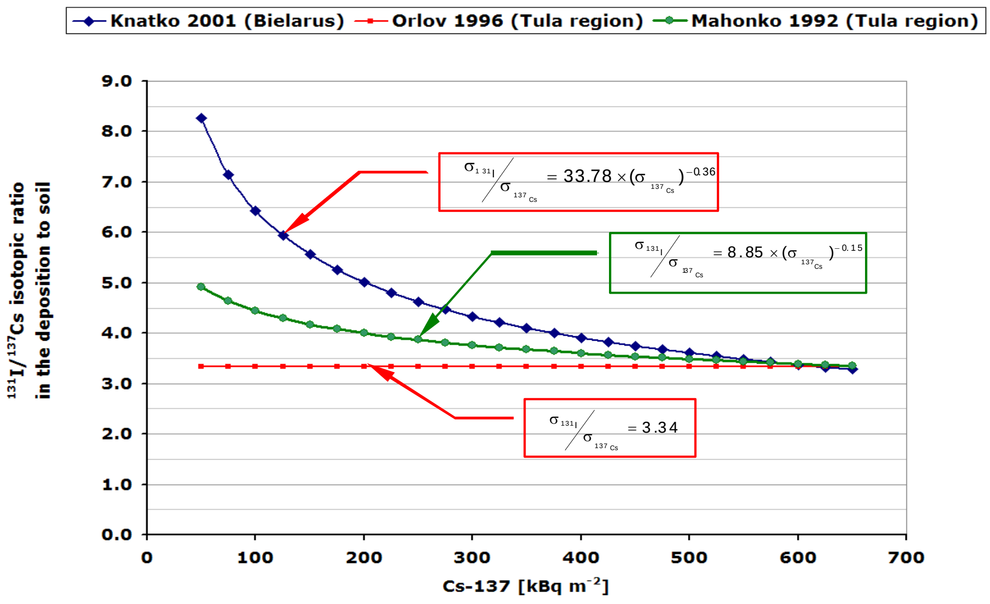

Fig. 4.1. The activity ratio of ^{131}I/ ^{137}Cs deposited after Chernobyl accident calculated on 10 may 1986 as a function of ^{137}Cs content in soil – different approaches of evaluation

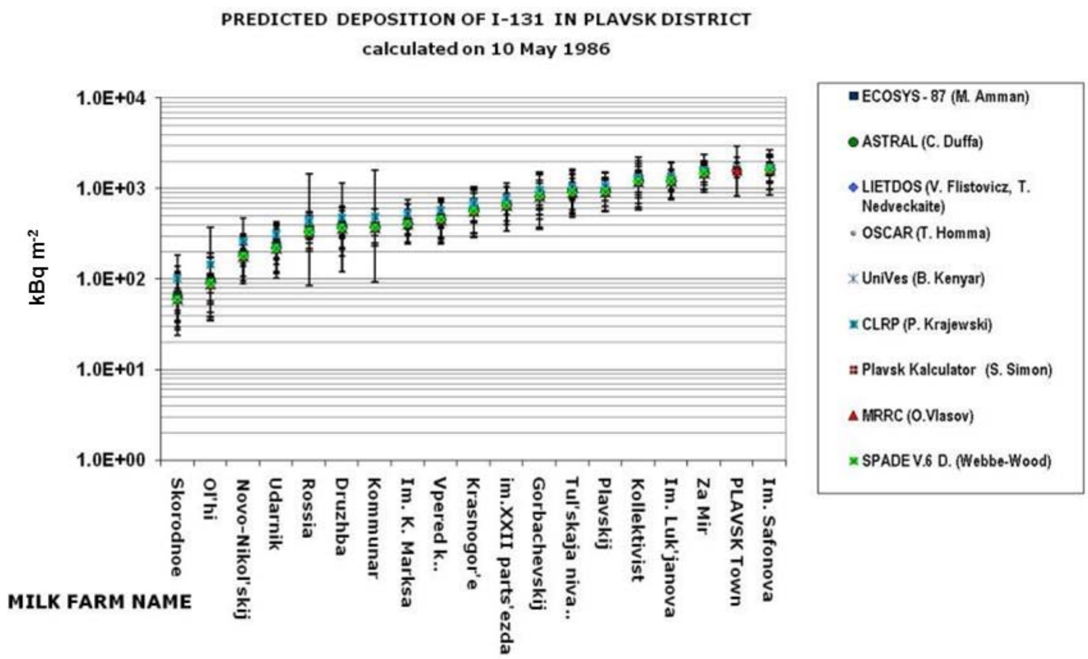

Fig. 4.2. Summary of predicted ^{131}deposition in particular areas of milk farm of Plavsk District (^{131}I deposition sorted in ascending order).

Table 4.2. Predicted ^{131}I (kBq m^{-2}) deposition in particular areas of milk farm of Plavsk district calculated on 10 May 1986 (^{131}I deposition sorted in ascending order).

Collective farm	Arithmetic mean	*95% Confidence interval* Lower Bound	*95% Confidence interval* Upper Bound	Ratio ^{131}I to ^{137}Cs	Arithmetic mean	*95% Confidence interval* Lower Bound	*95% Confidence interval* Upper Bound	Ratio ^{131}I to ^{137}Cs	Arithmetic mean	*95% Confidence interval* Lower Bound	*95% Confidence interval* Upper Bound	Ratio ^{131}I to ^{137}Cs
	(M. Amman) ECOSYS - 87				**(C. Duffa) ASTRAL**				**(V. Flistovicz, T. Nedveckaite) LIETDOS**			
Krasnogor'e	69	*29*	*140*	3.84	63	*42*	*79*	3.50	60	*27*	*112*	3.34
Za Mir	97	*43*	*194*	3.60	93	*58*	*117*	3.44	90	*38*	*171*	3.34
Im. Safonova	189	*107*	*312*	3.50	184	*151*	*211*	3.41	180	*108*	*280*	3.34
Plavskij	242	*120*	*434*	3.67	225	*173*	*277*	3.41	220	*117*	*388*	3.34
Vpered k kommunizmu	350	*202*	*559*	3.50	332	*284*	*365*	3.32	334	*216*	*479*	3.34
Im. Luk'janova	389	*221*	*639*	3.54	374	*280*	*430*	3.40	367	*213*	*574*	3.34
Gorbachevskij	386	*234*	*601*	3.45	379	*361*	*396*	3.38	374	*307*	*451*	3.34
Tul'skaja niva (NIISH)	428	*252*	*672*	3.48	410	*367*	*448*	3.33	411	*300*	*535*	3.34
Im. K. Marksa	476	*276*	*744*	3.47	453	*362*	*527*	3.31	458	*259*	*708*	3.34
Rossia	599	*325*	*978*	3.54	570	*442*	*666*	3.37	564	*319*	*890*	3.34
Kollektivist	675	*405*	*1060*	3.44	659	*614*	*697*	3.36	655	*524*	*810*	3.34
Kommunar	870	*463*	*1450*	3.51	824	*583*	*988*	3.32	828	*372*	*1417*	3.34
Druzhba	955	*547*	*1570*	3.50	959	*760*	*1106*	3.51	912	*525*	*1432*	3.34
im.XXII parts'ezda	959	*570*	*1500*	3.45	937	*830*	*1031*	3.37	929	*639*	*1246*	3.34
Udarnik	1280	*686*	*2220*	3.58	1205	*906*	*1482*	3.37	1196	*625*	*1905*	3.34
Ol'hi	1250	*751*	*1990*	3.43	1229	*1155*	*1298*	3.38	1216	*976*	*1474*	3.34
Skorodnoe	1520	*907*	*2410*	3.44	1490	*1398*	*1586*	3.37	1476	*1171*	*1835*	3.34
Novo-Nikol'skij					1586	*1334*	*1951*	3.34				
PLAVSK Town	1680	*975*	*2660*	3.46	1616	*1388*	*1789*	3.33	1620	*1149*	*2223*	3.34

Table 4.2. (Continued) Predicted ^{131}I (kBq m^{-2}) deposition in particular areas of milk farm of Plavsk district calculated on 10 May 1986 (^{131}I deposition sorted in ascending order).

Collective farm	Arithmetic mean	*95% Confidence interval*		Ratio ^{131}I to ^{137}Cs	Arithmetic mean	*95% Confidence interval*		Ratio ^{131}I to ^{137}Cs	Arithmetic mean	*95% Confidence interval*		Ratio ^{131}I to ^{137}Cs
		Lower Bound	*Upper Bound*			*Lower Bound*	*Upper Bound*			*Lower Bound*	*Upper Bound*	
	(T. Homma) OSCAAR				**(B. Kenyar) UniVes**				**(P. Krajewski) CLRP**			
Krasnogor'e	61	*35*	*118*	3.38	59	*45*	*73*	3.28	59	*45*	*73*	3.28
Za Mir	89	*35*	*175*	3.30	89	*70*	*110*	3.30	89	*70*	*110*	3.30
Im. Safonova	180	*89*	*317*	3.33	180	*140*	*220*	3.33	180	*140*	*220*	3.33
Plavskij	220	*165*	*415*	3.34	220	*170*	*280*	3.33	220	*170*	*280*	3.33
Vpered k kommunizmu	335	*85*	*548*	3.35	330	*250*	*410*	3.30	330	*250*	*410*	3.30
Im. Luk'janova	368	*121*	*646*	3.35	360	*310*	*410*	3.27	360	*310*	*410*	3.27
Gorbachevskij	374	*94*	*593*	3.34	370	*300*	*460*	3.30	370	*300*	*460*	3.30
Tul'skaja niva (NIISH)	411	*243*	*673*	3.35	410	*320*	*500*	3.33	410	*320*	*500*	3.33
Im. K. Marksa	458	*290*	*790*	3.34	450	*380*	*520*	3.28	450	*380*	*520*	3.28
Rossia	564	*294*	*999*	3.34	560	*430*	*690*	3.31	560	*430*	*690*	3.31
Kollektivist	654	*340*	*1045*	3.34	650	*520*	*790*	3.32	650	*520*	*790*	3.32
Kommunar	827	*515*	*1482*	3.34	820	*660*	*980*	3.31	820	*660*	*980*	3.31
Druzhba	910	*586*	*1659*	3.33	900	*740*	*1100*	3.30	900	*740*	*1100*	3.30
im.XXII parts'ezda	929	*641*	*1547*	3.34	920	*740*	*1100*	3.31	920	*740*	*1100*	3.31
Udarnik	1195	*787*	*2223*	3.34	1200	*920*	*1600*	3.35	1200	*920*	*1600*	3.35
Ol'hi	1214	*802*	*1947*	3.34	1200	*930*	*1500*	3.30	1200	*930*	*1500*	3.30
Skorodnoe	1476	*919*	*2379*	3.34	1500	*1100*	*1800*	3.39	1500	*1100*	*1800*	3.39
Novo-Nikol'skij	1586	*837*	*2926*	3.34								
PLAVSK Town	1619	*852*	*2684*	3.34	1600	*1200*	*2000*	3.30	1600	*1200*	*2000*	3.30

Table 4.2. (Continued) Predicted ^{131}I deposition (kBq m^{-2}) in particular areas of milk farm of Plavsk district calculated on 10 May 1986 (^{131}I deposition sorted in ascending order).

Collective farm	Arithmetic mean	95% Confidence interval		Ratio ^{131}I to ^{137}Cs	Arithmetic mean	95% Confidence interval		Ratio ^{131}I to ^{137}Cs	Arithmetic mean	95% Confidence interval		Ratio ^{131}I to ^{137}Cs
		Lower Bound	*Upper Bound*			*Lower Bound*	*Upper Bound*			*Lower Bound*	*Upper Bound*	
	Plavsk Kalculator (S. Simon)				**(O.Vlasov) MRRC**				**SPADE V.6 D. (Webbe-Wood)**			
Krasnogor'e	60			3.34	61	*33*	*120*	3.38	60	*24*	*114*	3.34
Za Mir	90			3.34	89	*53*	*154*	3.30	90	*36*	*178*	3.34
Im. Safonova	180			3.34	180	*140*	*237*	3.33	180	*97*	*296*	3.34
Plavskij	220			3.34	220	*147*	*354*	3.34	220	*102*	*387*	3.34
Vpered k kommunizmu	334			3.34	335	*274*	*417*	3.35	334	*201*	*510*	3.34
Im. Luk'janova	367			3.34	368	*297*	*474*	3.35	367	*182*	*614*	3.34
Gorbachevskij	374			3.34	374	*354*	*397*	3.34	374	*249*	*502*	3.34
Tul'skaja niva (NIISH)	411			3.34	411	*357*	*481*	3.35	411	*259*	*579*	3.34
Im. K. Marksa	458			3.34	458	*381*	*558*	3.34	458	*243*	*762*	3.34
Rossia	564			3.34	564	*424*	*778*	3.34	564	*287*	*953*	3.34
Kollektivist	655			3.34	654	*601*	*714*	3.34	655	*437*	*887*	3.34
Kommunar	828			3.34	827	*611*	*1142*	3.34	828	*355*	*1522*	3.34
Druzhba	912			3.34	910	*791*	*1168*	3.33	912	*485*	*1453*	3.34
im.XXII parts'ezda	929			3.34	929	*838*	*1032*	3.34	929	*558*	*1338*	3.34
Udarnik	1196			3.34	1195	*845*	*1773*	3.34	1196	*590*	*2007*	3.34
Ol'hi	1216			3.34	1214	*1115*	*1322*	3.34	1216	*799*	*1638*	3.34
Skorodnoe	1476			3.34	1476	*1352*	*1616*	3.34	1476	*984*	*2016*	3.34
Novo-Nikol'skij	1587			3.34	1586	*1334*	*1951*	3.34				
PLAVSK Town	1620			3.34	1619	*1392*	*1893*	3.34	1620	*975*	*2409*	3.34

4.1.2. ^{131}I concentration in grass

In Section I.4.3.1 of Appendix I states that the height of the grass in 30 April 1986 was about 5–10 cm, that gives yield of the grass of about 0.05 kg m^{-2} dry weight. Although, the low grass yield results in lower interception fractions, it did not affect remarkably the predictions of ^{131}I concentration in grass (less than 10%) compared with fully developed grass (yield 0.2 kg m^{-2} dry weight) (see Figure 4.3).

The ratios of ^{131}I concentration in grass on 1 May 1986[3] to the ^{131}I deposition calculated for particular models range from 0.65 m^2 kg^{-1}(UniVes) to 15.5 m^2 kg^{-1} (CLRP) and reflect different assumptions that were made by particular models with respect to the date when the radioiodine plume arrival and departure. For example, UniVes assumed a long period of airborne radioiodine over the Plavsk district comparing with other modellers that assumed a one day period (see Table 3.1). The various assumptions on interception of airborne and waterborne radionuclides 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 Figure 4.4).

The weathering half-life of ^{131}I in grass is given in the Section I.6 of Appendix I (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 4 days (ECOSYS run 1) to 25 days (ECOSYS run 2) based on post Chernobyl knowledge (see Table 3.1) and this parameter had a major contribution to the predictions of ^{131}I concentration in milk especially for the second half of May .The SPADE V.6 code took into account the effect of the removal of ^{131}I in grass after approximately two weeks from initial contamination (cows grazing???) that also affected predictions of ^{131}I concentration in milk.

4.1.3. ^{131}I concentration in milk

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

4.1.3.1. *Grass intake by cows*

The values range from 40–45 kg/day of fresh grass as suggested in Scenario descriptions, were applied by most of models. Information on gradual transfer of cattle in grazing regime[4] after winter period was not been reflected by measurements.

[3] Approximate maximum value of ^{131}I in grass due to deposition on 30 April 1986.

[4] 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.

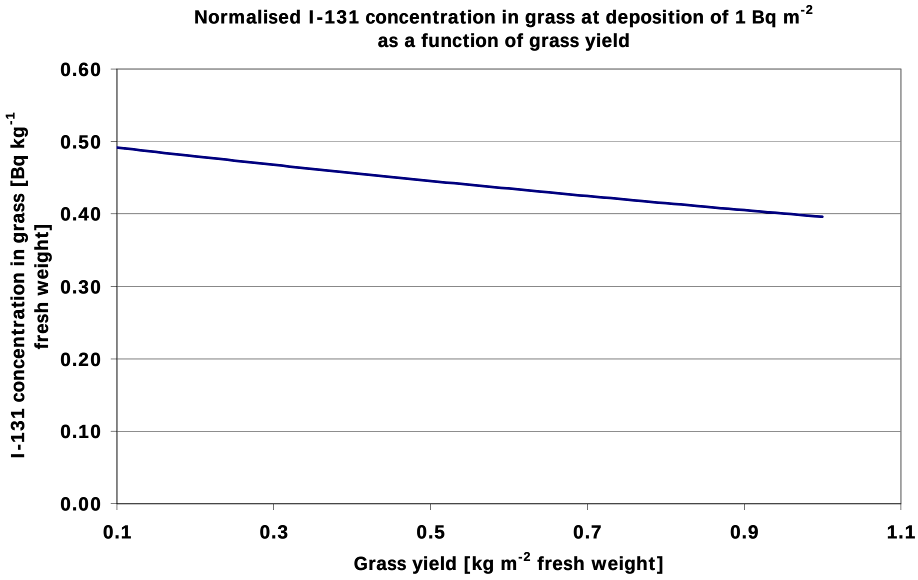

Fig. 4.3. Normalised ^{131}I concentration in grass at deposition of 1 Bq m^{-2} as a function of grass yield.

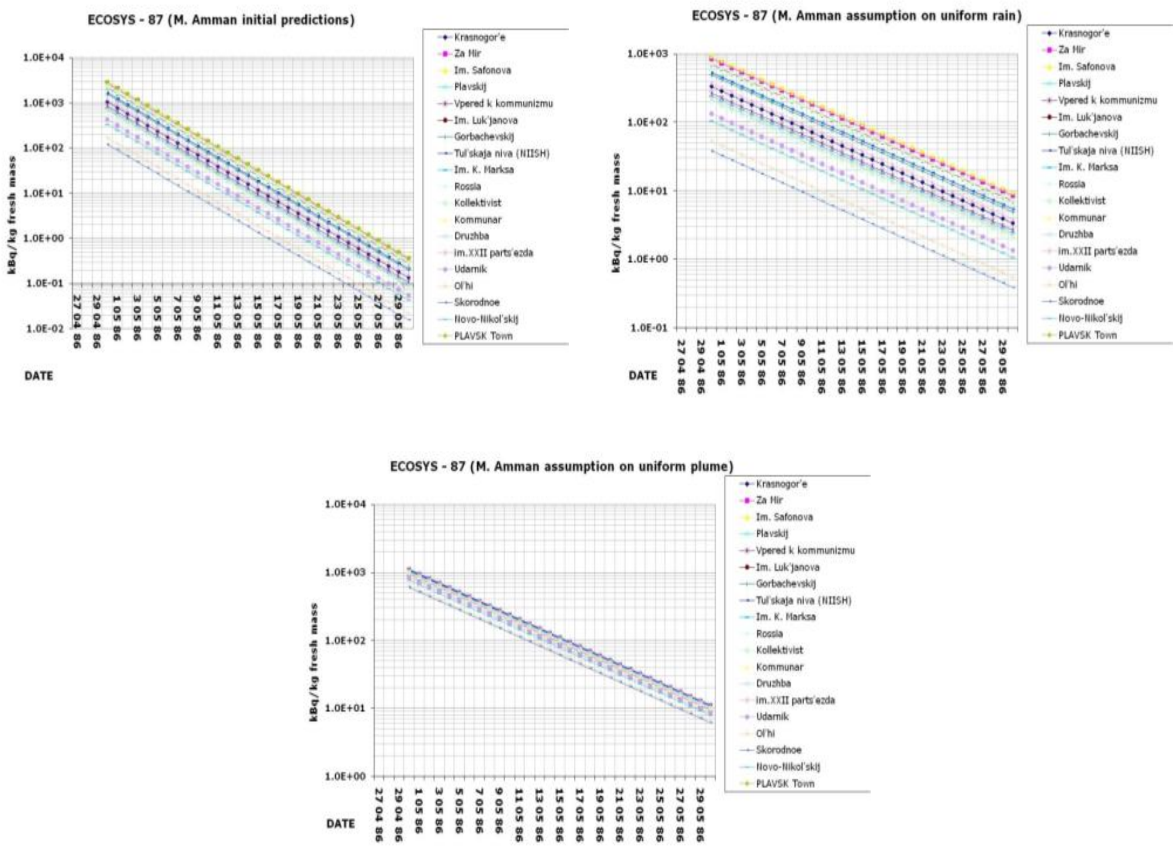

Fig. 4.4. Examples of predictions of ^{131}I concentration in grass by ECOSYS 98 (M. Ammann).

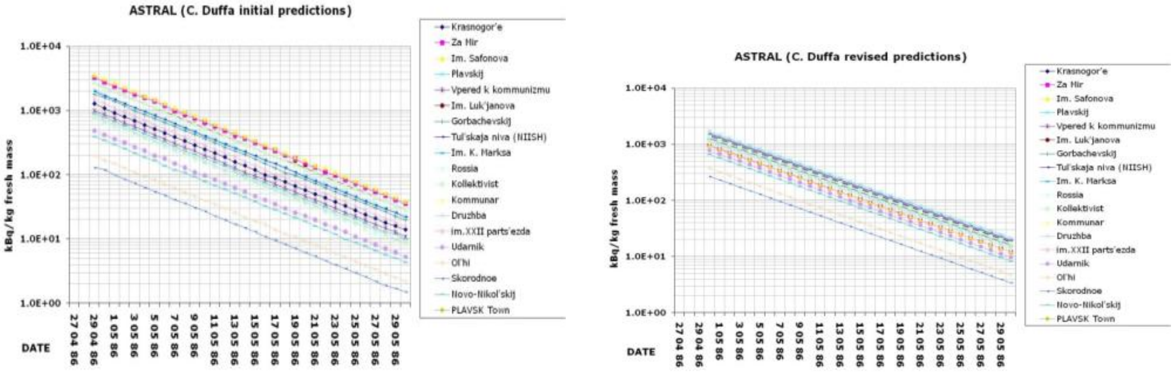

Fig. 4.5. Examples of predictions of ^{131}I concentration in grass by ASTRAL (C. Duffe).

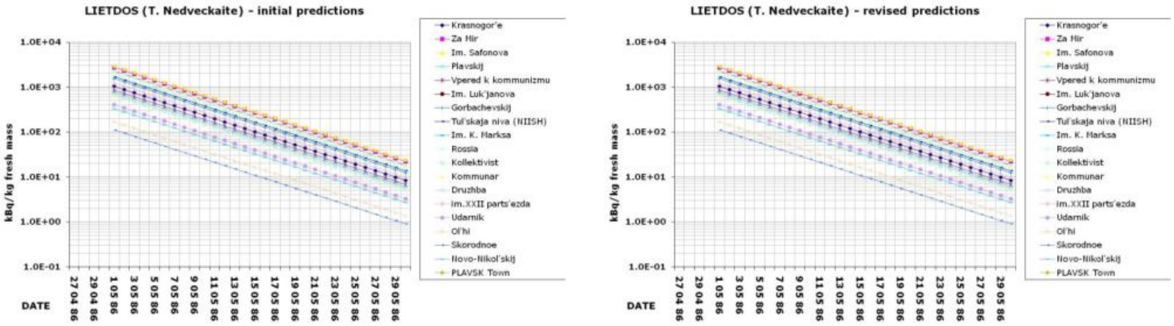

Fig. 4.6. Examples for predictions of ^{131}I concentration in grass. by LITEDOS (T. Nedveckaite).

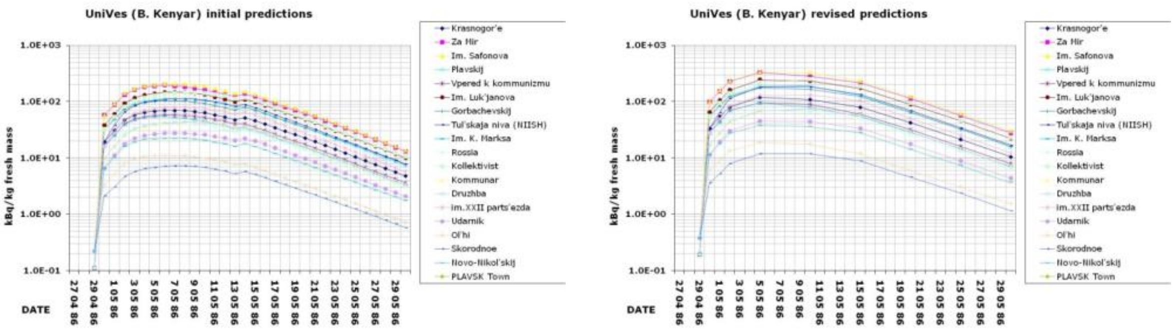

Fig. 4.7. Examples for predictions of ^{131}I concentration in grass by UNIVES (B. Kenyar).

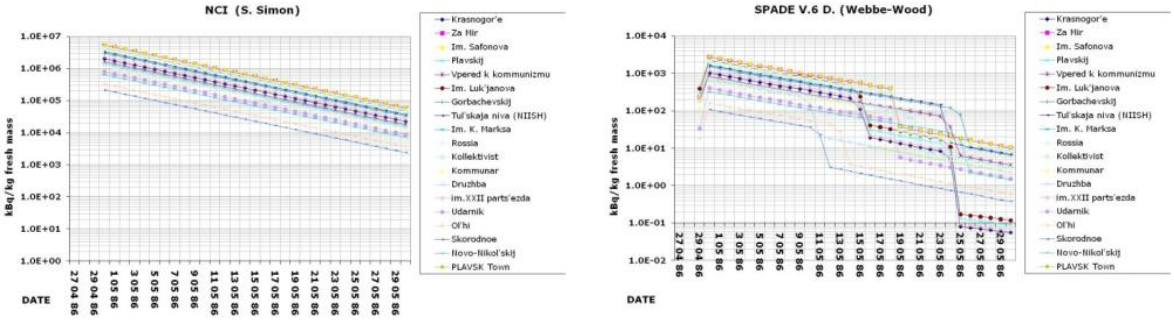

Fig. 4.8. Examples for predictions of ^{131}I concentration in grass by NCI (S. Simon) and SPADE (Webbe-Wood).

4.1.3.2. Dates of the beginning of pasturing collective and private cattle

According to the interviews of the collective farms directors (Table I.14) and inhabitants (Table I.13) given in Plavsk Scenario description (Appendix I) grazing of collective cattle began approximately 10 days later than that of private cows. This phenomena was not always confirmed by observations. 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 the dates for collective farms. Especially the reported dates after 20 May were not confirmed by results of measurements for following milk farms: “Novo-Nicolsky”, “Rossia”, “Im. K. Marksa”, “Tuls’kaja niva”, “Gorbachevsky”, “Vpieriod k komunizmu “ and “Krasnogorie”

One could suggest that the dates of 12–15 May 1986 could perhaps be more representative for start grazing in collective farms, as the warm weather with a temperature of about 15 °C occurred in the Plavsk district. These modellers who assumed date of 12 May 1986 for start grazing overall milk farms achieved better agreement with observed data

4.1.3.3. Representativeness of milk samples

The main uncertainty was due to 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 the 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 from private cows. These details were not pointed in the working notebooks (Irina Zvonowa communications).

4.1.3.4. Iodine Metabolic model for cow

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

4.1.3.5. *Comparison of observed and predicted ^{131}I concentration in milk*

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

More than 50% of the predicted ^{131}I concentrations in milk are 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 reason for mispredictions and need to be carefully considered.

4.1.4. ***^{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 than 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 Figure 4.19). The settlements can be considered as small villages that belong to the particular milk farm. Participants had to calculate 33 various time series with the 95% uncertainty ranges. At least six modellers performed this task. There were several factors with respect of model capability to predict of ^{131}I content in thyroids.

4.1.4.1. *Milk consumption rate*

The milk consumption rate is reported in Section 4.4.2 of the Scenario descriptions. One could notice that there is no substantial difference in milk consumption within different age groups in rural and urban population (seeTable 4.3). The variation in milk consumption for different age groups contributes to the predictions uncertainty no more than approximately 30%. The urban population used to drink about half of the milk consumed by rural population. The measurements of ^{131}I activity in thyroid present a much higher variability than one could expect from reported data about milk consumption rates.

4.1.4.2. *Iodine metabolic model for different age groups*

An Excel program based on the iodine metabolism model developed by Johnson [24] was provided for the models that did not have the possibility of calculation of ^{131}I content in the thyroid (see Table 4.4). Some models used own formulas based on ICRP-56 [25]. 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 4.4 entitled: "^{131}I 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 levels in thyroid but it could not be included in the Scenario.

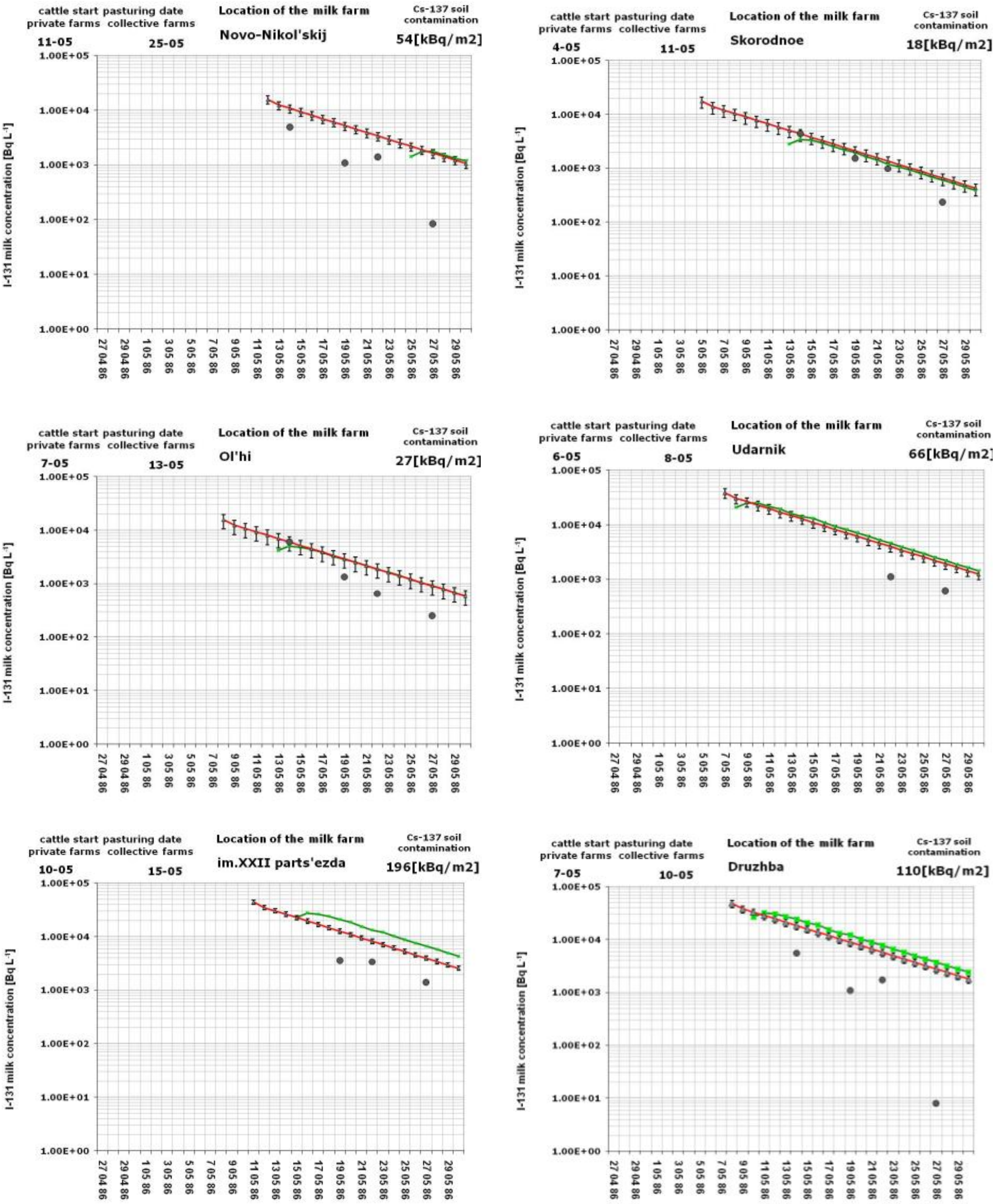

Fig. 4.9. Comparison of private farms (triangles), collective farms (crosses) predictions and observed ^{131}I concentration in milk for ASTRAL (C. Duffa) in particular locations of Plavsk district. On the top of picture: dates of start pasturing cows, location name, average ^{137}Cs surface contaminations.

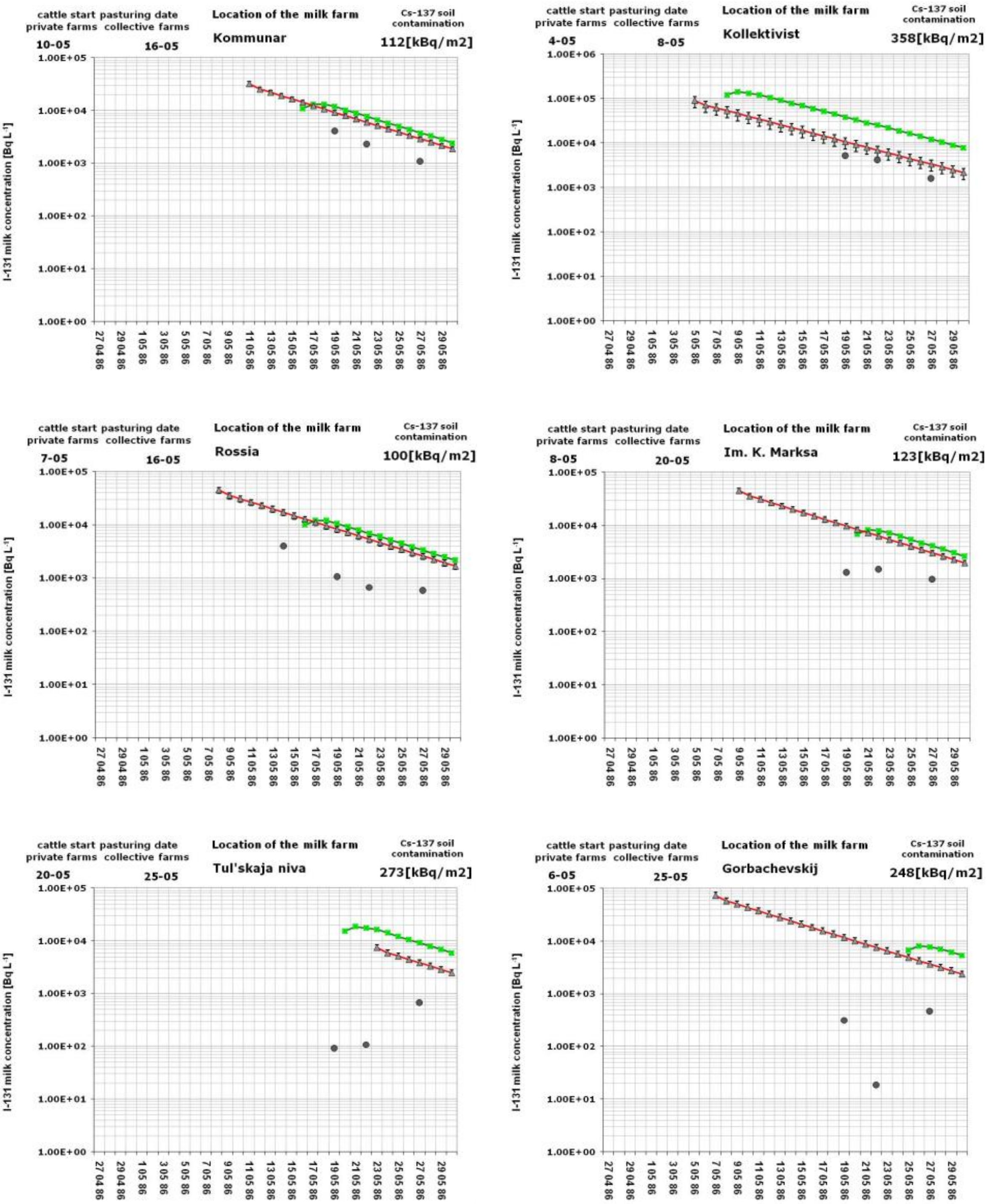

Fig. 4.9. (Continued) Comparison of private farms (triangles), collective farms (crosses) predictions and observed ^{131}I concentration in milk for ASTRAL (C. Duffa) in particular locations of Plavsk district. On the top of picture: dates of start pasturing cows, location name, average ^{137}Cs surface contaminations.

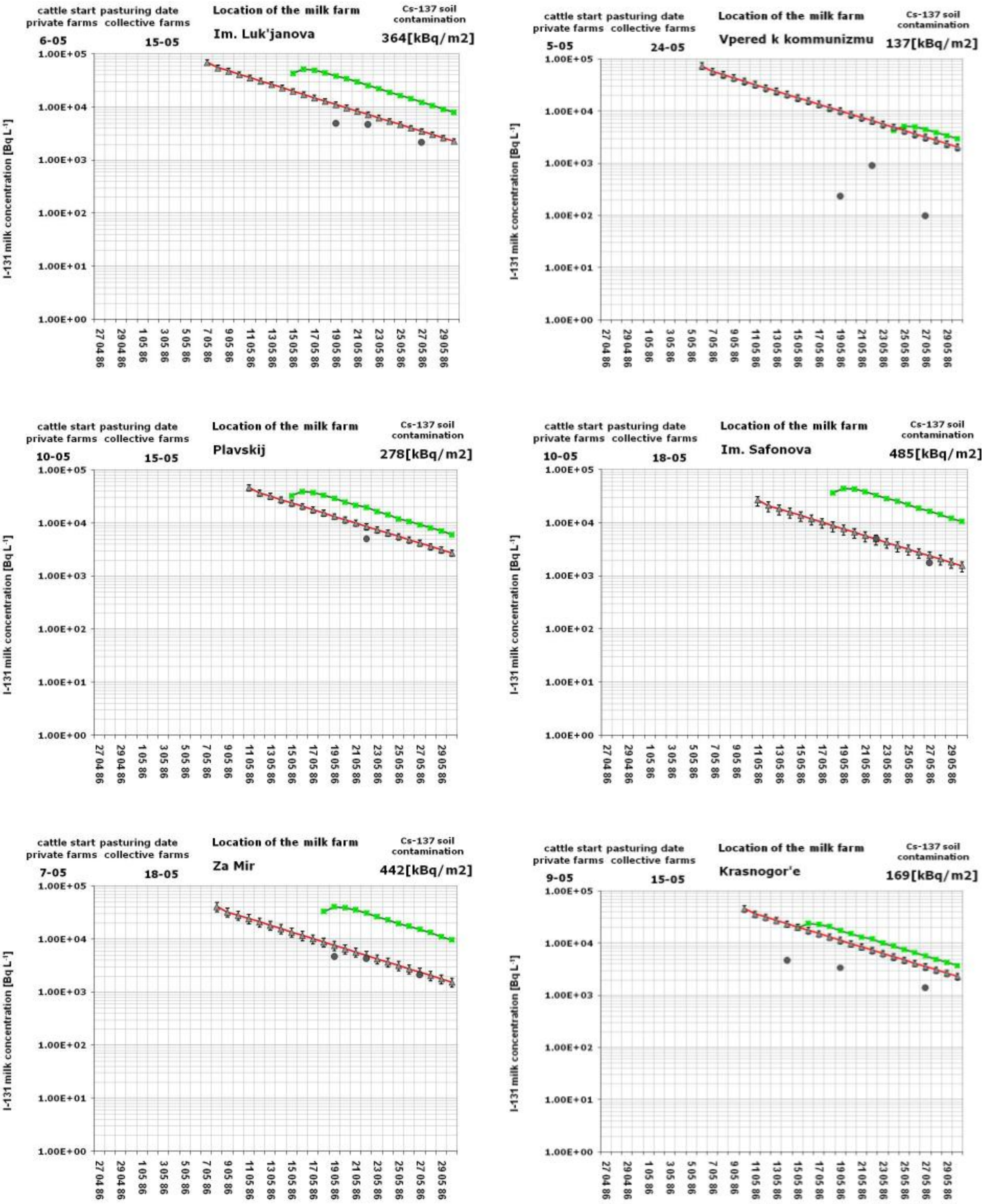

Fig. 4.9. (Continued) Comparison of private farms (triangles), collective farms (crosses) predictions and observed ^{131}I concentration in milk for ASTRAL (C. Duffa) in particular locations of Plavsk district. On the top of picture: dates of start pasturing cows, location name, average ^{137}Cs surface contaminations.

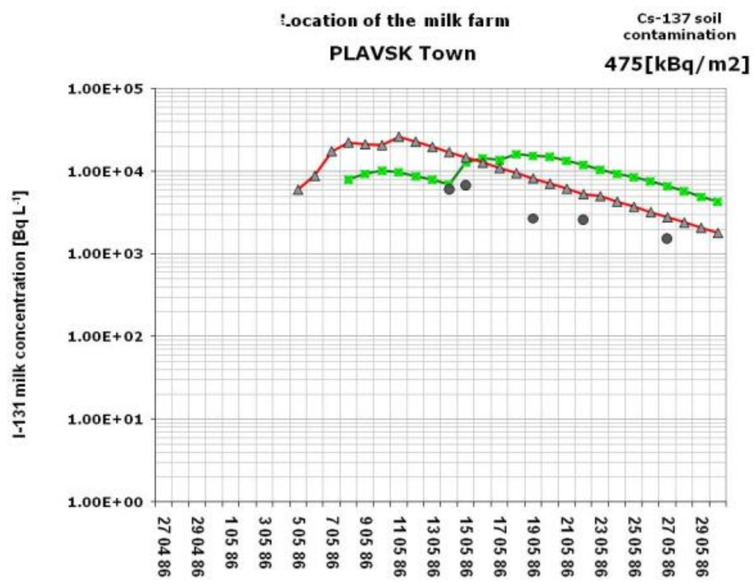

Fig. 4.10. Comparison predictions and observed ^{131}I concentration in milk for (C. Duffa) ASTRAL in Town Plavsk: private farms (triangles), collective farms (crosses). On the top of picture: location name, average ^{137}Cs surface contaminations.

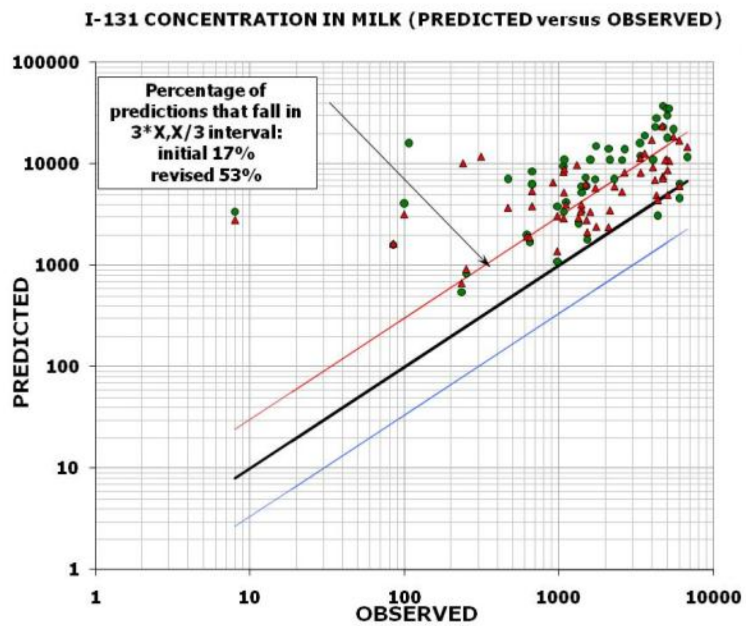

Fig. 4.11. Predicted versus observed ^{131}I concentration in milk for ASTRAL (C. Duffa) for all Plavsk districts: private farms (triangles), collective farms (crosses).

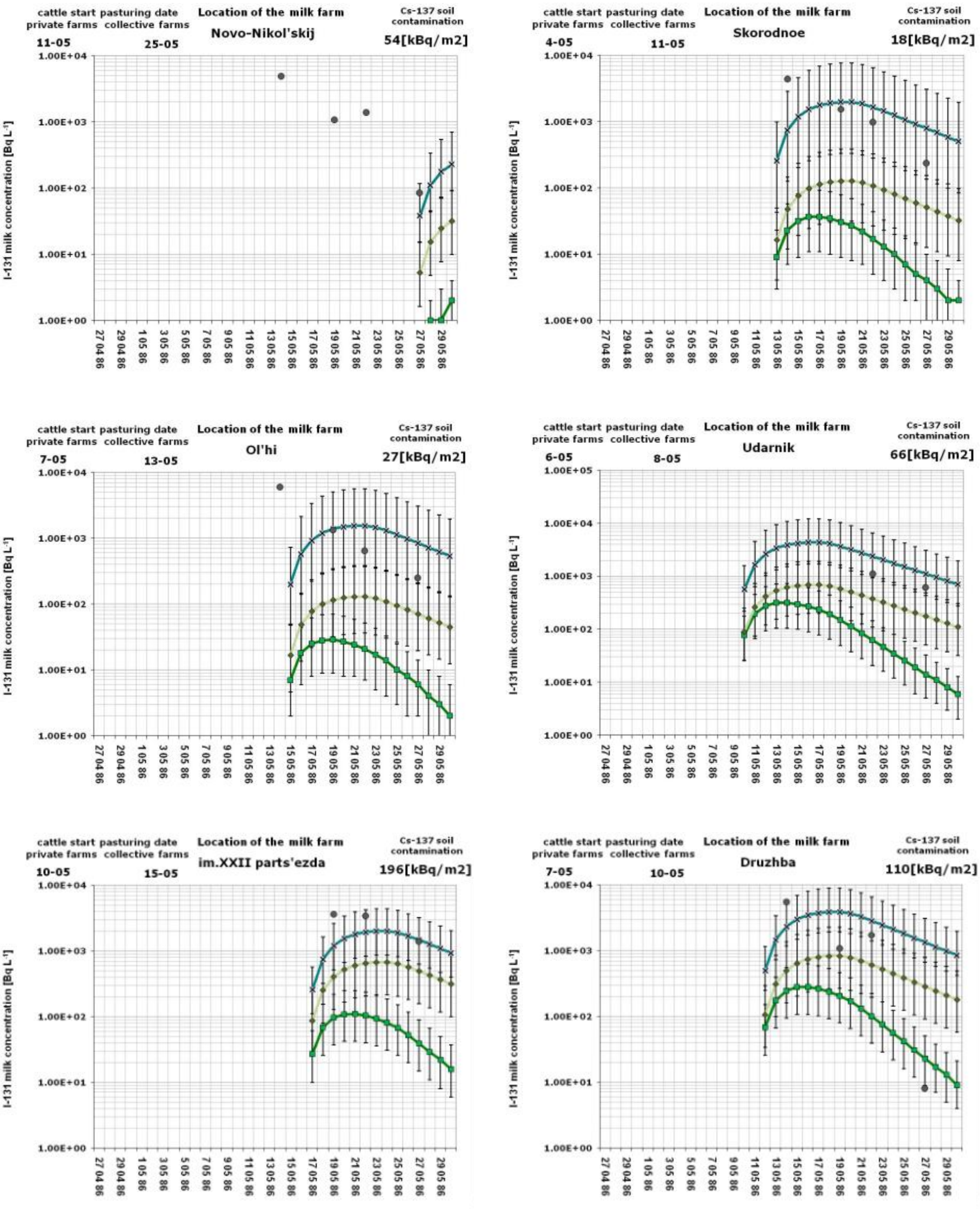

Fig. 4.12. Comparison of initial (squares), uniform rain (diamonds), uniform plume (crosses) predictions and observed ^{131}I concentration in milk for ECOSYS – 87 (M. Amman) in particular locations of Plavsk district. On the top of picture: dates of start pasturing cows, location name, average ^{137}Cs surface contaminations. Collectives farms start cows pasturing date was considered.

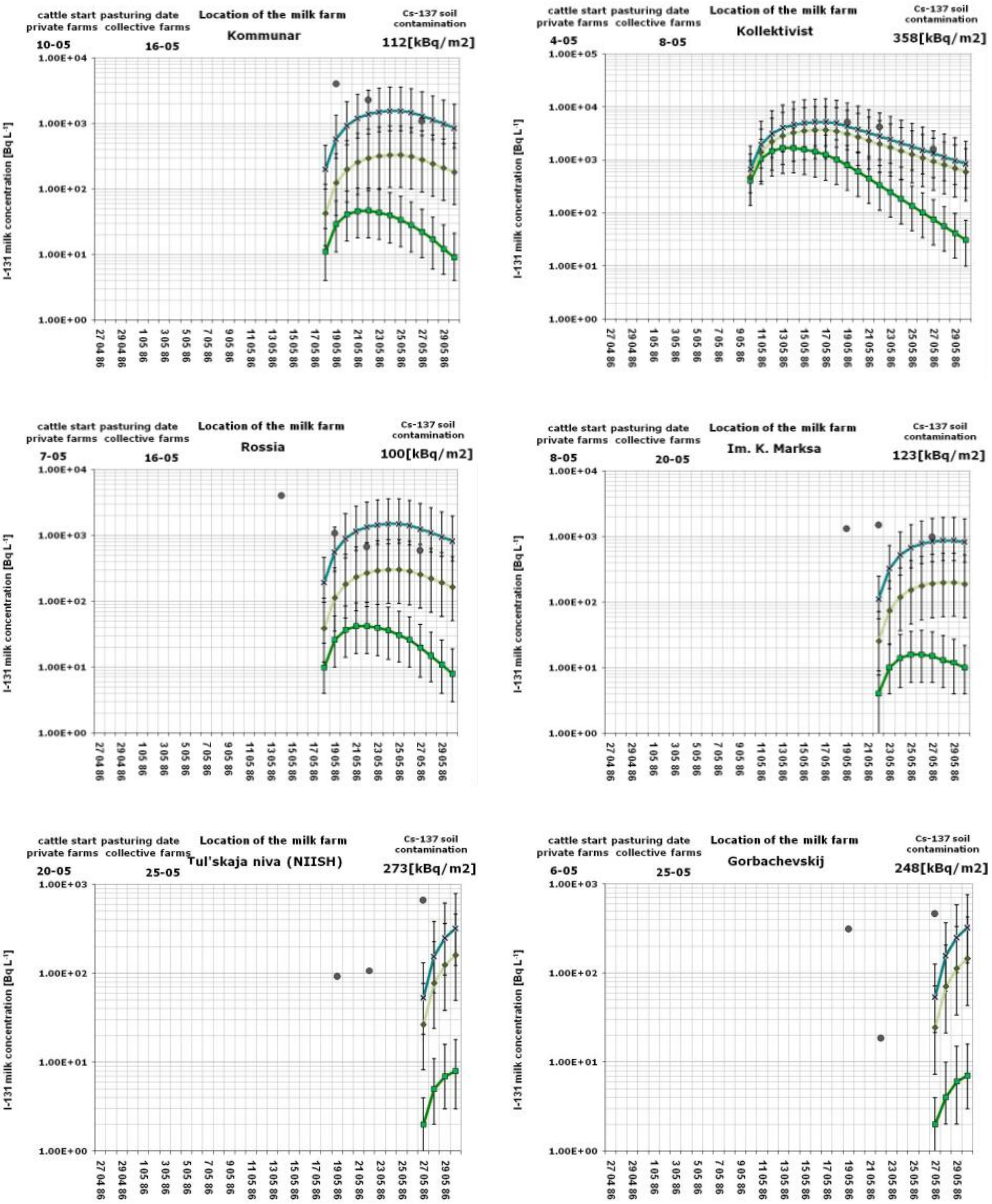

Fig. 4.12. (Continued) Comparison of initial (squares), uniform rain (diamonds), uniform plume (crosses) predictions and observed ^{131}I concentration in milk for ECOSYS – 87(M. Amman) in particular locations of Plavsk district. On the top of picture: dates of start pasturing cows, location name, average ^{137}Cs surface contaminations. Collectives farms start cows pasturing date was considered.

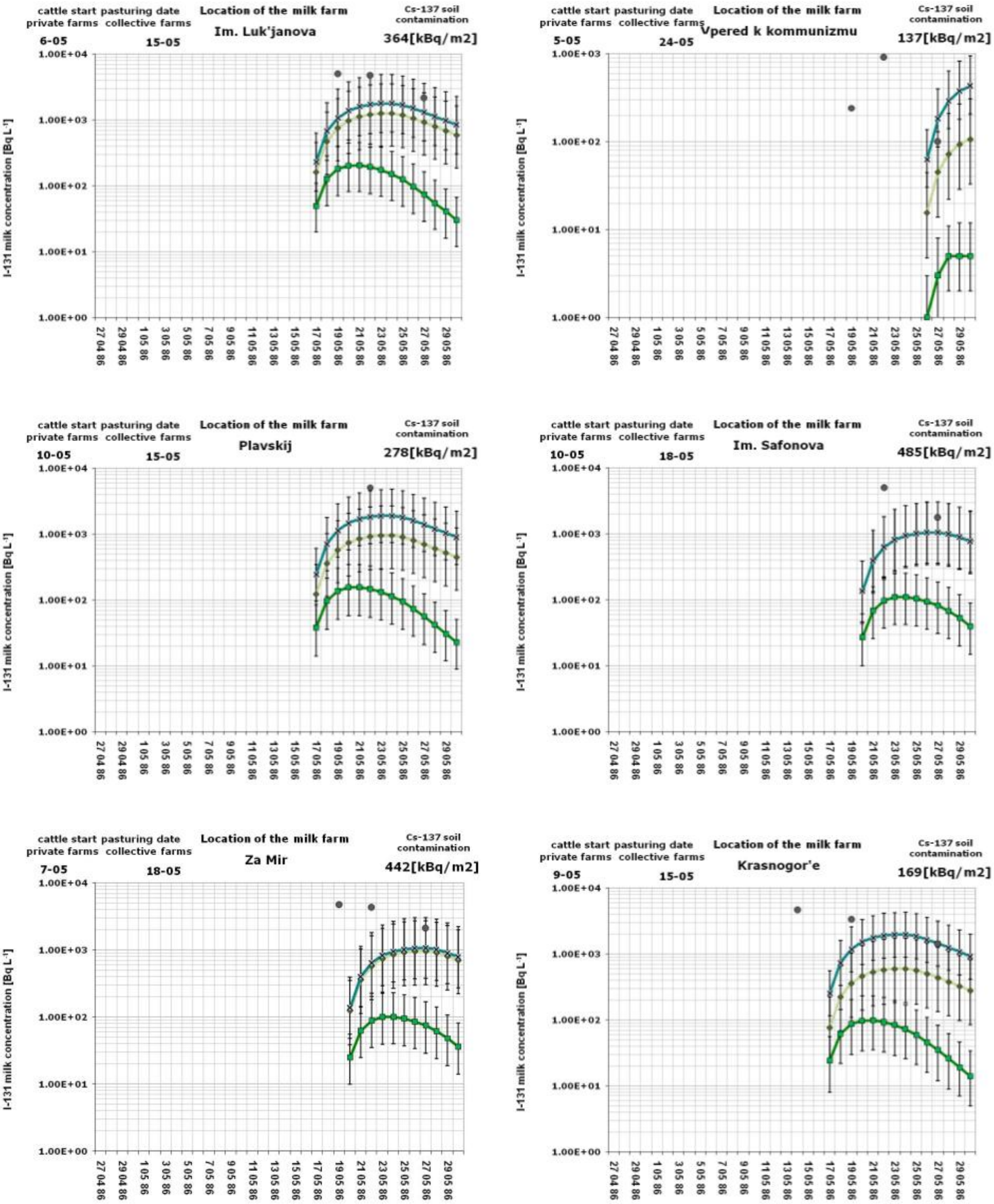

Fig. 4.12. (Continued) Comparison of initial (squares), uniform rain (diamonds), uniform plume (crosses) predictions and observed ^{131}I concentration in milk for (M. Amman) ECOSYS – 87 in particular locations of Plavsk district. On the top of picture: dates of start pasturing cows, location name, average ^{137}Cs surface contaminations. Start cows pasturing date of collectives farms was considered.

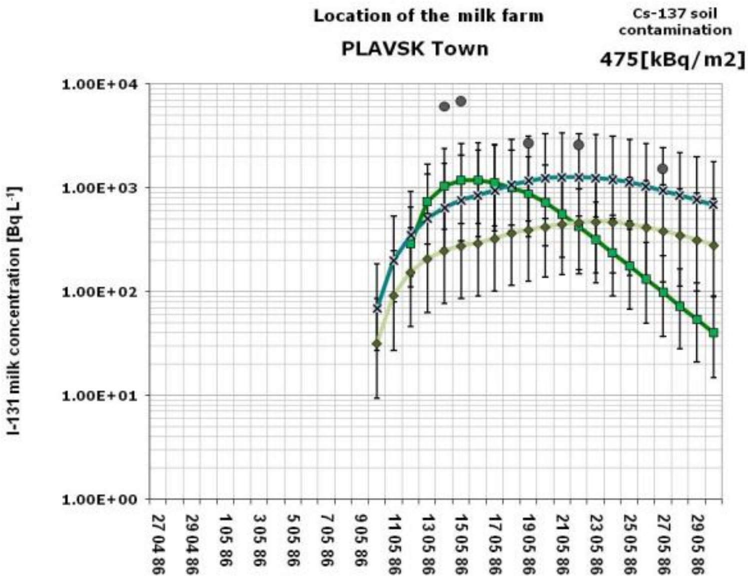

Fig. 4.13. Comparison of initial (squares), uniform rain (diamonds), uniform plume (crosses) predictions and observed ^{131}I concentration in milk for (M. Amman) ECOSYS - 87 in the Town Plavsk. On the top of picture: location name, average ^{137}Cs surface contaminations.

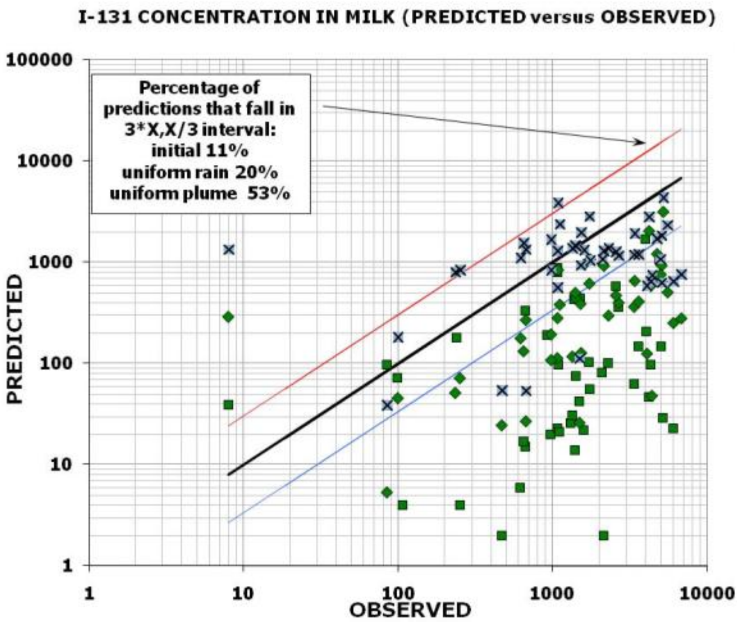

Fig. 4.14. Predicted versus observed ^{131}I concentration in milk for ECOSYS – 87(M. Amman) for all Plavsk districts: initial predictions (squares), uniform rain (diamonds), uniform plume (crosses).

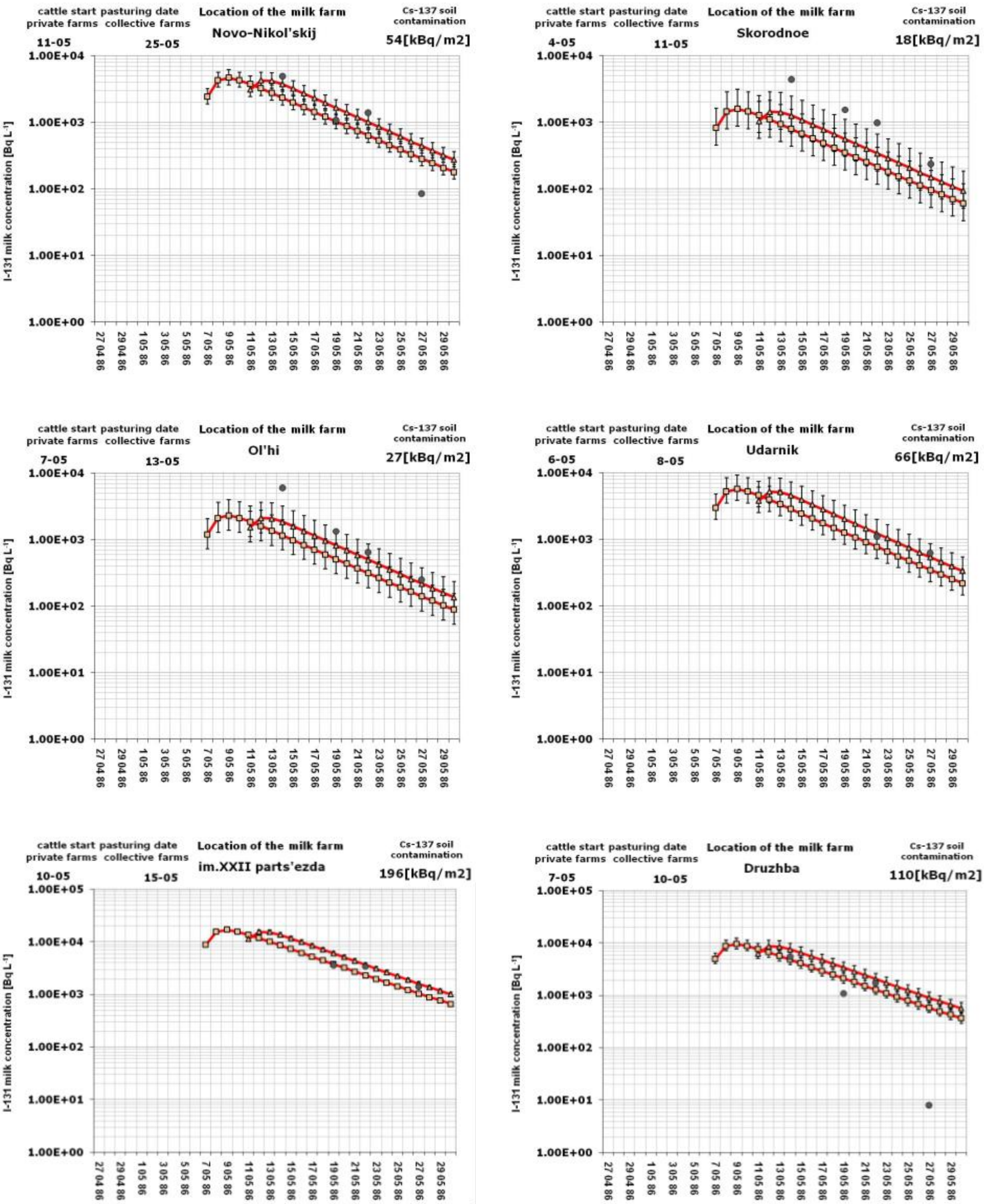

Fig. 4.15. Comparison of private farms (squares), collective farms (triangles) predictions and observed ^{131}I concentration in milk for MRRC (O.Vlasov) in particular locations of Plavsk district. On the top of picture: dates of start pasturing cows, location name, average ^{137}Cs surface contaminations. A unique date of start cows pasturing for all private and all collective farms was assumed: 7.05.1986 and 11.05.1986 respectively.

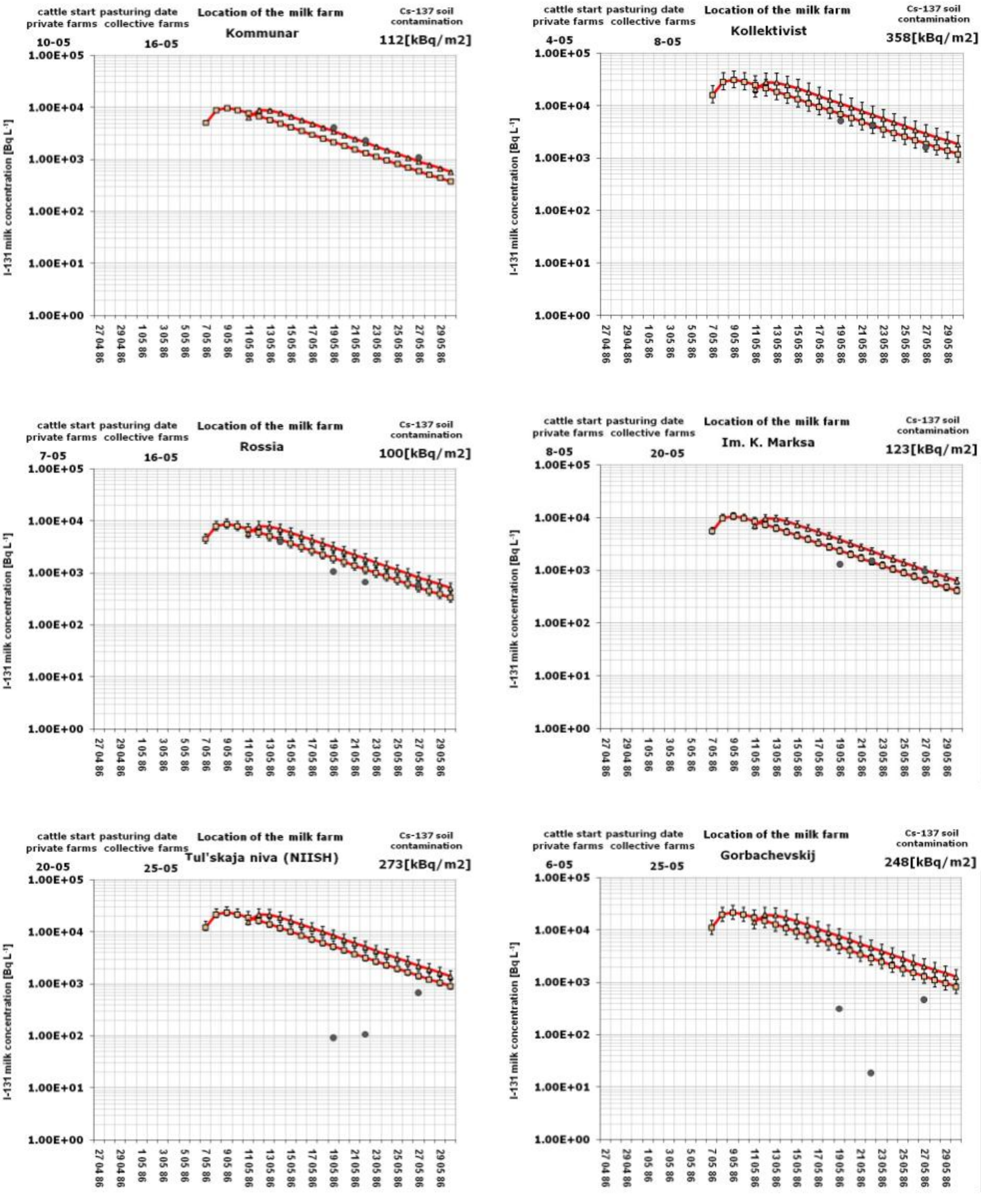

Fig. 4.15. (Continued) Comparison of private farms (squares), collective farms (triangles) predictions and observed ^{131}I concentration in milk for MRRC (O.Vlasov) in particular locations of Plavsk district. On the top of picture: dates of start pasturing cows, location name, average ^{137}Cs surface contaminations. A unique date of start cows pasturing for all private and all collective farms was assumed: 7.05.1986 and 11.05.1986 respectively.

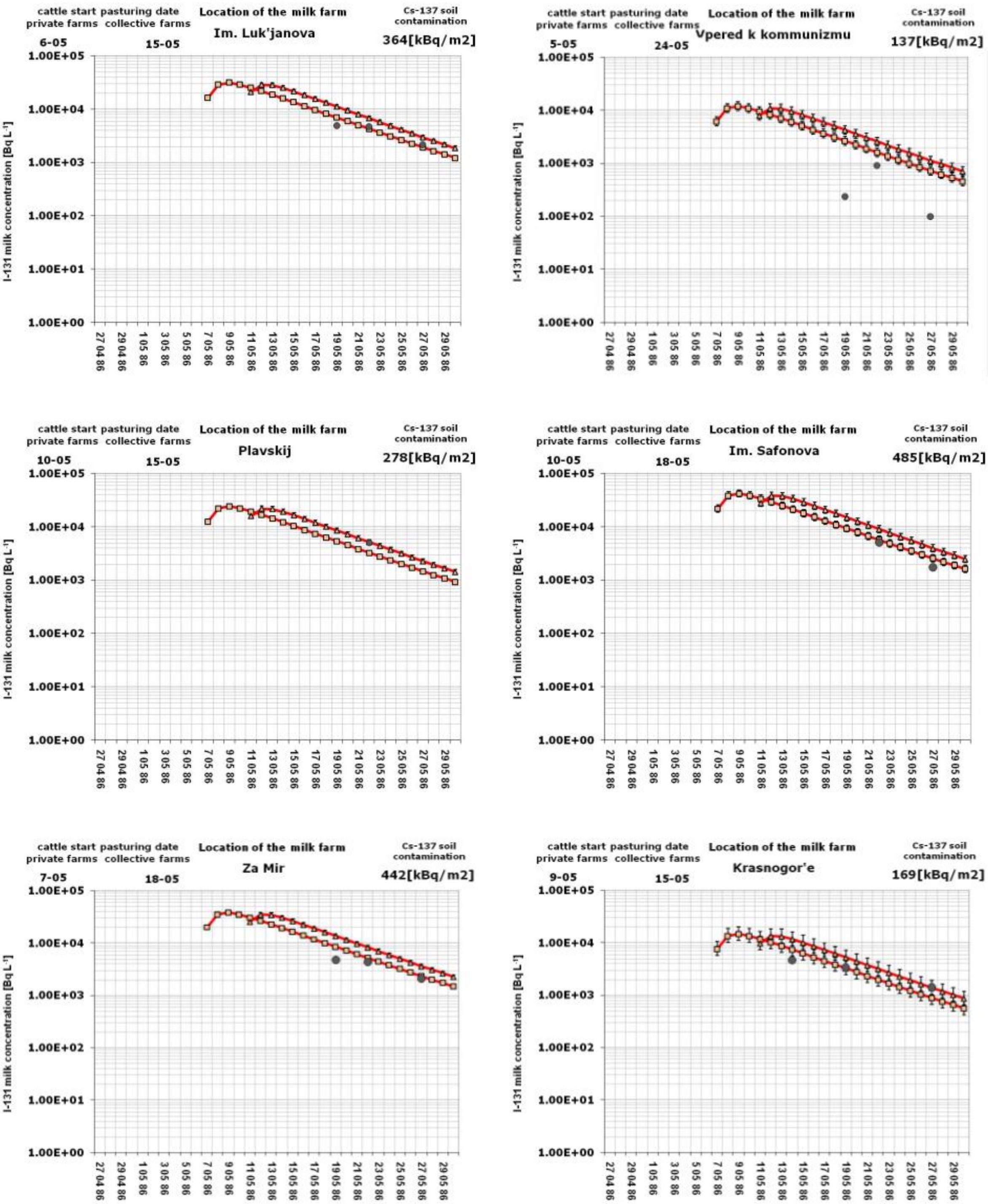

Fig. 4.15. (Continued) Comparison of private farms (squares), collective farms (triangles) predictions and observed ^{131}I concentration in milk for) MRRC (O.Vlasov in particular locations of Plavsk district. On the top of picture: dates of start pasturing cows, location name, average ^{137}Cs surface contaminations. A unique date of start cows pasturing for all private and all collective farms was assumed: 7.05.1986 and 11.05.1986 respectively.

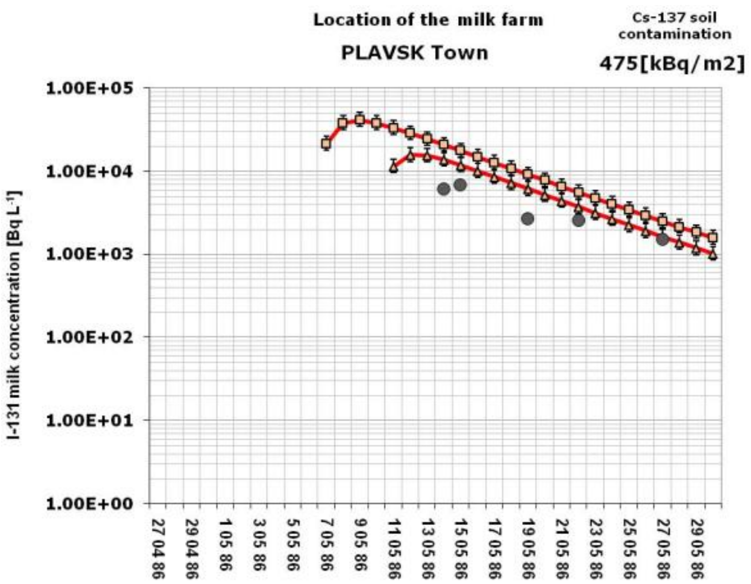

Fig. 4.16. Predicted versus observed ^{131}I concentration in milk for for (O.Vlasov) MRRC for all Plavsk districts: private farms (squares), collective farms (triangle), uniform plume (crosses).

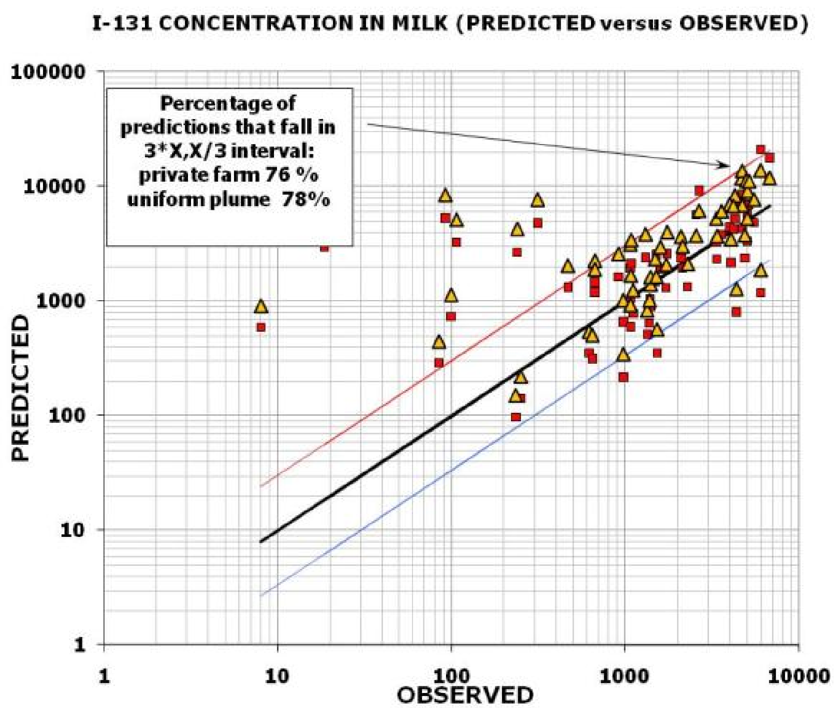

Fig. 4.17. Comparison of private farms (squares), collective farms (triangles) predictions and observed ^{131}I concentration in milk for MRRC (O.Vlasov) in the Town Plavsk. On the top of picture: location name, average ^{137}Cs surface contaminations. A unique date of start cows pasturing for all private and all collective farms was assumed: 7.05.1986 and 11.05.1986 respectively.

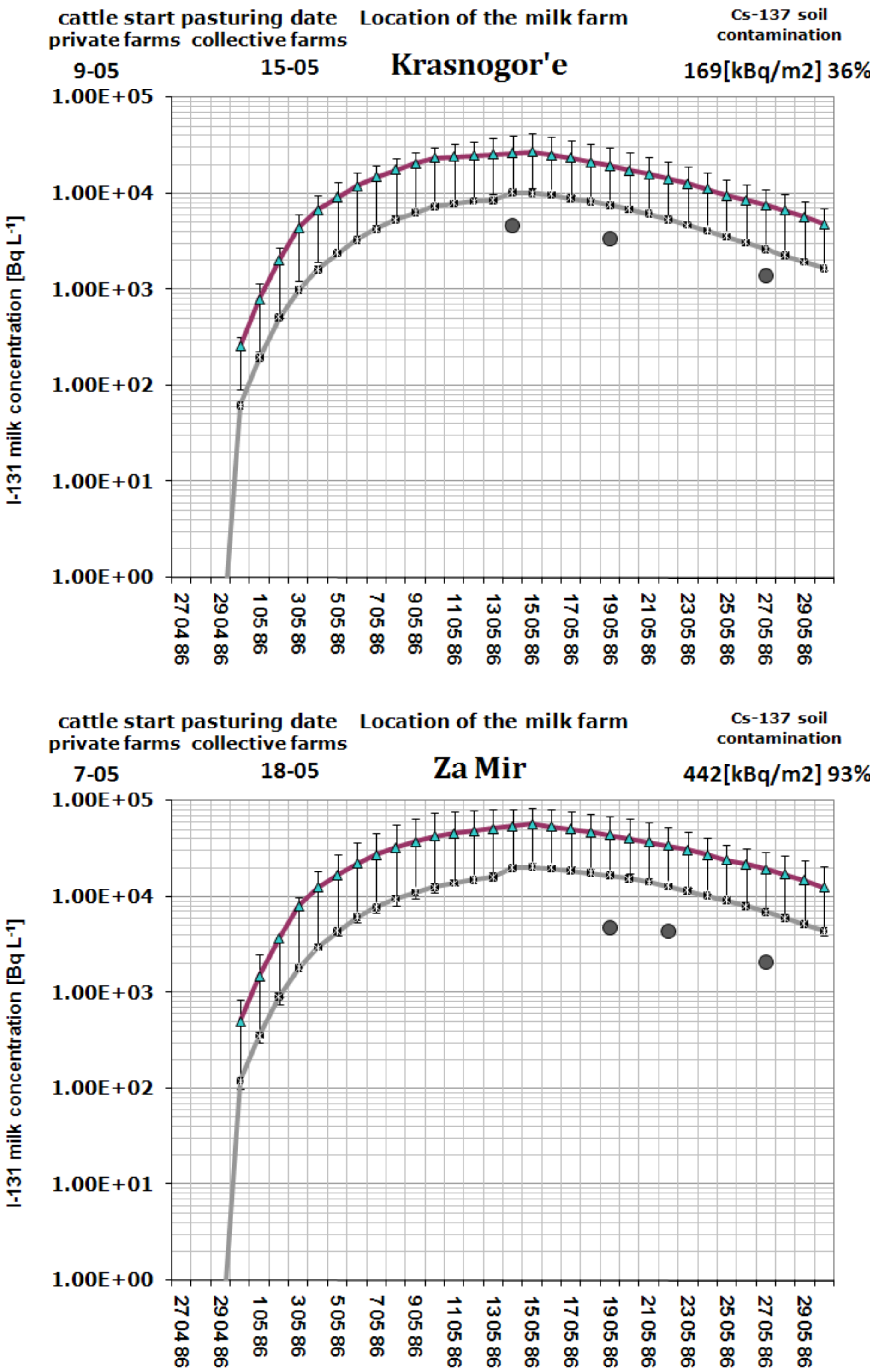

Fig. 4.18. Comparison of private farms (squares), collective farms (triangles) predictions and observed ^{131}I concentration in milk for UNIVES (B.Kanyar) in particular locations of Plavsk district. On the top of picture: dates of start pasturing cows, location name, average ^{137}Cs surface contaminations.

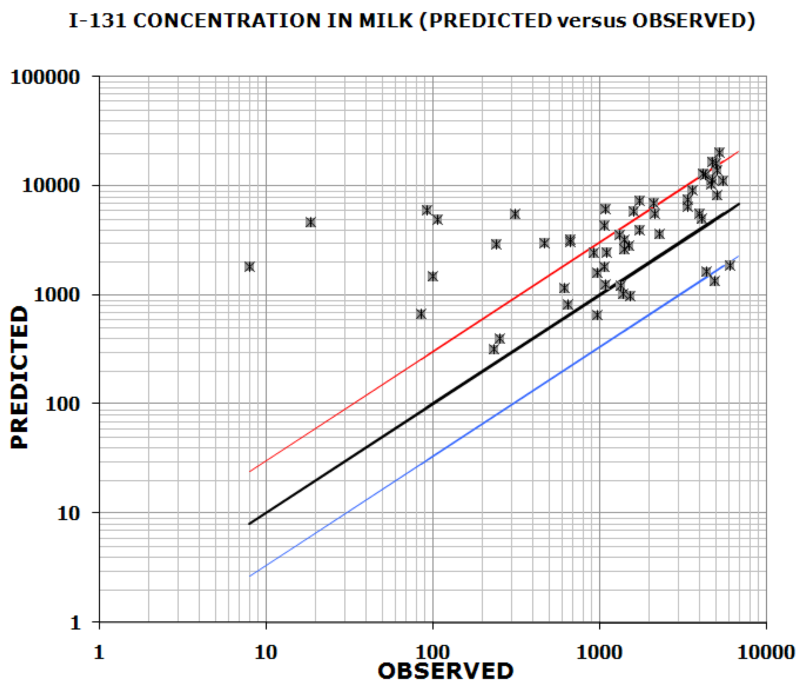

Fig. 4.19. Predicted versus observed ^{131}I concentration in milk for (B.Kanyar) UNIVES for all Plavsk districts.

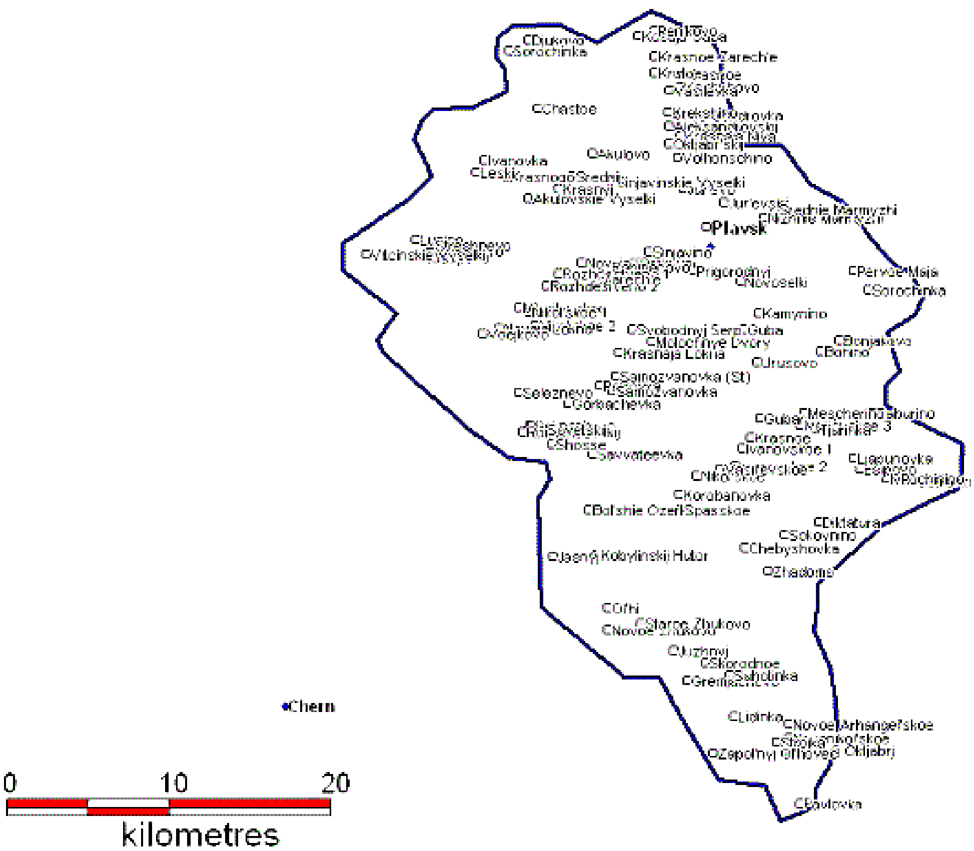

Fig. 4.20. Location of 107 settlements in Plavsk District.

Table 4.3. 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*	0.59	0.57	0.61
13–17, female*	0.38	0.36	0.40
> 17, male*	0.71	0.69	0.73
> 17, female*	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*	0.3	0.28	0.32
13–17, female*	0.22	0.20	0.24
> 17, male*	0.3	0.29	0.31
> 17, female*	0.25	0.24	0.26

* Values for these age groups are taken from the poll of the Bryansk population.

Table 4.4. The iodine metabolism model [24].

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 [μg 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 $s_2 = 65 *(M_s/70)$ [μg 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}]	0.010 8	0.022 3	0.033 7	0.020 6	0.010 0	0.006 6	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
^{131}I 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**

4.1.5. ^{131}I thyroid burden from inhalation

Radioiodine uptake due to inhalation of contaminated air was an additional task for Scenario Plavsk; 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 Figure 4.21).

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

A comparison of measured and predicted values for adult inhabitants of Rahmanovo and Plavsk Town are presented in Figures 4.21 and 4.22 respectively. Measurements of thyroids in the Plavsk district were performed about two weeks later after passing of the radioactive cloud, i.e., during the period 13–30 May 1986, but during only one day for each location. The 95% confidence interval of the mean[5] for each age group in a particular settlement ranges over two orders of magnitude and is presented in graph format. Verification of the ^{131}I in thyroids variation with time based 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, however Scenario description suggests estimating radioiodine intakes from predictions of ^{131}I concentration in local milk (for settlement) rather than milk from collective farms.

The predicted and observed data for ^{131}I contents in thyroids of individuals from 15 settlements and Plavsk town are presented in Figure 4.24. The main reasons of discrepancies are discussed in previous sections. Generally, for all models, the predicted activity of ^{131}I in thyroids follow previously predicted ^{131}I concentrations in consumed milk and reflect assumptions about the time when cows had been put on pasture. About 70% of the predictions of one modeller that is closest to the observed data (MRRC, Vlasov) fit in a range of a factor of 3 (3×observed, 1/3×observed). For the 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 (Plavsk calculator, Simon).

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

An additional task of the Plavsk scenario required participants to reconstruct the ^{131}I concentration in air over Plavsk districts based on the ^{131}I deposition. Consequently the contribution of inhalation doses to the total doses could be estimated. Models needed to assess radioiodine species in air (aerosol, elemental, organic), the contribution of dry and wet deposition to the total deposition, dry deposition velocity, washout ratio. Assumption and parameters for particular models are summarized in Table 3.1. Predicted values fit in a range of a factor of 3 for a particular milk farm (Figure 4.25). 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 run 2) assumed a constant ^{131}I concentration in air over whole Plavsk district. Some questions aroused about reality of this assumptions. Despite the consistency in the predictions, verification the of assumptions mentioned above need more detailed consideration and advanced analysis using plume dispersion models and more detailed information on meteorological conditions.

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[5] Assuming normal distribution.

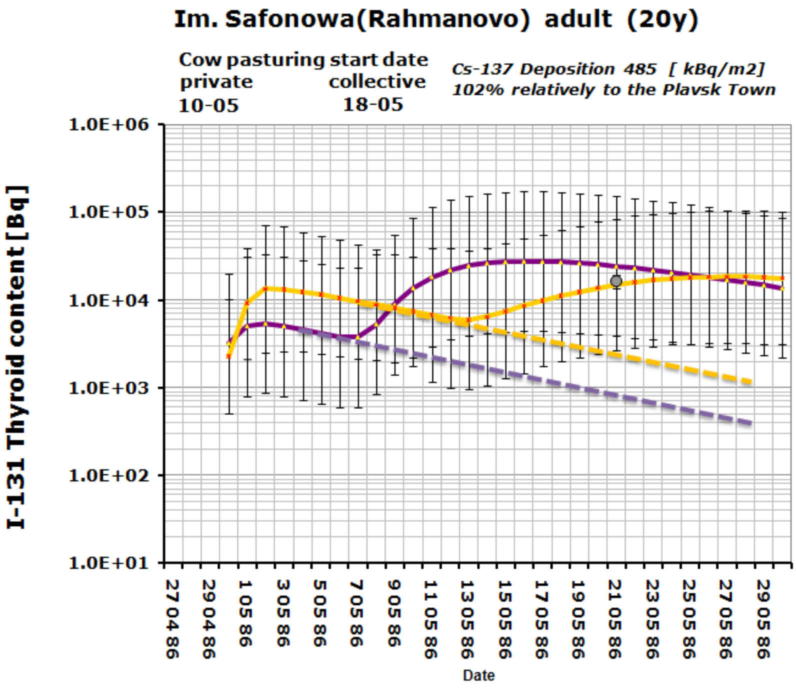


Fig. 4.21. A comparison of the expected activity of ^{131}I in thyroid (dashed lines) due to inhalation to the activity of ^{131}I in thyroid due to ingestion and inhalation: MRRC (Vlasow) and CLRP (Krajewski) predictions.

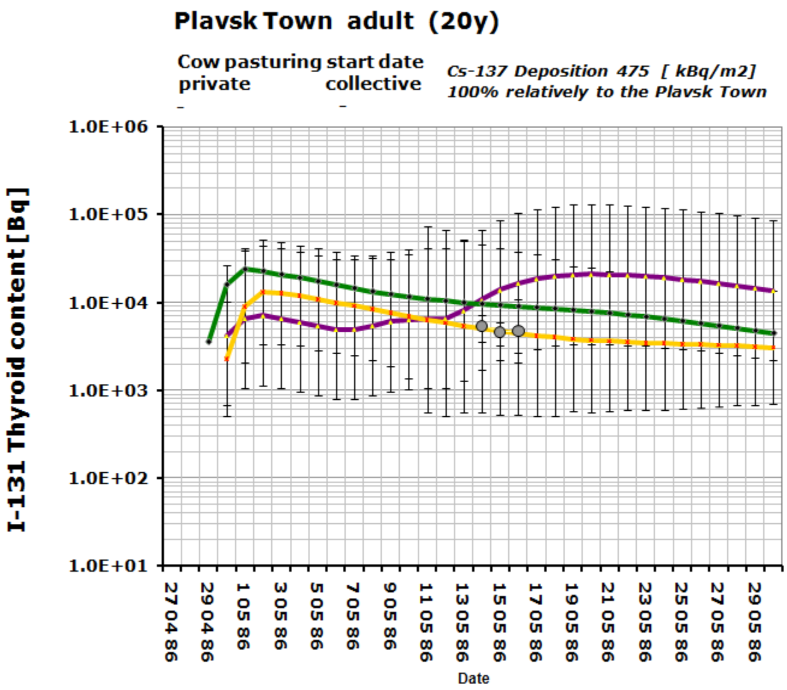


Fig. 4.22. Example of predictions of ^{131}I content in thyroid for inhabitants (adults) of Plavsk TownAverage measurements values(gray dots), MRRC (O. Vlasow) – violet line, CLRP (P. Krajewski) – yellow line, OSCAAR (T. Homma) – green line.

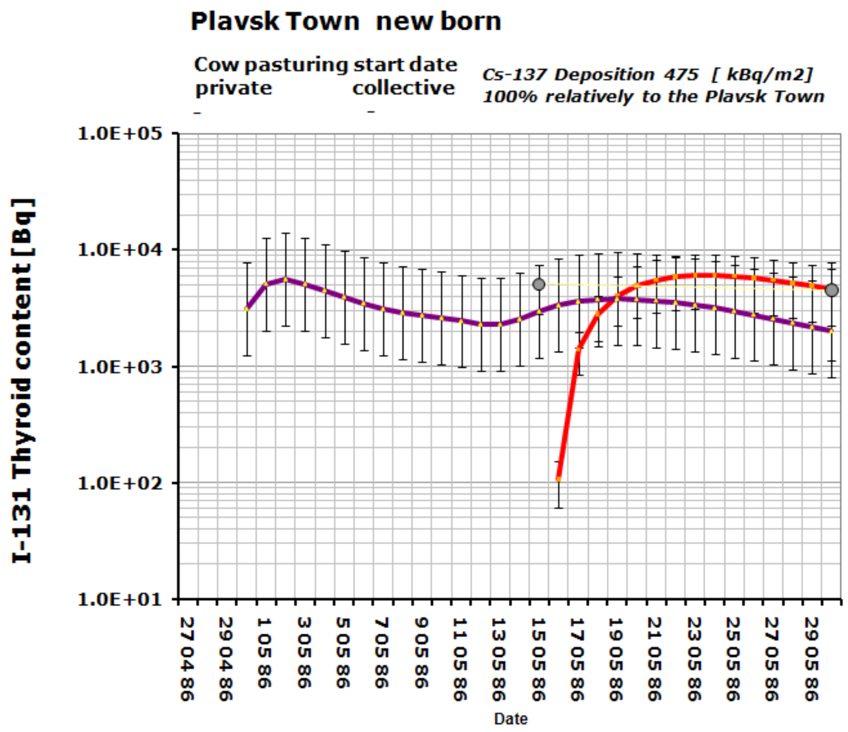


Fig. 4.23. Predictions of the ^{131}I in thyroid for new born in town Plavsk. Average measurements values(gray dots), MRRC (O. Vlasow) – violet line, LETDOS(V. Filistovic) – red line.

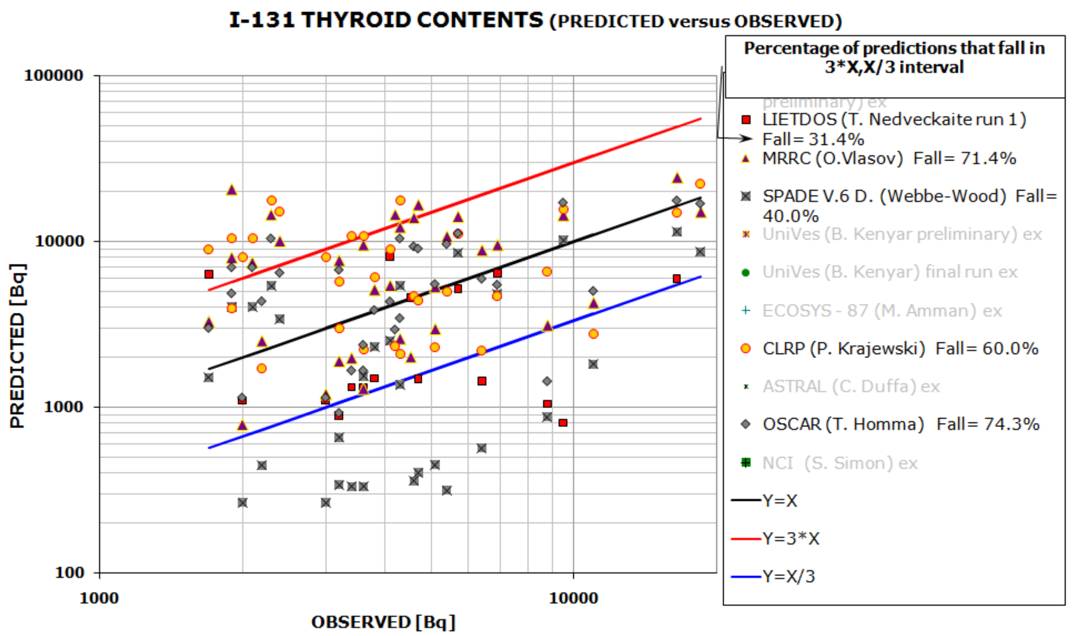


Fig. 4.24. Selected predictions of ^{131}I thyroid content against observed data for Plavsk Scenario. Red and blue line indicate range of (3, 1/3) observation interval. In the square box the percentage of predictions that fall in (3,1/3) interval for particular participant are shown.

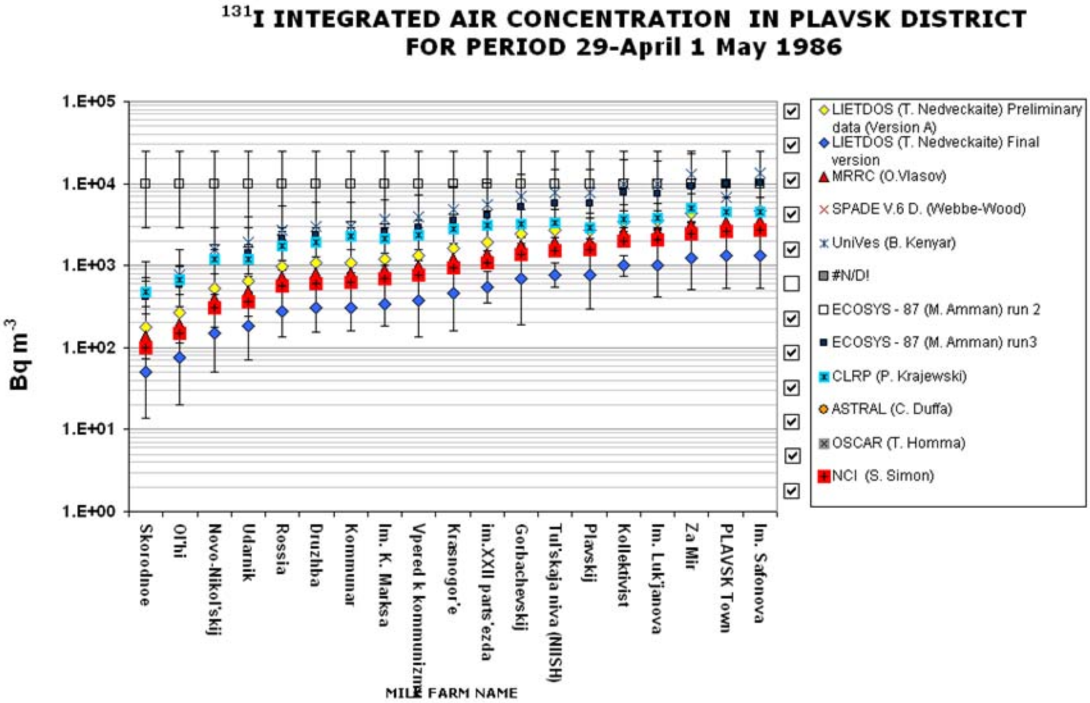


Fig. 4.25. Reconstruction of ^{131}I concentration in air for Plavsk Scenario (sorted according ^{137}Cs deposition.

Table 4.5. Reconstruction of ^{131}I concentration in air ($Bq \cdot m^{-2}$) for milk farm locations in Plavsk area (sorted according ^{137}Cs deposition).

Milk Farm	**^{137}Cs deposition $kBq \cdot m^{-2}$**	**LIETDOS (V. Filistovic, T. Nedveckaite) final version**	**MRRC (O.Vlasov)**	**UniVes (B. Kenyar)**	**ECOSYS – 87 (M. Amman) uniform rain**	**ECOSYS – 87 (M. Amman) uniform plume**	**CLRP (P. Krajewski)**	**NCI (S. Simon)**
Skorodnoe	*175*	50	136	242	412	9940	471	100
Ol'hi	*263*	75	192	377	580	9940	676	150
Novo-Nikol'skij	*526*	149	383	796	1132	9940	1200	301
Udarnik	*643*	183	477	965	1438	9940	1186	367
Rossia	*974*	277	707	1355	2100	9940	1756	557
Druzhba	*1071*	304	789	1490	2320	9940	1900	612
Kommunar	*1091*	310	785	1510	2320	9940	2315	623
Im. K. Marksa	*1198*	340	866	1830	2560	9940	2135	685
Vpered k kommunizmu	*1334*	379	968	1962	2860	9940	2364	763
Krasnogor'e	*1646*	468	1204	2393	3580	9940	2825	941
im.XXII parts'ezda	*1909*	542	1374	2791	4040	9940	3128	1091
Gorbachevskij	*2416*	687	1753	3536	5180	9940	3251	1381
Tul'skaja niva (NIISH)	*2659*	755	1928	3898	5700	9940	3271	1520
Plavskij	*2708*	770	1951	3858	5740	9940	2866	1548
Kollektivist	*3487*	991	2569	4857	7660	9940	3659	1993
Im. Luk'janova	*3546*	1008	2550	4963	7500	9940	3765	2026
Za Mir	*4305*	1224	3101	6414	9120	9940	4992	2460
PLAVSK Town	*unknown*	1315	3327	3404	9900	9940	4577	2644
Im. Safonova	*4724*	1343	3407	6764	10060	9940	4469	2700

4.1.8. Dose assessment

The final target of the scenario was to predict mean values of the thyroid dose (committed equivalent dose to thyroid) from ingestion and inhalation for 6 different age groups, i.e., new born, age 1–3 age, 3–7, age 8–12 and adult for a particular milk farm area and Plavsk Town. The example of predicted doses from ingestion (mainly contaminated milk) are shown in Figure 4.26. The range of predicted ingestion doses is about one order of magnitude for each location that reflects differences in predicted ^{131}I concentration in milk by the participants. The example of predicted doses from inhalation are presented on (Figure 4.27). 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, and assumptions by modellers on residence time of inhabitants and house filtration factors. Generally, inhalation doses are 10% of the total dose, that is in agreement with an assessment 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 matter of discussion.

4.1.9. Concluding remarks

Nine experts in environmental modelling participated in the Plavsk Scenario, including four who had not previously been involved in the international model testing programs.

During this exercise several aspects of model performance were evaluated. The following problems were identified:

(1) ^{131}I deposition can be reconstructed with acceptable uncertainty using ^{137}Cs deposition data. A constant ratio for ^{131}I to ^{137}Cs deposition can be used for highly contaminated areas (where wet deposition occurred) but can underestimate the ^{131}I deposition in low contaminated locations. Then, an empirically established nonlinear relationship between ^{131}I and ^{137}Cs depositions in the areas with mixed radioactive fallout (dry and wet) has to be used.

(2) When modelling the grass interception fraction its dependence on precipitation should be taken into account, for example using the experimental data.

(3) The time when cows were go on pasture seems to be the most important factor affecting model predictions.

(4) Keeping dairy cattle indoors on a diet of stored food without any supplementation of fresh grass, and a delayed start of grazing seems to be very effective measures for reducing the public's intake of ^{131}I through consuming contaminated dairy products.

(5) ^{131}I doses assessed by ecological models and dose estimations based on direct measurements shows acceptable level of agreement not exceeding a factor of ten.

In general, although IWG was dealing with areas of assessment modelling 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 within 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.

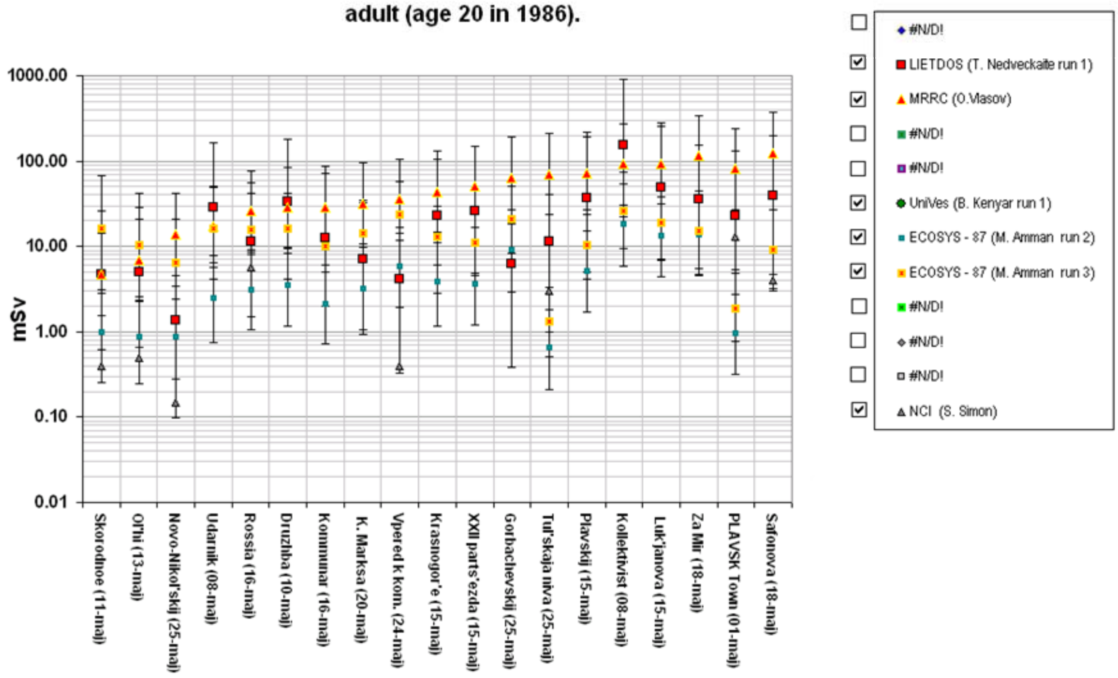


Fig. 4.26. Example of predictions of thyroid doses from ingestion in Plavsk district (adults) – doses sorted according deposition of ^{137}Cs.

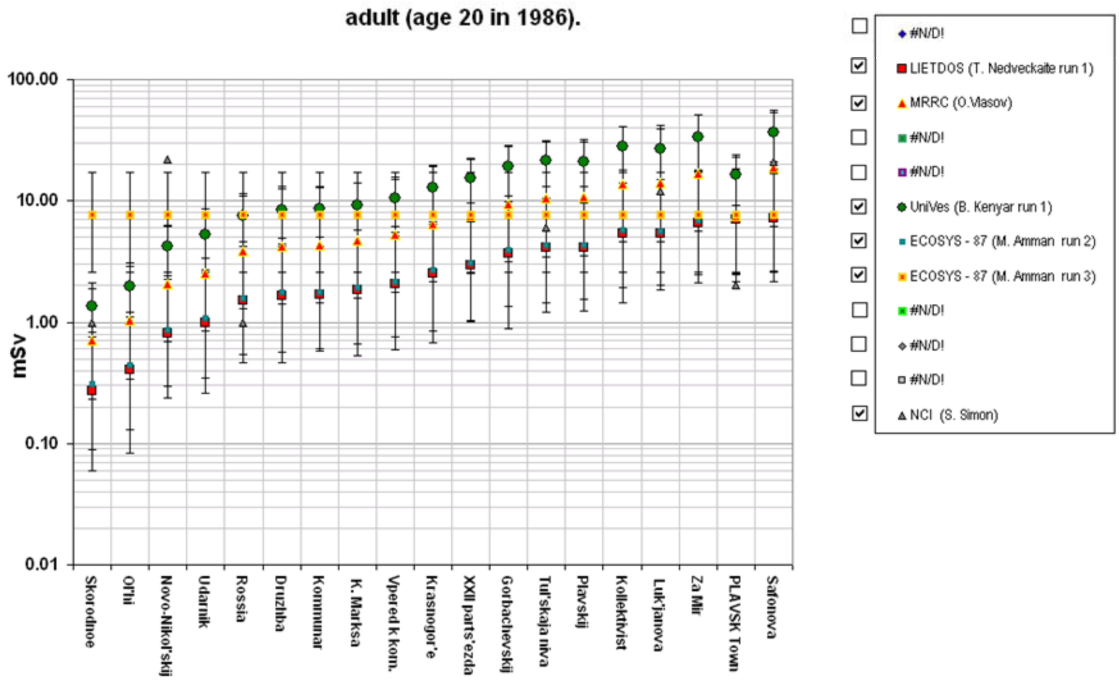


Fig. 4.27. Example of predictions of thyroid doses from inhalation in Plavsk district (adults) – doses sorted according deposition of ^{137}Cs.

4.2. Warsaw Scenario

With respect of ongoing IWG activity, particular emphasis is now given to the improvement of models to simulate countermeasures. Such measures include evacuation, sheltering and food controls as well as iodine prophylaxis. The optimum response will often involve the combined use of these countermeasures. One could have thought that combined use of countermeasures had significantly mitigated thyroid exposures both from inhaled and ingested radioiodine. However, in emergency circumstances, it may be foreseen that the rapid distribution of stable iodine or the use of stored feed cannot be arranged or planned. Regarding diet restrictions (milk and milk products and leafy vegetables) as well as cows' pasturage ban, there were no means to make items compulsory but only to raise the level of public awareness. Therefore, the requirements of emergency response preparedness need a validated methodology for realistic dose and uncertainty assessment. Furthermore, the justification of different variants of protective action should include an analysis. As a starting point for further considerations in the 2005–2006 IWG activity, the second scenario (Scenario W) has been elaborated. The main goal of the Scenario W would be a versatile assessment of the effectiveness of short-term protective measures that had been applied in this province during the period 29–30 April 1986 to reduce the radioiodine thyroid burden of inhabitants.

This provides a good opportunity to compare a number of modelling approaches to an assessment of effectiveness of countermeasures, in an avertable dose context.

The participants of the IWG were asked to provide input and sound advice on methods for evaluation of countermeasures' effectiveness for radioiodine and related uncertainties. Effectiveness of countermeasures should also be assessed when several of protective actions are applied. The critical groups are considered with special attention.

4.2.1. ^{131}I concentration in grass

There are only a few measurements of ^{131}I concentration in grass at one location, near the CLOR aerosol sampling station A, from 3-18 May 1986. Fresh grass was cut to 2 cm in height and measured in 0.5 L Marinelli Backer by gamma spectrometry Table 4.6. The ^{131}I concentration in grass decreased with time depending on meteorological conditions. An important factor was the amount of precipitation that was reflected by the short half-life of about 1.7 days from 3–7 May 1986 and 3.3 days 8–18 May 1986.

It is difficult for models that use semi-empirical weathering half-life in the order of 8–10 days (see Figures 4.28 and 4.29). Only CLIMRAD (O. Vlasov) (see Figure 4.29) was able to reflect that phenomena using more sophisticated formulas on grass interception factors[6] and weathering half-life in dependence on rain intensity and amount of precipitation. Some modellers (IRH-model, I. Zvonova) (see Figure 4.29) based on information given in the scenario about low biomass of grass due to early spring period, made assumption about lower interception factor that gave fairly good agreement with observed data in the further period, i.e., 8–18 May 1986. The model's performance with respect of ^{131}I concentration in grass are presented in Figure 4.30. Fife models were able to make predictions of ^{131}I concentration in grass within less than one order of magnitude range of measured values. The lack of more sophisticated formulas to reflect an influence of weather conditions on iodine removal from leaf surface result that three models (see Figure 4.28) were not able to predict ^{131}I concentration in grass in the subsequent period of contamination.

[6] Detailed model CLIMRAD (O. Vlasov) model descriptions can be found in Appendix IV.

Table 4.6. ^{131}I concentration in grass in WARSAW [Bq kg fresh weight].

Date of Sample	^{131}I concentration in grass [Bq kg fresh weight]
03 05 86	62000
04 05 86	41000
06 05 86	11000
07 05 86	19620
08 05 86	6702
09 05 86	5800
10 05 86	4380
11 05 86	2350
12 05 86	4300
13 05 86	1270
14 05 86	2800
15 05 86	2790
16 05 86	1330
18 05 86	511

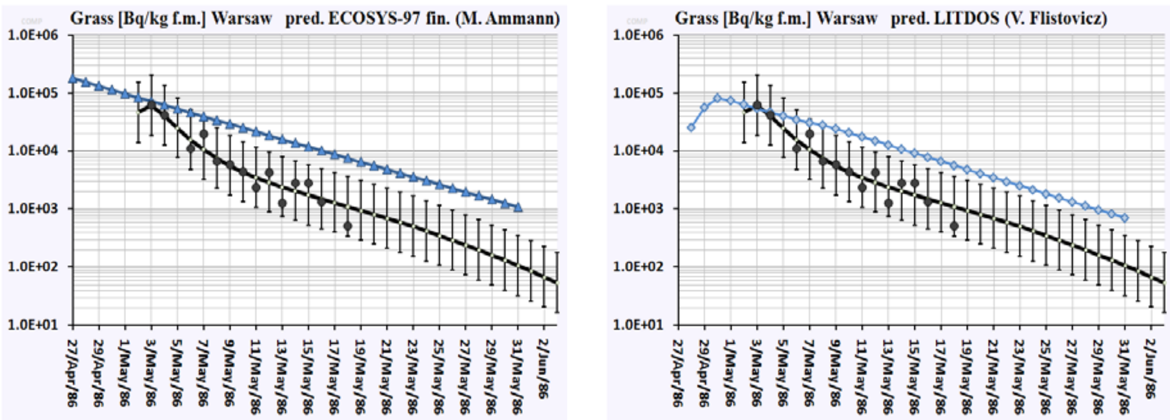


Fig. 4.28. Predicted ^{131}I concentration in grass for Warsaw by ECOSYS-97 (M. Ammann) and LIETDOS (V. Flistovich; T. Nedveckaite) versus measured values in Warsaw.

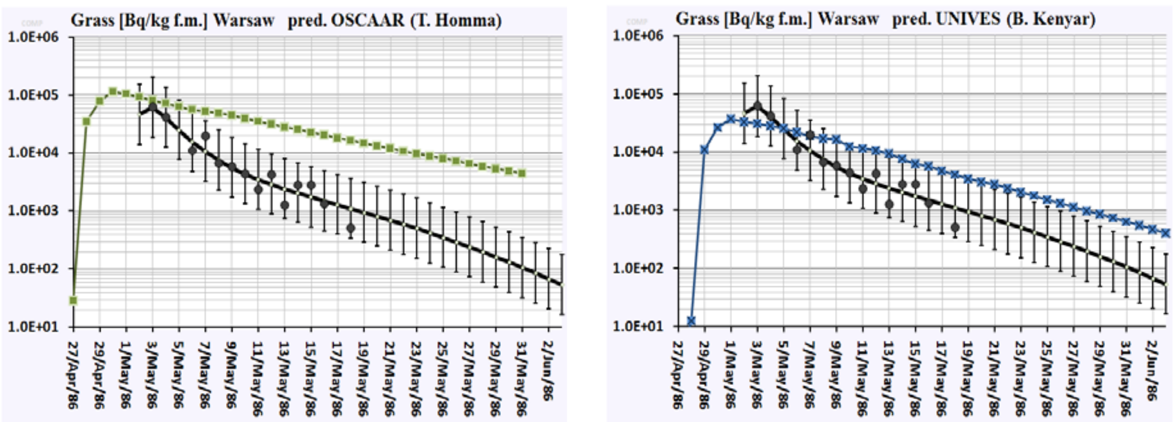


Fig. 4.29. Predicted ^{131}I concentration in grass for Warsaw by OSCAAR (T. Homma) and UNIVES (B. Kanyár) versus measured values in Warsaw.

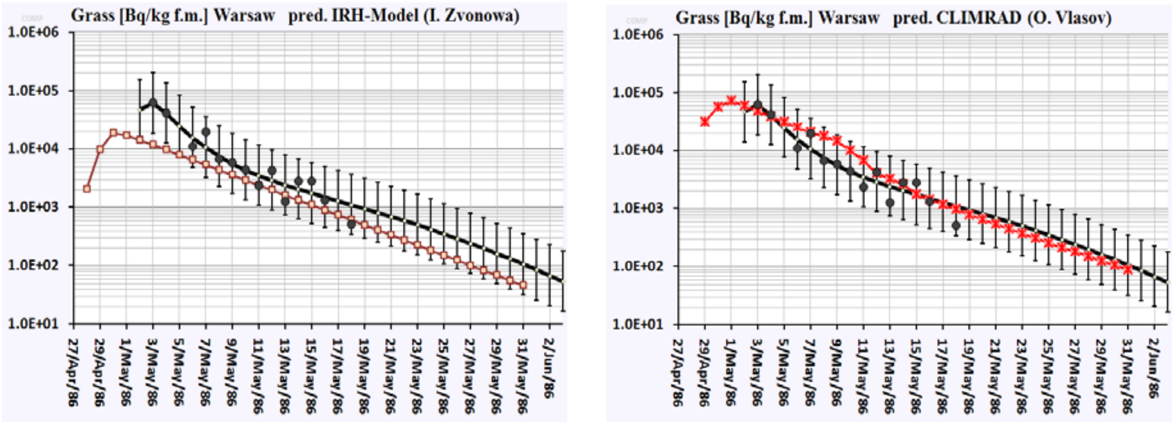


Fig. 4.30. Predicted ^{131}I concentration in grass for Warsaw and Ostroleka by CLIMRAD (O. Vlasov), by IRH-model (I. Zvonova) versus measured values in Warsaw.

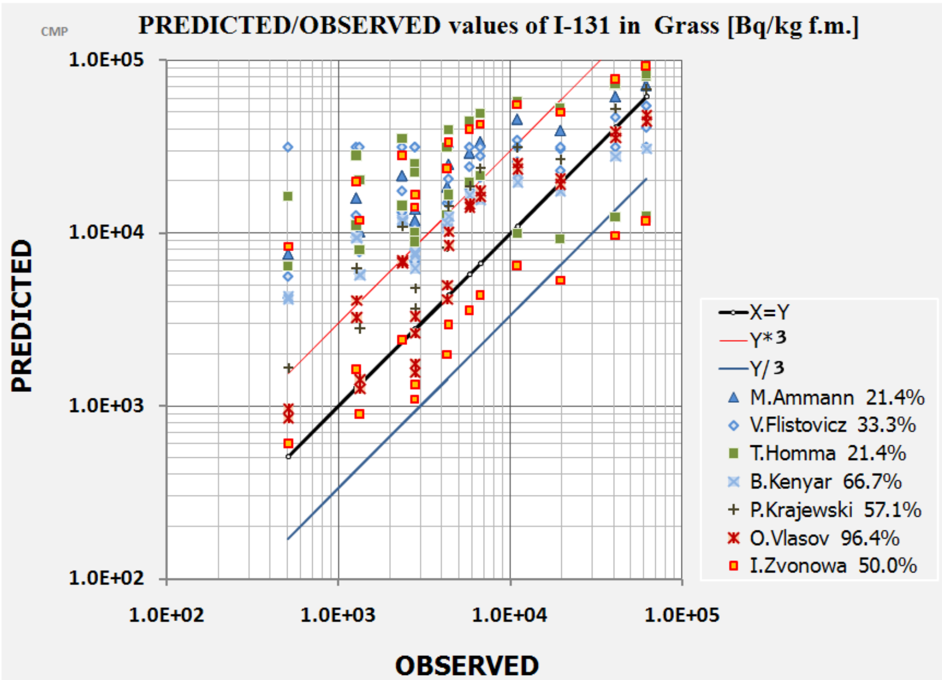


Fig. 4.31. Comparison of predicted versus observed ^{131}I concentration in grass for Warsaw. Straight lines represent: predicted equal to observed values, order of magnitude bounds. Percentage values next to modeller's name are the percentage of predictions within the one order of magnitude measured values.

4.2.2. ^{131}I concentration in milk

The Mazovia scenario provided three data sets on ^{131}I concentrations in milk that represent three different radiological situations:

(1) cows' pasturage limitation – for collective farm (named Falenty) situated near Warsaw where it was reported that cows had been kept in cowshed during the whole period of the Chernobyl cloud passage;
(2) average milk from big dairy – bulk milk samples taken daily from the WARSAW Town dairy; and
(3) no pasture limitation – bulk milk samples taken daily from the OROLEKA dairy. It was reported that most of the private farms in this area suffer from shortage of uncontaminated hay.

The main aim of this exercise was to check models ability to 'simulate situations where cows' pasturage ban was recommended by governmental authority, but there are no means to make items compulsory but only to raise the level of public recognition. Assuming that the WARSAW Town dairy and the OSTROLEKA town dairy area were supplied by milk from surrounding local farms, in the scenario an evaluation about the percentage of cows that could have been kept in cowsheds up to 31 May 1986 was performed[7]. Weighted average based on the contribution to the total milk production equal to 83% for Warsaw town dairies and 59% for Ostroleka town dairies.

Table 4.7. An assessment of fodder resources in particular counties of Mazovia province in1986.

POWIAT	Delivery area	F_{eff} percentage of cows kept in cowsheds up to 31 May 1986	T_e Time until cows could have been kept in cowshed
grodziski mazowiecki	WARSAW AREA	91%	7 May 1986
grojecki	WARSAW AREA	99%	26 May 1986
legionowski	WARSAW AREA	113%	27 June 1986
minski	WARSAW AREA	66%	10 March 1986
nowodworski mazow.	WARSAW AREA	67%	14 March 1986
otwocki	WARSAW AREA	119%	9 July 1986
piaseczynski	WARSAW AREA	79%	8 April 1986
pruszkowski	WARSAW AREA	110%	20 June 1986
pultuski	WARSAW AREA	54%	10 February 1986
warszawski	WARSAW AREA	128%	1 August 1986
warszawski zachodni	WARSAW AREA	97%	19 May 1986
wolominski	WARSAW AREA	97%	22 May 1986
wyszkowski	WARSAW AREA	84%	20 April 1986
Weight average for WARSAW AREA 83%			
kolnenski	OSTROLEKA AREA	51%	4 February 1986
lomzynski	OSTROLEKA AREA	63%	3 March 1986
makowski	OSTROLEKA AREA	56%	15 February 1986
ostrolecki	OSTROLEKA AREA	69%	17 March 1986
piski	OSTROLEKA AREA	85%	23 April 1986
przasnyski	OSTROLEKA AREA	28%	12 December 1985
szczycienski	OSTROLEKA AREA	110%	20 June 1986
zambrowski	OSTROLEKA AREA	19%	22 November 1985
Weight average for OSTROLEKA AREA 59%			

[7] More detailed information on the methodology used is included in Appendix II, Mazovia Scenario.

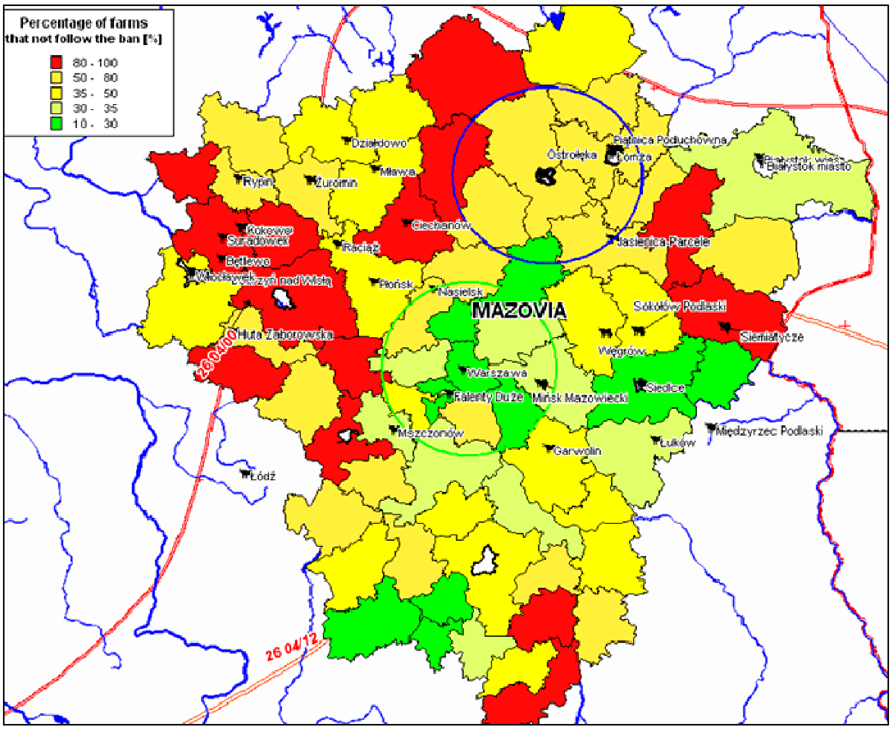


Fig. 4.32. Map of the hay and fodder resources in Mazovia province broken by particular county.

4.2.2.1. Predictions for collective farm FALENTY

It became clear that models that assume that radioactive iodine come to milk only due to cows inhalation pathway underestimated predictions ECOSYS-97 (M. Ammann), OSCAAR (T. Homma), CLIMRAD (O. Vlasov) (see Figure 4.33). The major difficulty in this task was to estimate the surface contamination of hay in storage (collected in previous summer 1985) which was used to feed the Falenty's cows. The modellers who assumed that in this case from 5 to 10 percent of ^{131}I activity concentration (in relation to ^{131}I which could be intercepted by fresh grass during the period 28 April – 5 May 1986 r) come additionally with hay obtained fairly good agreement with measured values UNIVES (B. Kanyár), CLRP (P. Krajewski), IRH-model (I. Zvonova) (see Figures 4.34 and 4.35). As concerns CLIMRAD (O. Vlasov) it applied much higher transfer factor grass-milk (2×10^{-2}) to compensate assumption on only inhalation pathway.

4.2.2.2. Predictions for WARSAW town dairy

To predict a radioactive iodine ^{131}I concentration in bulk milk samples taken daily from the WARSAW Town dairy, some modellers tried to predict ^{131}I concentration in each county (see Figure 4.32) and calculate the weighted average. This approach led to good agreement with observed values if both, reliable data on contribution of particular county milk production to the average milk yield in a big town dairy as well as agricultural practices in each county, would be well known. Also, validation of this approach requires numerous data from samples taken from dairies that did not carry on during the Chernobyl period. However, with respect of CLIMRAD (O. Vlasov) and IRH-model (I. Zvonova), about 70% of predicted values fit in a range of one order magnitude to the observed values (see Figure 4.38). Other models

ECOSYS-97 (M. Ammann) and OSCAAR (T. Homma) took in to account the indication given in the scenario and made weighed average, i.e., 80% cows' inhalation pathway and 20% cows' ingestion pathway that led to pretty good agreement with measured values (see Figure 4.36). On the contrary, models UNIVES (B. Kanyár) and by LIETDOS (V. Flistovich; T. Nedveckaite) made conservative assumption that all cows went to a pasture at the middle of April and stayed for May that led to predictions order of magnitude higher (see Figure 4.37). One could remark that the value of the weathering half-life of radioiodine in grass assumed by particular models had less influence on the predicted ^{131}I concentration in milk than the assumption on cows feeding practice during the critical period when ^{131}I contamination occurred.

4.2.2.3. Predictions for OSTROLEKA dairy

The similar approaches to that discussed in the section above (4.2.2.2) were applied in the calculation of ^{131}I concentration in milk for Ostroleka dairy. Assumption on 50% of cows' inhalation pathway and 50% cows' ingestion pathway made by ECOSYS-97 (M. Ammann) and OSCAAR (T. Homma) led to fairly good agreement with measured values (see Figure 4.39). On the other hand, in this case, the conservative assumption on cows staying on the pasture critical period gave predictions being closer to observed values (see Figure 4.40).

The overall modeller performance with respect of this task is presented in Figure 4.42. One order of magnitude discrepancies between predictions and measured data seems to be the best fit in a case of radioactive iodine ^{131}I release into the environment, however a scatter of measured values very often exceeds one order of magnitude.

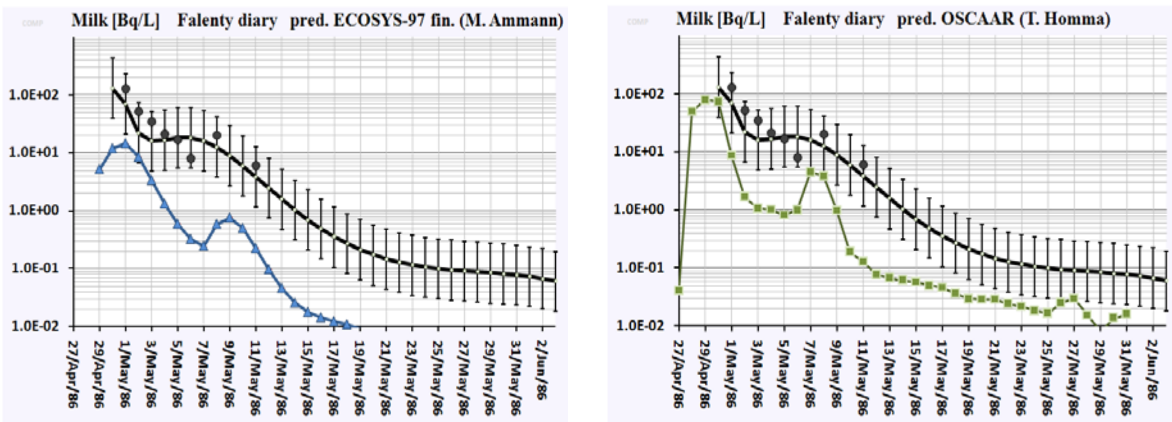


Fig. 4.33. Predicted ^{131}I concentration in milk for Falenty dairy (cows kept in cowsheds), by ECOSYS-97 (M. Ammann) and by OSCAAR (T. Homma) versus measured values.

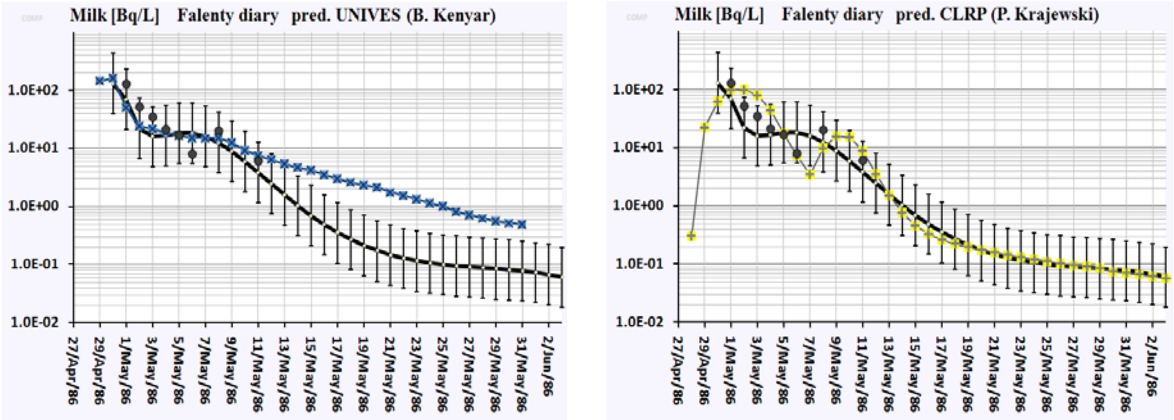


Fig. 4.34. Predicted ^{131}I concentration in milk for Falenty dairy (83%cows kept in cowsheds), by UNIVES (B. Kanyár) and by CLRP (P. Krajewski-scenario provider) versus measured values.

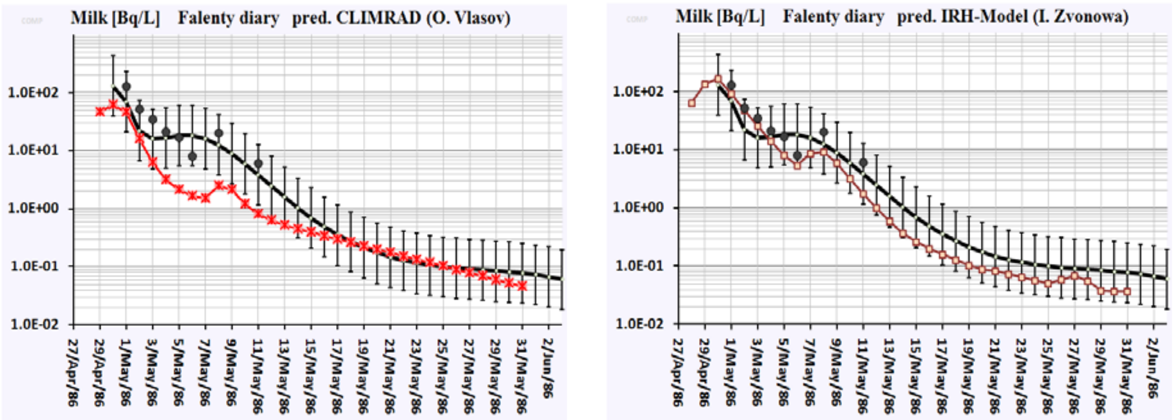


Fig. 4.35. Predicted ^{131}I concentration in milk for Falenty dairy (cows kept in cowsheds), by CLIMRAD (O. Vlasov) and by IRH-model (I. Zvonova) versus measured values.

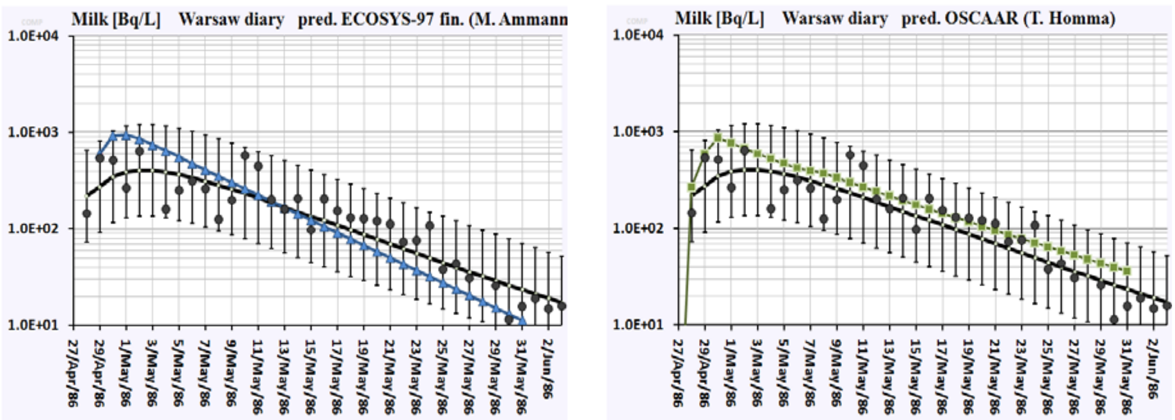


Fig. 4.36. Predicted ^{131}I concentration in milk for WARSAW dairy (about 80% cows was kept in cowsheds) by ECOSYS-97 (M. Ammann) and by OSCAAR (T. Homma) versus measured values.

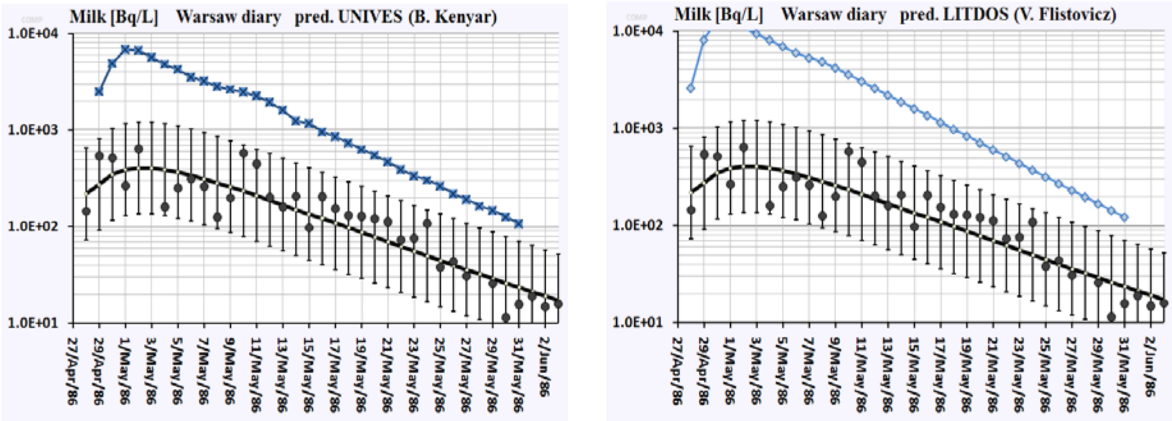


Fig. 4.37. Predicted ^{131}I concentration in milk for WARSAW dairy (no assumption about pasturing ban) by UNIVES (B. Kanyár), and by LIETDOS (V. Flistovich; T. Nedveckaite) versus measured values.

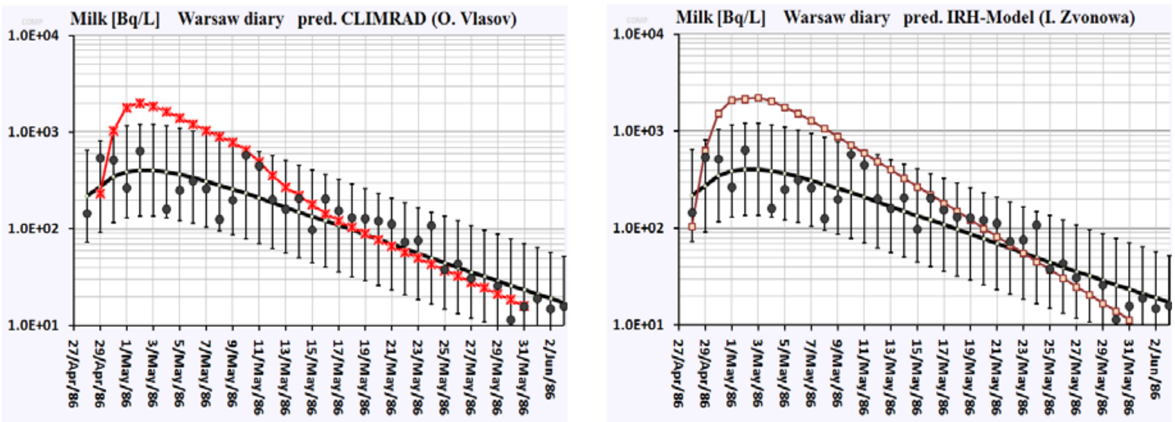


Fig. 4.38. Predicted ^{131}I concentration in milk for WARSAW dairy (about 80% cows was kept in cowsheds) CLIMRAD (O. Vlasov) and by IRH-model (I. Zvonova) versus measured values.

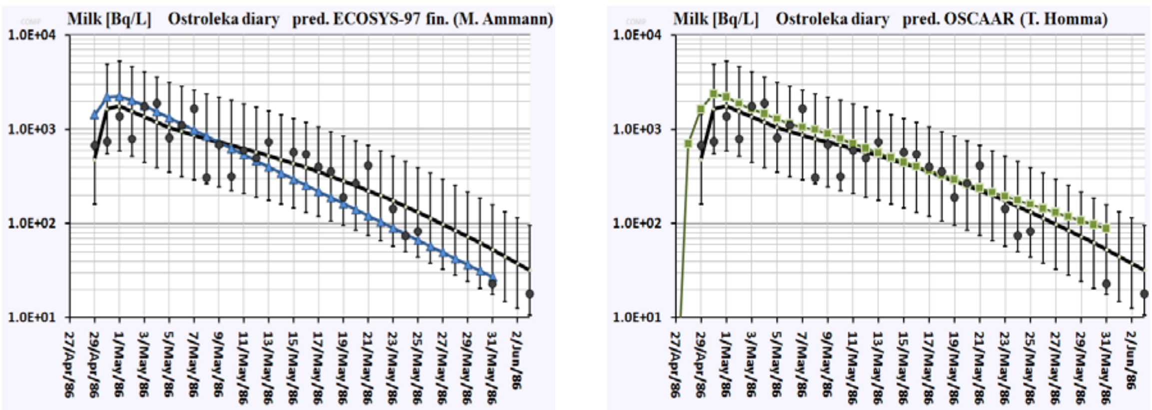


Fig. 4.39. Predicted ^{131}I concentration in milk for OSTROLEKA dairy (about 50% cows was kept in cowsheds) by ECOSYS-97 (M. Ammann) and by OSCAAR (T. Homma) versus measured values.

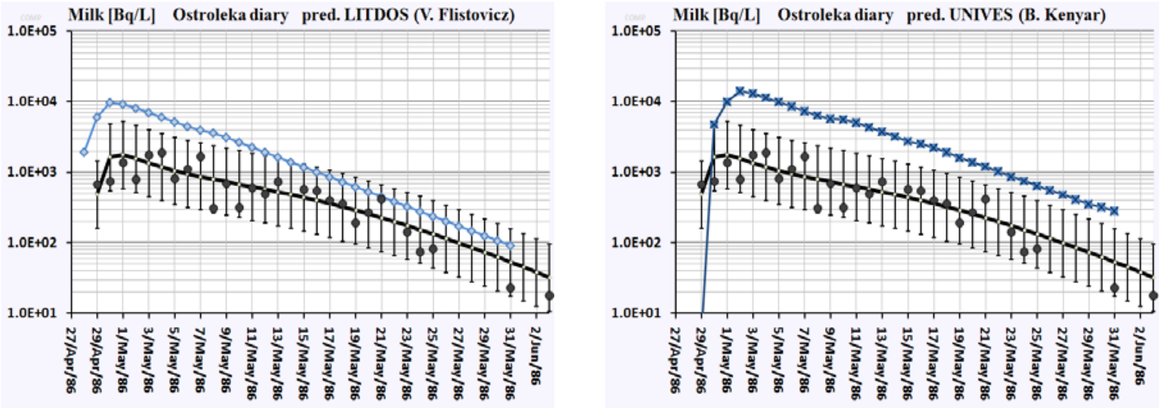


Fig. 4.40. Predicted ^{131}I concentration in milk for OSTROLEKA dairy (no assumption about pasturing ban) by UNIVES (B. Kanyár), and by LIETDOS (V. Flistovich; T. Nedveckaite) versus measured values.

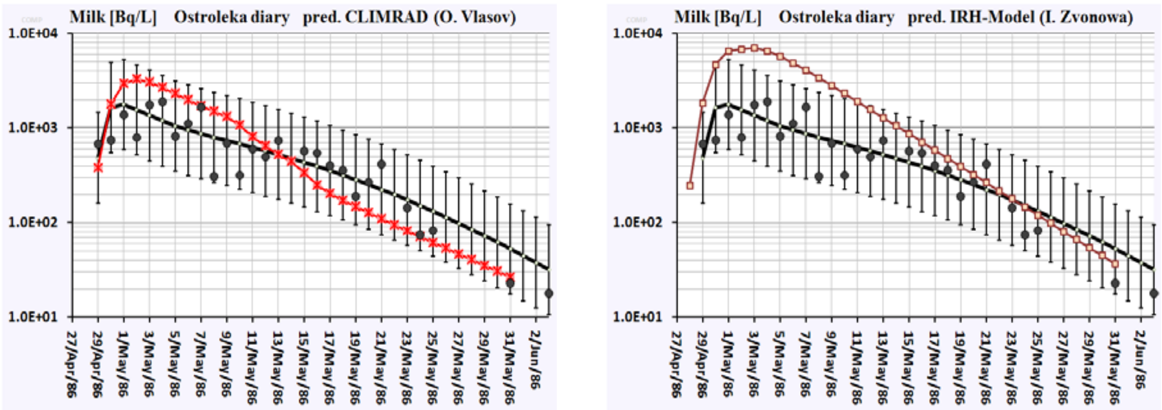


Fig. 4.41. Predicted ^{131}I concentration in milk for OSTROLEKA dairy (about 80% cows was kept in cowsheds) CLIMRAD (O. Vlasov) and by IRH-model (I. Zvonova) versus measured values.

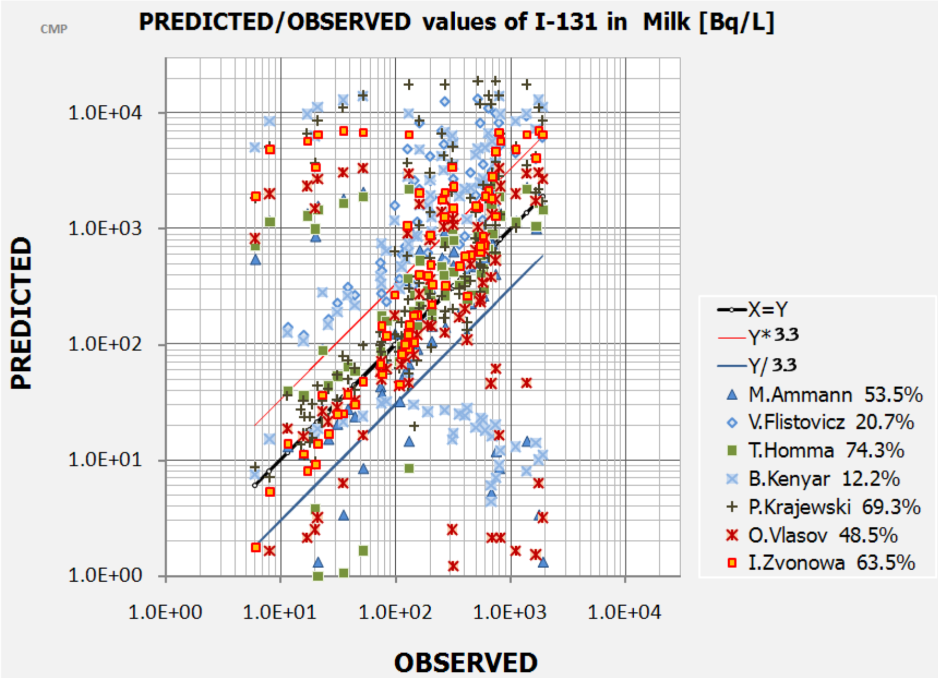


Fig. 4.42. Comparison of predicted versus observed ^{131}I concentration in milk for Falenty, Warsaw, Ostroleka dairies . Straight lines represent: predicted equal to observed values, order of magnitude bounds. Percentage values next to modeller's name are the percentage of predictions within the one order of magnitude measured value.

4.2.3. ^{131}I thyroid content

The main target of this task was to check models performance in evaluation of effectiveness of administration of stable iodine tablets. Both urban population (Warsaw town) and rural population (Ostroleka area) were taken into account and the proposed age's groups and various variants of stable iodine "treatment" were as follows:

(1) children at the ages between 3–10, who had been given a stable iodine dose of 30 mg on 29 April 1986 12:00;
(2) children at the ages between 3–10 who had been given a stable iodine dose of 30 mg on 30 April 1986 12:00;
(3) teenagers at the ages between 10–17 who had been given a stable iodine dose of 60 mg on 29 April 1986 12:00;
(4) teenagers at the ages between 10–17 who had been given a stable iodine dose of 60 mg on April 1986 12:00;
(5) adults at the age 20 who had not taken any stable iodine dose;
(6) adults at the age 20 who had voluntary taken a stable iodine dose of 60 mg on 29 April 1986 12:00; and
(7) adults at the age 20 who had voluntary taken a stable iodine dose of 60 mg on 30 April 1986 12:00.

It made in total 14 radiological cases and subsequently fourteen variants of ^{131}I thyroid content, however only several cases were sufficiently supported by measurements, and only these cases are presented in the following figures.

4.2.3.1. Predicted ^{131}I content in thyroid for Warsaw – Adults without stable iodine treatment

In this case (see Figure 4.43) predictions of ^{131}I thyroid content were quite consistent with previously calculated ^{131}I concentrations in milk for all models thus the models which produced predictions of milk close to measured values (ECOSYS-97 (M. Ammann), OSCAAR (T. Homma)). Models which overestimated ^{131}I concentration in milk due to some conservative assumptions (see Section 4.22), overestimated ^{131}I content in thyroid, i.e., UNIVES (B. Kanyár), CLIMRAD (O. Vlasov). On the other hand some models as LIETDOS (V. Flistovich; T. Nedveckaite) and IRH-model (I. Zvonova) demonstrated compensatory effect.

4.2.3.2. Predicted ^{131}I content in thyroid for Warsaw - Adults who took stable iodine on 29 April 1986 r.

All models clearly demonstrated ability to reduce ^{131}I thyroid content due to presence of stable iodine in body fluids (see Figure 4.44), but some models ECOSYS-97 (M. Ammann), IRH-model (I. Zvonova) considered it more effective and lasted longer that other models UNIVES (B. Kanyár), LIETDOS (V. Flistovich; T. Nedveckaite). Evaluation and validation of this feature for each particular model is more complex because it would depend on iodine metabolism applied in the model as well as method of calculation and assumed time of intakes. Similar to the case discussed in Section 4.2.3.1 predictions of ^{131}I thyroid content were quite consistent with previously calculated ^{131}I concentrations in milk for all models.

4.2.3.3. Predicted ^{131}I content in thyroid for Warsaw -Children age 3 – 10- stb. iodine was given on 29 April 1986

The test data used for models validation in this particular case included measurements that were performed for children from Warsaw and small towns surrounding Warsaw; therefore these data represent somewhat elevated level than ^{131}I content in thyroids children from Warsaw only. It might explain why predictions of some models, i.e., ECOSYS-97 (M. Ammann) and OSCAAR (T. Homma) demonstrated underestimation and predictions of others, i.e., LIETDOS (V. Flistovich; T. Nedveckaite), CLIMRAD (O. Vlasov) and IRH-model were closer to the measured values (see Figure 4.45).

4.2.3.4. Predicted ^{131}I content in thyroid for Ostroleka inhabitants - Children aged 3–10, stb. iodine was administrated on 30 April 1986

In this case, the test data included measurements of ^{131}I content in thyroids of children from villages situated in Ostroleka area. Inhabitants of some villages, especially children, used to drink much more milk than it is shown in statistics moreover because of poor living conditions they could not follow the ban. It might explain why predictions of "conservative" models as UNIVES (B. Kanyár), LIETDOS (V. Flistovich; T. Nedveckaite) were closer to the observed values than 'best estimate" models as ECOSYS-97 (M. Ammann) or OSCAAR (T. Homma). Besides, the last model demonstrated wide uncertainty ranges that covered measured values (see Figure 4.46).

The overall modeller performance with respect of this task can be seen in Figure 4.47. The models' predictions for all fourteen radiological variants discussed above were taken into account. More than 50% of predictions fit within one order of magnitude discrepancy with measured values, what appears to be the best fit taking into account that a scatter of measured values very often exceeds one order of magnitude.

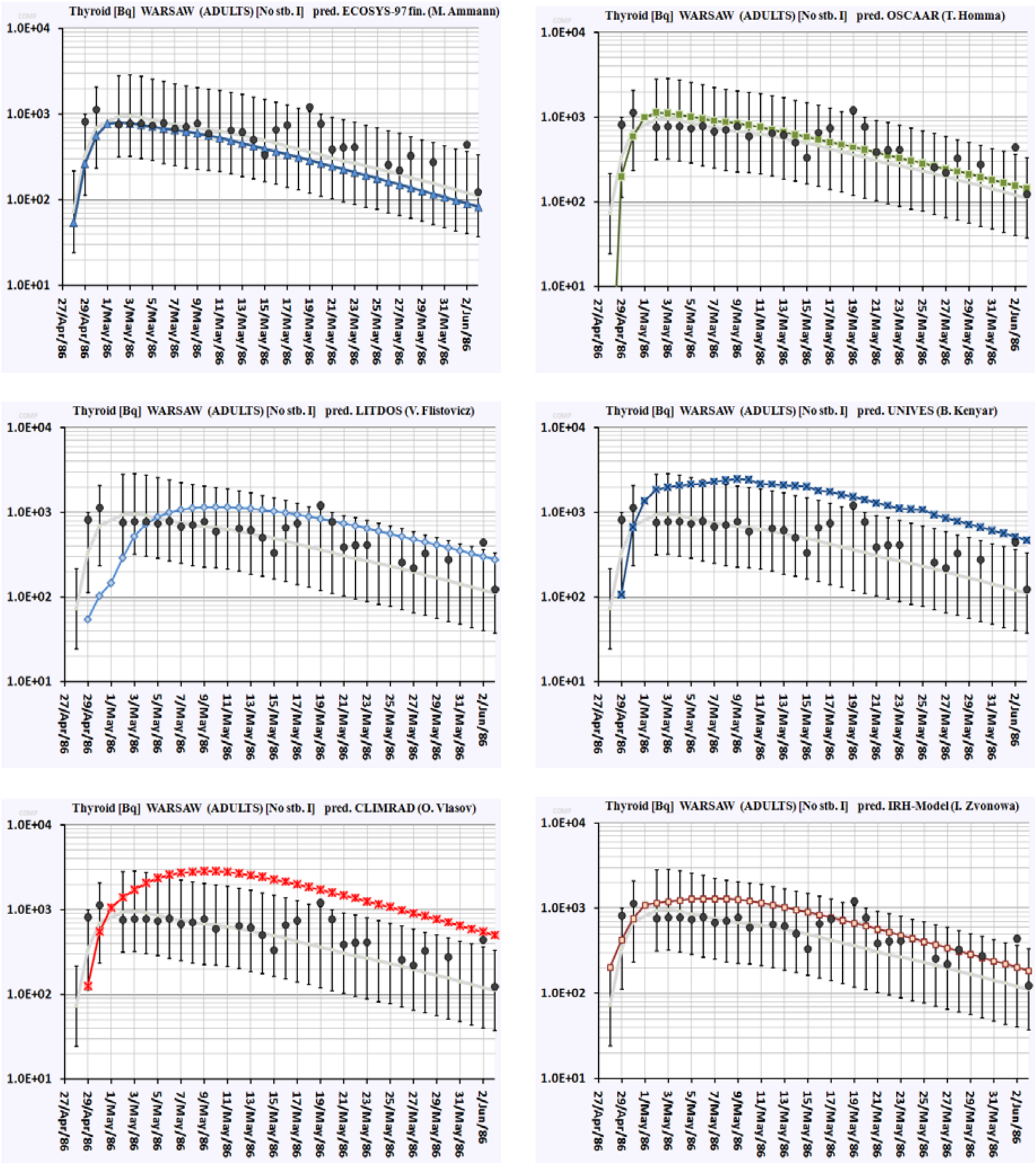


Fig. 4.43. Predicted ^{131}I content in thyroid for Warsaw inhabitants (Adults age >=20,No stb. Iodine) by ECOSYS-97 (M. Ammann), by OSCAAR (T. Homma), UNIVES (B. Kanyár), LIETDOS (V. Flistovich; T. Nedveckaite), CLIMRAD (O. Vlasov) and IRH-model (I. Zvonova) versus measured values.

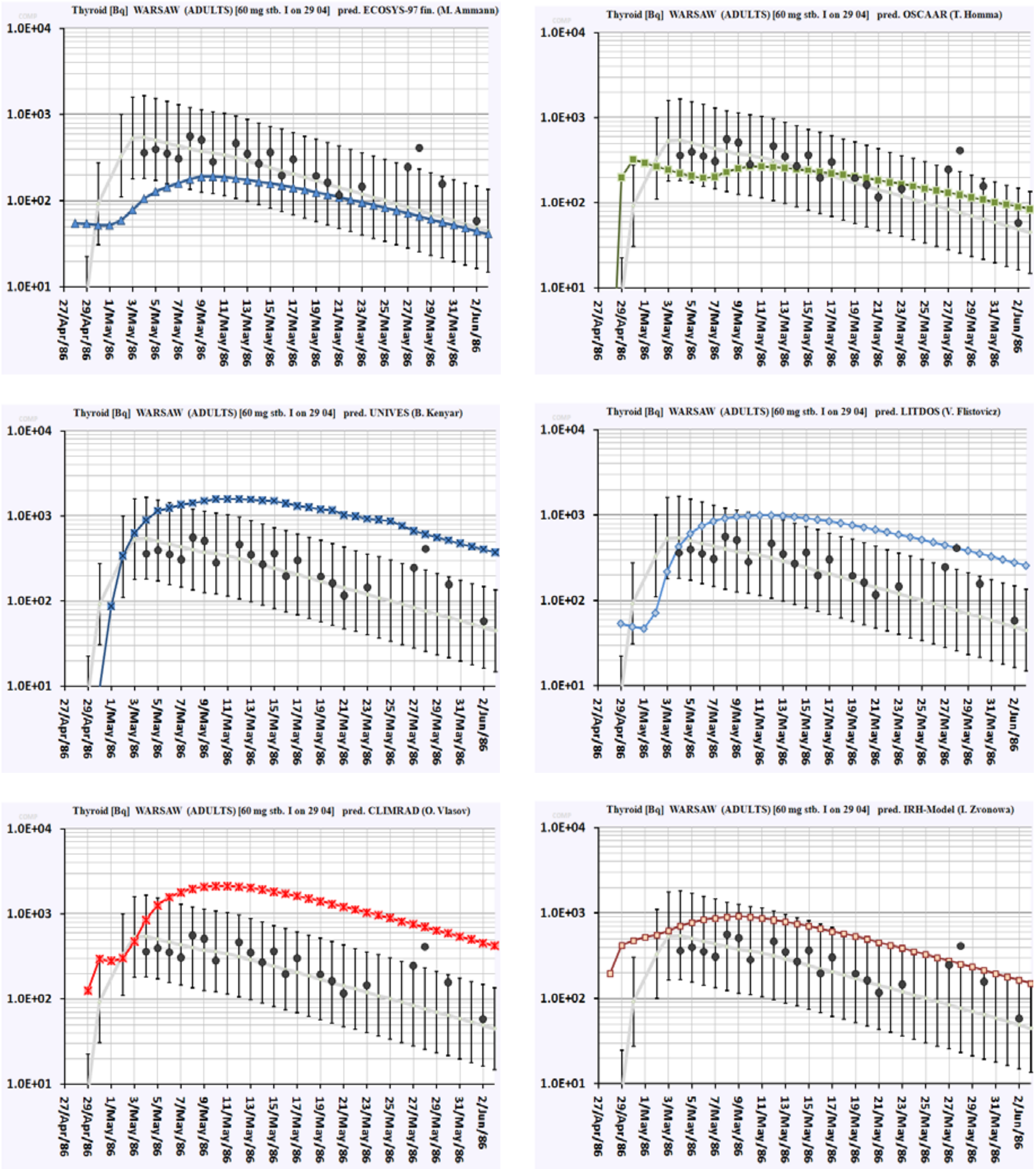


Fig. 4.44. Predicted ^{131}I content in thyroid for Warsaw inhabitants (Adults age >=20,Stb. Iodine on 29April 1986) by ECOSYS-97 (M. Ammann), by OSCAAR (T. Homma), UNIVES (B. Kanyár), LIETDOS (V. Flistovich; T. Nedveckaite), CLIMRAD (O. Vlasov) and IRH-model (I. Zvonova) versus measured values.

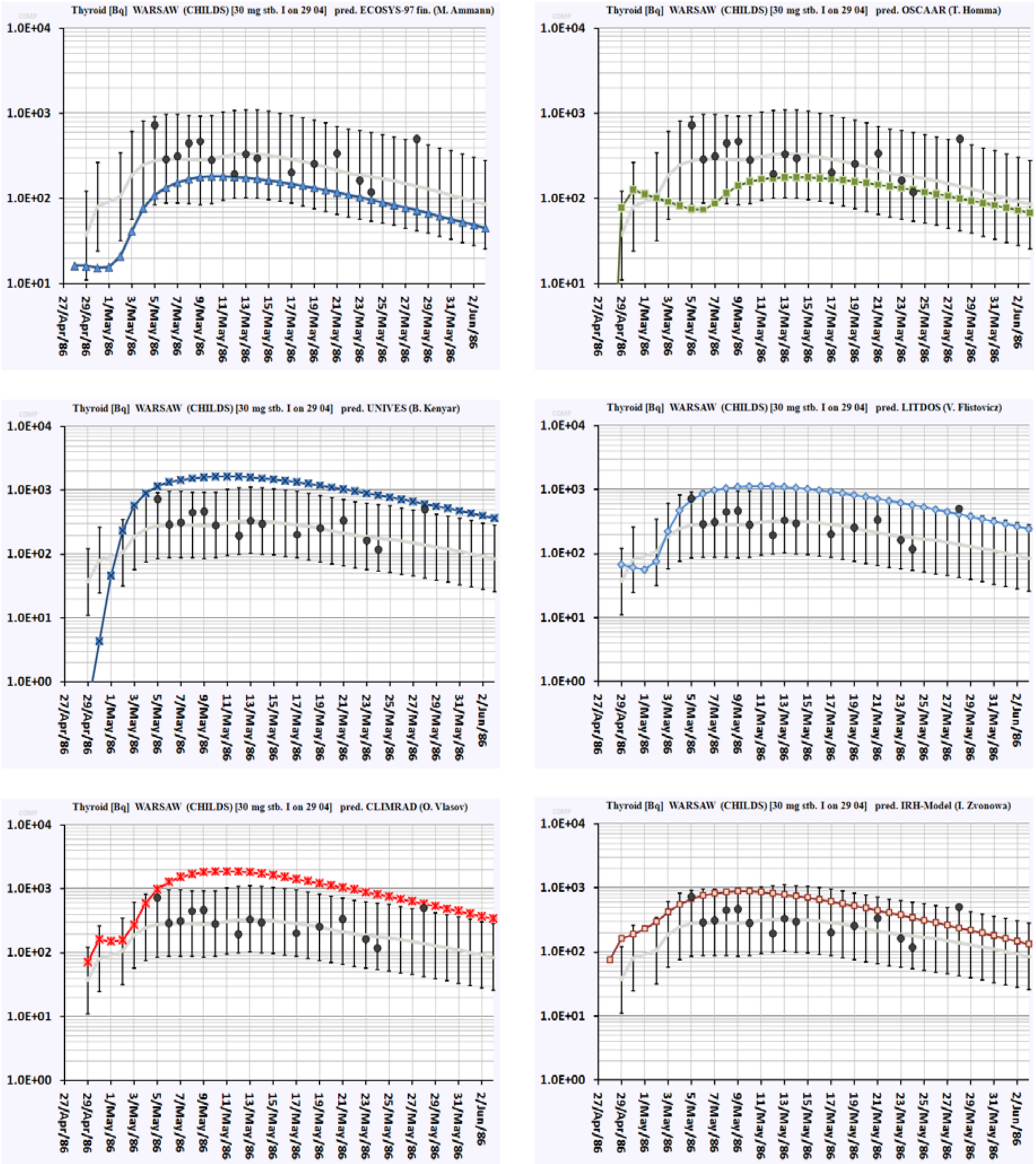


Fig. 4.45. Predicted ^{131}I content in thyroid for Warsaw inhabitants (Children age 3–10,Stb. Iodine on 29April 1986) by ECOSYS-97 (M. Ammann), by OSCAAR (T. Homma), UNIVES (B. Kanyár), LIETDOS (V. Flistovich; T. Nedveckaite), CLIMRAD (O. Vlasov) and IRH-model (I. Zvonova) versus measured values.

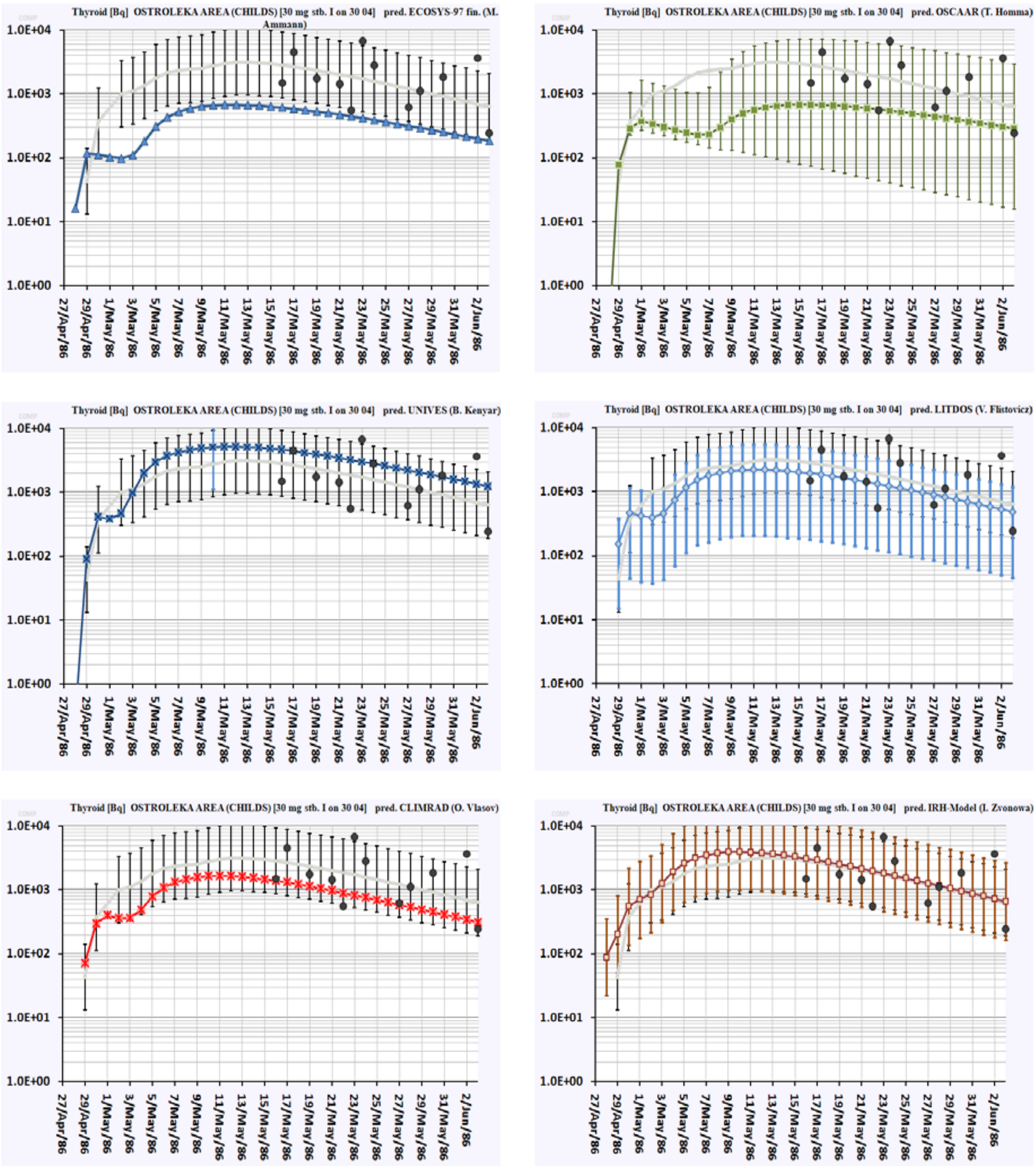


Fig. 4.46. Predicted ^{131}I content in thyroid for Ostroleka inhabitants (Children age 3–10,Stb. Iodine on 30 April 1986) by ECOSYS-97 (M. Ammann), by OSCAAR (T. Homma), UNIVES (B. Kanyár), LIETDOS (V. Flistovich; T. Nedveckaite), CLIMRAD (O. Vlasov) and IRH-model (I. Zvonova) versus measured values.

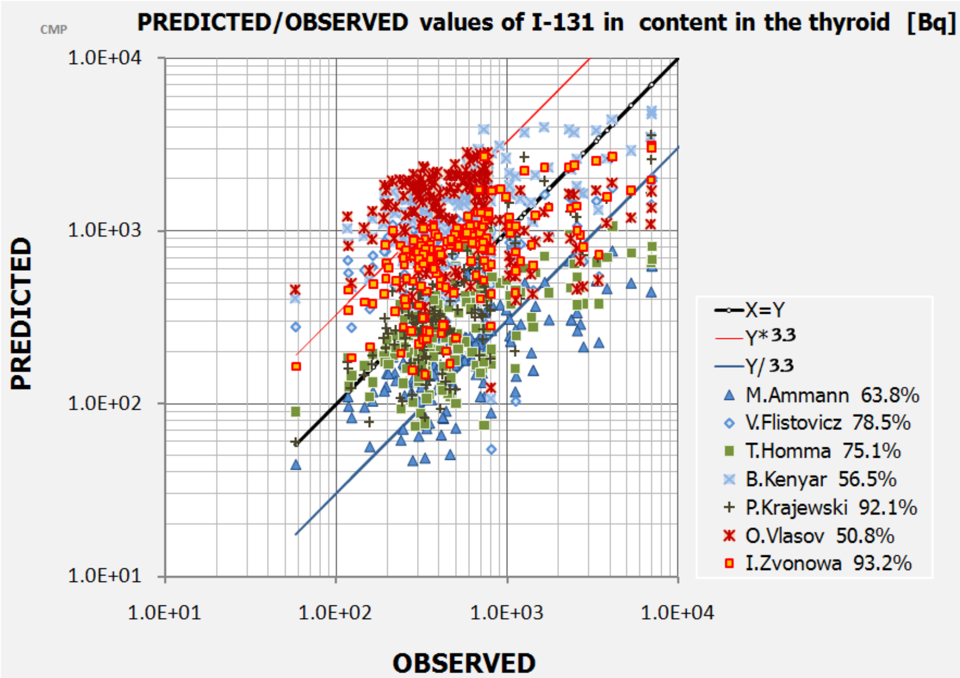


Fig. 4.47. Comparison of predicted versus observed ^{131}I content in thyroid for inhabitants of Warsaw and Ostroleka areas. Straight lines represent: predicted equal to observed values, order of magnitude bounds. Percentage values next to modeller's name are the percentage of predictions within the one order of magnitude measured value.

4.2.4. Dose assessment

The final target of the scenario relates to prediction of the thyroid doses (committed equivalent dose to thyroid) from inhalation and ingestion for different age groups, i.e., 1 year, 5 years, 10 years and adult including various variants of countermeasures applied in two locations, i.e., Warsaw town and rural Ostroleka area.

This task provided an opportunity for the dose assessment professionals, to examine their skills, methods and conceptual approaches for the specified level of the assessment, when applied countermeasures need to be evaluated with respect of their real practicability.

The thyroid dose from inhalation were calculated for different time of administration of stable iodine during the critical period of radioactive clouds passage from 27 April – 2 May 1986, i.e., 28-04-86 12:00, 29-04-86 12:00, 30-04-86 12:00, 01-05-86 12:00.

The thyroid doses from ingestion were calculated for more complex countermeasures that involve a combination of pasturage restrictions as well as administration of stable iodine on different time. The dates of pasturage restriction were selected taking into account most effective and ineffective variants: 28 April 1986, 1 May 1986, 15 May 1986 and 1 June 1986 respectively. For the sake of model comparison transparency, participants were asked to make assumption, that whole milk is consumed by representatives of the particular age groups.

Representative examples of calculation are presented in Figures 4.48–4.51. The highest thyroid doses (as one could expect) appear when no countermeasures are undertaken, i.e., no stable iodine administration and no pasturing ban. The distribution of a single dose of stable iodine reduces thyroid doses only from inhalation when is introduced immediately (no later than 8 hours) when radioiodine clouds occur, it has insignificant influence on dose reduction when ingestion pathway, namely consumption of contaminated milk takes place. However, when deposition of airborne radioiodine on the pasture is possible, only withdrawing milky cows from open area to the cowshed and deliver them uncontaminated fodder during one month can highly reduce risk of thyroid doses. There was no consensus among modellers how effective this countermeasure would be, conservative evaluation indicates on dose reduction by factor 10, more optimistic on factor 100 and even more. Dose reduction effect depends remarkably on not predictable factors as fodder stock and public concern.

4.3. Prague Scenario

The Prague Scenario was characterized by countermeasures consisting of limitation of fresh pasture/fodder for dairy cows.

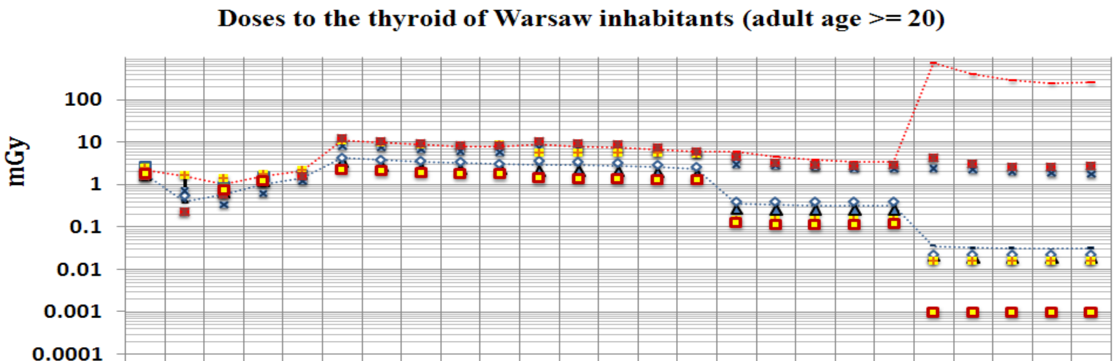
The regions of three big dairies were subject of models exercise. Maps of the sampling regions of Prague-Troja, Prague-Kyje and Benešov dairies are presented in Figure 2.6 in Chapter 2. Scenario provided information about weather conditions (wind directions, rain and temperature), agriculture, demography, food consumption and measurements data of aerosols bound ^{131}I iodine in air in three stations in Prague (in station Prague-Libeň, aerosol and gaseous forms of iodine were measured separately). Participants of this exercise had to use their expert judgment to estimate the fallout of iodine for the places because not enough experimental data was collected. It was possible either to derive the data from the nearest aerosol station or to make use of the measurement of ^{137}Cs concentrations in soil and the available isotopic $^{131}I/^{137}Cs$ ratio from the measurements of fallout at location for which more data existed.

4.3.1. ^{131}I concentration in grass

There were only a few measurements of ^{131}I concentration in grass in one location in Prague (the measurements started on 10 May 1986), later these data were supplemented by measurements ^{131}I in grass from Bratislava (the measurements started earlier on 1 May 1986). The models predictions of ^{131}I concentration in grass reflected individual judgment of airborne ^{131}I over Prague as well as contribution of aerosol bound and gaseous forms of radioiodine. The models traditionally used semi-empirical weathering half-life in the order of 10–15 days. Weathering half-time evaluated from measurements was equal to 15.5 days (effective for ^{131}I = 5.5 days) and was correctly assumed by modellers as similar values were frequently reported in literature. Unfortunately, in this scenario results of ^{131}I measurements in grass could not be used for predictions of ^{131}I concentrations in milk, because of countermeasures that restrict the use of fresh pasture/fodder for dairy cows.

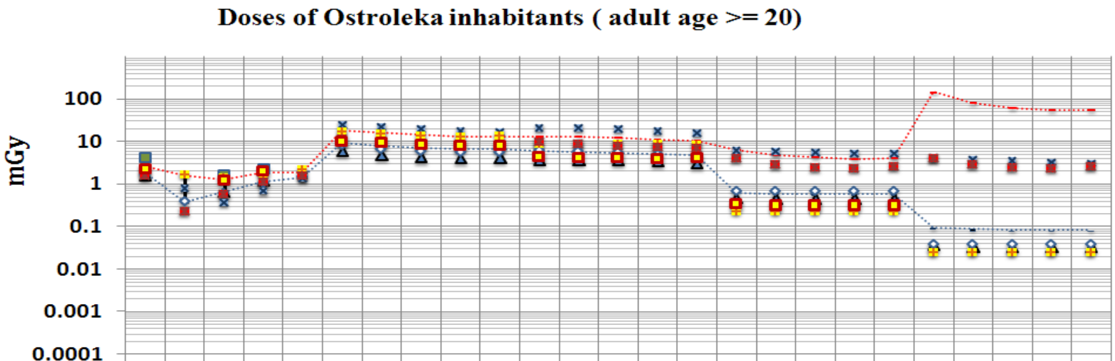
Table 4.8. Variants of complex countermeasures that involve a combination of pasturage restrictions as well as administration of stable iodine on different time, considered in Mazovia scenario.

Pathway	**Symbol on the graph**	**Countermeasures**
INHALATION	No I	No administration of stable iodine and
	28/4	Administration of stable iodine on 28 April 1986 12:00
	29/4	Administration of stable iodine on 29 April 1986 12:00
	30/4	Administration of stable iodine on 30 April 1986 12:00
	1/5	Administration of stable iodine on 1 May 1986 12:00
INHALATION and INGESTION	C28/4 NoI	No administration of stable iodine and no fresh grass limitation
	C28/4 28/4	Administration of stable iodine on 28 April 1986 12:00 and no fresh grass limitation
	C28/4 29/4	Administration of stable iodine on 29 April 1986 12:00 and no fresh grass limitation
	C28/4 30/4	Administration of stable iodine on 30 April 1986 12:00 and no fresh grass limitation
	C28/4 1/5	Administration of stable iodine on 1 May 1986 12:00 and no fresh grass limitation
	C1/5 NoI	No administration of stable iodine and Cows kept in cowsheds up to 1 May 1986
	C1/5 28/4	Administration of stable iodine on 28 April 1986 12:00 and Cows kept in cowsheds up to 1 May 1986
	C1/5 29/4	Administration of stable iodine on 29 April 1986 12:00 and Cows kept in cowsheds up to 1 May 1986
	C1/5 30/4	Administration of stable iodine on 30 April 1986 12:00 and Cows kept in cowsheds up to 1 May 1986
	C1/5 1/5	Administration of stable iodine on 1 May 1986 12:00 and Cows kept in cowsheds up to 1 May 1986
	C15/5 NoI	No administration of stable iodine and Cows kept in cowsheds up to 15 May 1986
	C15/5 28/4	Administration of stable iodine on 28 April 1986 12:00 and Cows kept in cowsheds up to 15 May 1986
	C15/5 29/4	Administration of stable iodine on 29 April 1986 12:00 and Cows kept in cowsheds up to 15 May 1986
	C15/5 30/4	Administration of stable iodine on 30 April 1986 12:00 and Cows kept in cowsheds up to 15 May 1986
	C15/5 1/5	Administration of stable iodine on 1 May 1986 12:00 and Cows kept in cowsheds up to 1 June 1986
	C1/6 NoI	No administration of stable iodine and Cows kept in cowsheds up to 1 June 1986
	C1/6 28/4	Administration of stable iodine on 28 April 1986 12:00 and Cows kept in cowsheds up to 1 June 1986
	C1/6 29/4	Administration of stable iodine on 29 April 1986 12:00 and Cows kept in cowsheds up to 1 June 1986
	C1/6 30/4	Administration of stable iodine on 30 April 1986 12:00 and Cows kept in cowsheds up to 1 June 1986
	C1/6 1/5	Administration of stable iodine on 1 May 1986 12:00 and Cows kept in cowsheds up to 1 June 1986



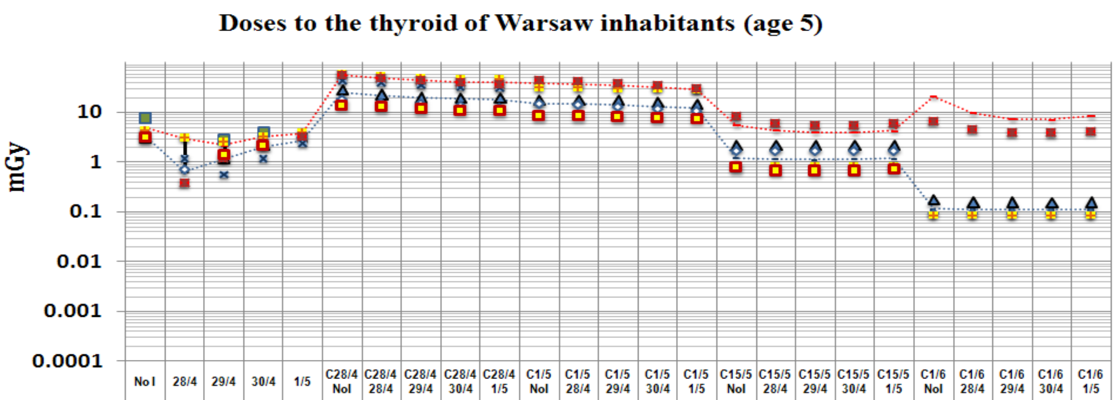
	No I	28/4	29/4	30/4	1/5	C28/4 NoI	C28/4 28/4	C28/4 29/4	C28/4 30/4	C28/4 1/5	C1/5 NoI	C1/5 28/4	C1/5 29/4	C1/5 30/4	C1/5 1/5	C15/5 NoI	C15/5 28/4	C15/5 29/4	C15/5 30/4	C15/5 1/5	C1/6 NoI	C1/6 28/4	C1/6 29/4	C1/6 30/4	C1/6 1/5
M.Ammann	1.6		0.6	1.2		3.3	2.7	2.4	2.3	2.3	2.1	2.1	2.1	1.9	1.7	0.3	0.3	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0
V.Flistovicz	2.3	0.5	0.8	1.5	2.1	4.3	3.9	3.7	3.4	3.0	3.6	3.4	3.2	2.9	2.6	0.4	0.4	0.4	0.4	0.4	0.0	0.0	0.0	0.0	0.0
T.Homma	2.7		0.9	1.6																					
B.Kenyar	1.8	0.7	0.3	0.6	1.2	8.4	7.6	6.8	6.2	5.9	7.4	7.1	6.6	6.0	5.5	3.1	2.9	2.7	2.5	2.4	2.5	2.3	2.1	1.9	1.8
P.Krajewski	2.4	1.7	1.4	1.8	2.2	11.0	9.9	8.9	8.5	8.8	5.8	5.8	5.7	5.6	5.4	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0
O.Vlasov	1.6	0.2	0.6	1.2	1.6	12.4	10.6	9.5	8.6	8.2	10.5	9.2	8.6	7.3	6.0	4.5	3.3	2.9	2.8	3.0	4.2	3.0	2.6	2.6	2.8
I.Zvonowa	1.9		0.8	1.3		2.4	2.1	2.0	1.8	1.8	1.4	1.4	1.4	1.3	1.3	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Logn AVG	2.0	0.8	0.8	1.3	1.8	7.1	6.2	5.6	5.2	5.1	5.2	5.0	4.7	4.3	3.8	1.5	1.2	1.1	1.1	1.1	5.2	3.7	3.1	2.8	2.9
L95 AVG	1.8	0.4	0.6	1.1	1.4	4.4	3.9	3.5	3.3	3.2	3.1	3.0	2.9	2.7	2.5	0.4	0.3	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0
U95 AVG	2.3	1.6	1.0	1.6	2.2	11.2	9.9	8.9	8.2	8.0	8.9	8.2	7.7	6.9	6.0	6.0	4.5	3.8	3.5	3.5	764.4	408.2	293.4	250.4	259.9

Fig. 4.48. Thyroid doses of Warsaw inhabitants (Adults) for various variants of countermeasures evaluated by modellers: by ECOSYS-97 (M. Ammann), LIETDOS (V. Flistovich; T. Nedveckaite), OSCAAR (T. Homma), UNIVES (B. Kanyár),CLRP (P. Krajewski), CLIMRAD (O. Vlasov) and IRH-model (I. Zvonova).



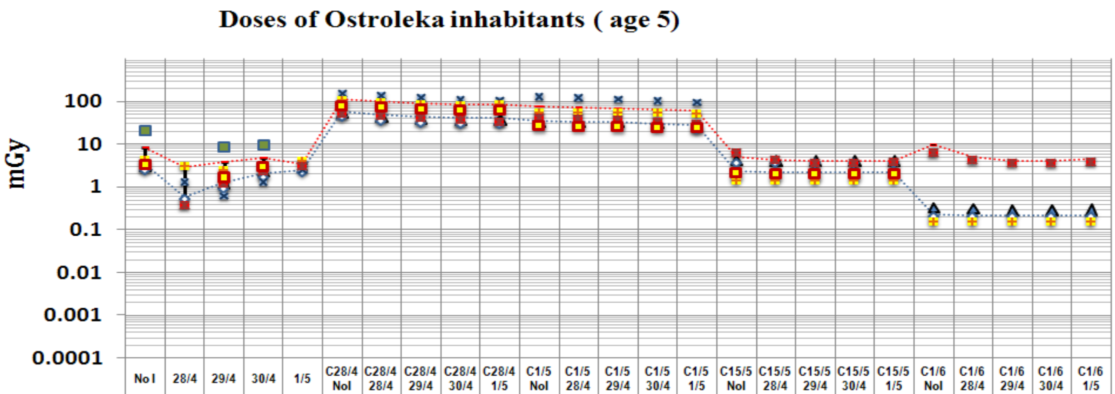
	No I	28/4	29/4	30/4	1/5	C28/4 NoI	C28/4 28/4	C28/4 29/4	C28/4 30/4	C28/4 1/5	C1/5 NoI	C1/5 28/4	C1/5 29/4	C1/5 30/4	C1/5 1/5	C15/5 NoI	C15/5 28/4	C15/5 29/4	C15/5 30/4	C15/5 1/5	C1/6 NoI	C1/6 28/4	C1/6 29/4	C1/6 30/4	C1/6 1/5
M.Ammann	1.6		0.6	1.2		5.9	4.8	4.2	4.0	4.1	3.7	3.7	3.6	3.4	3.0	0.5	0.5	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0
V.Flistovicz	1.7	0.4	0.6	1.1	1.6	8.6	7.0	6.4	5.9	6.0	6.5	6.2	5.8	5.2	4.6	0.7	0.7	0.7	0.7	0.7	0.0	0.0	0.0	0.0	0.0
T.Homma	4.3		1.6	2.3																					
B.Kenyar	2.0	0.8	0.4	0.7	1.3	25.0	22.0	20.0	18.0	17.0	21.0	21.0	20.0	18.0	16.0	6.3	5.9	5.6	5.3	5.2	4.2	3.8	3.5	3.3	3.1
P.Krajewski	2.4	1.7	1.4	1.8	2.2	17.2	15.5	13.9	13.3	13.7	9.1	9.1	8.9	8.7	8.4	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0
O.Vlasov	1.6	0.2	0.6	1.2	1.6	11.7	9.9	8.9	8.0	7.8	9.8	8.7	8.1	7.4	7.2	4.0	2.9	2.5	2.4	2.6	4.0	2.9	2.5	2.4	2.6
I.Zvonowa	2.3		1.3	2.1		10.7	9.7	9.0	8.4	8.1	4.5	4.4	4.3	4.1	4.2	0.3	0.3	0.3	0.3	0.3					
Logn AVG	2.3	0.8	0.9	1.5	1.7	13.2	11.5	10.4	9.6	9.5	9.0	8.7	8.3	7.7	7.2	2.0	1.7	1.6	1.5	1.6	3.7	2.7	2.3	2.2	2.2
L95 AVG	1.8	0.4	0.7	1.2	1.4	9.4	8.0	7.2	6.7	6.7	5.9	5.7	5.5	5.2	4.8	0.6	0.6	0.6	0.6	0.6	0.1	0.1	0.1	0.1	0.1
U95 AVG	2.8	1.6	1.3	1.9	1.9	18.3	16.4	15.0	13.7	13.3	13.7	13.2	12.6	11.5	10.7	6.4	4.9	4.4	4.1	4.2	150.2	84.1	62.9	55.8	56.7

Fig. 4.49. Thyroid doses of Ostroleka inhabitants (Adults) for various variants of countermeasures evaluated by modellers: by ECOSYS-97 (M. Ammann), LIETDOS (V. Flistovich; T. Nedveckaite), OSCAAR (T. Homma), UNIVES (B. Kanyár),CLRP (P. Krajewski), CLIMRAD (O. Vlasov) and IRH-model (I. Zvonova).



	No I	28/4	29/4	30/4	1/5	C28/4 Nol	C28/4 28/4	C28/4 29/4	C28/4 30/4	C28/4 1/5	C1/5 Nol	C1/5 28/4	C1/5 29/4	C1/5 30/4	C1/5 1/5	C15/5 Nol	C15/5 28/4	C15/5 29/4	C15/5 30/4	C15/5 1/5	C1/6 Nol	C1/6 28/4	C1/6 29/4	C1/6 30/4	C1/6 1/5
M.Ammann	3.0		1.2	2.2		28.2	22.9	20.0	19.2	19.7	17.9	17.9	17.4	16.2	14.5	2.2	2.2	2.2	2.2	2.2	0.2	0.2	0.2	0.2	0.2
V.Flistovicz	3.3	0.7	1.2	2.2	3.1	17.8	15.8	14.8	13.5	12.2	14.7	13.9	13.0	11.8	10.6	1.7	1.7	1.7	1.7	1.7	0.1	0.1	0.1	0.1	0.1
T.Homma	7.7		2.8	4.1																					
B.Kenyar	3.6	1.2	0.6	1.2	2.4	44.0	40.0	35.0	32.0	31.0															
P.Krajewski	4.4	3.1	2.6	3.3	4.0	59.8	53.8	48.4	46.2	47.8	31.5	31.5	31.0	30.4	29.3	0.8	0.8	0.8	0.8	0.8	0.1	0.1	0.1	0.1	0.1
O.Vlasov	3.4	0.4	1.2	2.4	3.2	55.6	49.0	44.0	39.2	36.1	44.3	41.7	38.3	34.0	29.3	8.1	6.0	5.4	5.3	6.0	6.6	4.5	3.9	3.8	4.2
I.Zvonowa	3.2		1.4	2.2		14.1	12.9	11.9	11.1	10.8	8.5	8.4	8.1	7.9	7.6	0.8	0.7	0.7	0.7	0.7					
Logn AVG	4.1	1.4	1.6	2.5	3.2	37.0	32.7	29.3	27.1	26.5	23.5	22.9	21.7	20.2	18.4	2.6	2.2	2.1	2.1	2.2	1.5	1.0	0.9	0.9	1.0
L95 AVG	3.4	0.6	1.1	2.0	2.7	24.7	21.8	19.7	18.3	17.7	14.7	14.4	13.8	12.9	11.9	1.2	1.1	1.1	1.1	1.2	0.1	0.1	0.1	0.1	0.1
U95 AVG	4.9	2.9	2.2	3.2	3.7	55.4	49.0	43.4	40.0	39.7	37.6	36.3	34.3	31.6	28.3	5.5	4.3	4.0	3.9	4.3	20.8	9.8	7.3	7.1	8.3

Fig. 4.50. Thyroid doses of Warsaw children (5 years old) for various variants of countermeasures evaluated by modellers: by ECOSYS-97 (M. Ammann), LIETDOS (V. Flistovich; T. Nedveckaite), OSCAAR (T. Homma), UNIVES (B. Kanyár),CLRP (P. Krajewski), CLIMRAD (O. Vlasov) and IRH-model (I. Zvonova).



	No I	28/4	29/4	30/4	1/5	C28/4 Nol	C28/4 28/4	C28/4 29/4	C28/4 30/4	C28/4 1/5	C1/5 Nol	C1/5 28/4	C1/5 29/4	C1/5 30/4	C1/5 1/5	C15/5 Nol	C15/5 28/4	C15/5 29/4	C15/5 30/4	C15/5 1/5	C1/6 Nol	C1/6 28/4	C1/6 29/4	C1/6 30/4	C1/6 1/5
M.Ammann	3.0		1.2	2.2		52.5	42.6	37.3	35.7	36.7	33.3	33.3	32.4	30.2	27.1	4.1	4.1	4.0	4.0	4.0	0.3	0.3	0.3	0.3	0.3
V.Flistovicz	2.5	0.5	0.9	1.7	2.3	44.7	35.3	31.9	29.7	30.0	33.6	31.7	29.2	26.1	22.9	3.8	3.8	3.8	3.8	3.8	0.2	0.2	0.2	0.2	0.2
T.Homma	20.8		8.6	9.6																					
B.Kenyar	4.0	1.3	0.6	1.3	2.6	159.0	141.0	126.0	114.0	110.0	134.0	124.0	116.0	107.0	98.0										
P.Krajewski	4.4	3.1	2.6	3.3	4.0	109.1	98.2	88.3	84.3	87.3	57.5	57.5	56.5	55.5	53.6	1.5	1.5	1.5	1.5	1.5	0.2	0.2	0.2	0.2	0.2
O.Vlasov	3.4	0.4	1.2	2.4	3.2	52.5	46.1	41.3	36.7	34.3	41.6	39.2	37.3	34.5	30.9	6.3	4.3	3.7	3.7	4.0	6.3	4.3	3.7	3.7	4.0
I.Zvonowa	3.3		1.7	3.0		80.3	72.9	67.6	63.2	61.3	26.7	26.2	25.8	24.8	24.0	2.1	2.0	2.0	2.0	2.0					
Logn AVG	5.4	1.3	2.2	3.3	3.0	82.6	72.5	65.2	60.5	59.8	53.1	50.9	48.5	45.5	42.0	3.6	3.1	3.0	3.0	3.1	1.5	1.1	1.0	1.0	1.0
L95 AVG	3.4	0.6	1.3	2.2	2.6	59.8	50.9	45.7	42.4	42.0	36.1	34.9	33.5	31.4	28.8	2.4	2.3	2.2	2.2	2.2	0.2	0.2	0.2	0.2	0.2
U95 AVG	8.6	3.0	4.0	4.9	3.6	114.0	103.2	93.1	86.2	85.2	78.2	74.0	70.2	66.0	61.2	5.3	4.4	4.1	4.1	4.2	10.0	5.2	4.2	4.1	4.7

Fig. 4.51. Thyroid doses of Ostroleka children (5 years old) for various variants of countermeasures evaluated by modellers: by ECOSYS-97 (M. Ammann), LIETDOS (V. Flistovich; T. Nedveckaite), OSCAAR (T. Homma), UNIVES (B. Kanyár),CLRP (P. Krajewski), CLIMRAD (O. Vlasov) and IRH-model (I. Zvonova).

4.3.2. ^{131}I concentration in milk

The next point of model validation task was the comparison of measurements with model calculations of ^{131}I milk concentration from the three dairies as well as the ^{131}I content in thyroid of Prague inhabitants.

It appears that modellers who used previously predicted ^{131}I concentration in grass to calculate radioiodine in milk, but underestimated ^{131}I concentration in grass, obtained good agreement with predictions of ^{131}I concentration in milk with observed data, i.e., LIETDOS (V. Flistovich; T. Nedveckaite) (see Figure 4.55), CLIMRAD (O. Vlasov) (see Figure 4.53) and IRH-model (I. Zvonova) (see Figure 4.58), whereas models that obtained good agreement with measured ^{131}I concentration in grass, overestimated of ^{131}I concentration in milk, i.e., ECOSYS-97 (M. Ammann) (see Figure 4.54), OSCAAR (T. Homma) (see Figure 4.56). Only is UNIVES (B. Kanyár) (see Figure 4.57) who independently evaluated limitation of fresh pasture, achieved pretty good agreement with measured values. CLRP (P. Krajewski) predictions based on assumption similar to Mazowia scenario assuming gradual increase in fresh grass delivery during the critical period, i.e., 5 kg fresh grass from 30 April 1986 to 2 May 1986, 15 kg fresh grass from 3 May to 15 May 1986 and 35 kg fresh grass from 14 May to 20 October 1986. That assumption yielded to pretty good agreement with observed data (see Figure 4.59). However, supposition on feeding cows with no contaminated fodder in Prague dairies failed, since calculated levels of ^{131}I in milk due to inhalation of contaminated air appeared to be much lower than observed data (see Figure 4.60). It was not possible to assign precise composition of contaminated and uncontaminated fodder for particular dairy, mixed consumption was probable. Because of uncertainty in the feeding regime of dairy cows, after the first run of model calculation, measured data for milk was given to modellers.

4.3.3. ^{131}I thyroid content

Results of model calculations for adult Prague inhabitants together with measured data are presented in Figure 4.62. For the early period of measurements from the 4 May to the 11 May 1986 all models underestimate measurements values; this is probably due to measured data which came from whole body counting and measured values were probably influenced by surface contamination of hair and beards. Nevertheless, as all model used as an input milk data, about of 80% of prediction of ^{131}I thyroid content fit in a order of magnitude range of measured values.

4.3.4. Dose assessment

The most important feature of the Prague Scenario was keeping the dairy cows in sheds on a special feeding regime during May 1986. However, it was difficult to give modellers exact data about this countermeasure, as it was not publicly announced (it was a centrally governed communist regime in Czechoslovakia); this recommendation was given through official channels only. In addition to this, the beginning to mid-May used to be the transition time from dry to fresh fodder, so to define quantitatively part of fresh and dry fodder in dependence with the time is problematic even in a normal situation. It is nearly impossible to reconstruct how individual collective farms respected internal instructions because most of them do not exist anymore or have been transformed to the private sector. Therefore, it was decided that modellers would calculate two extreme cases – when no fresh fodder was consumed by cattle and when cattle were in pasture from the beginning of the accident; for both cases ^{131}I milk concentration and thyroid doses have to be calculated.

Surprisingly, former point e.g. when no fresh fodder was consumed by cattle, yielded to discrepancy of dose assessment that exceeded a factor of ten due to the different methods and conceptual approaches applied by modellers.

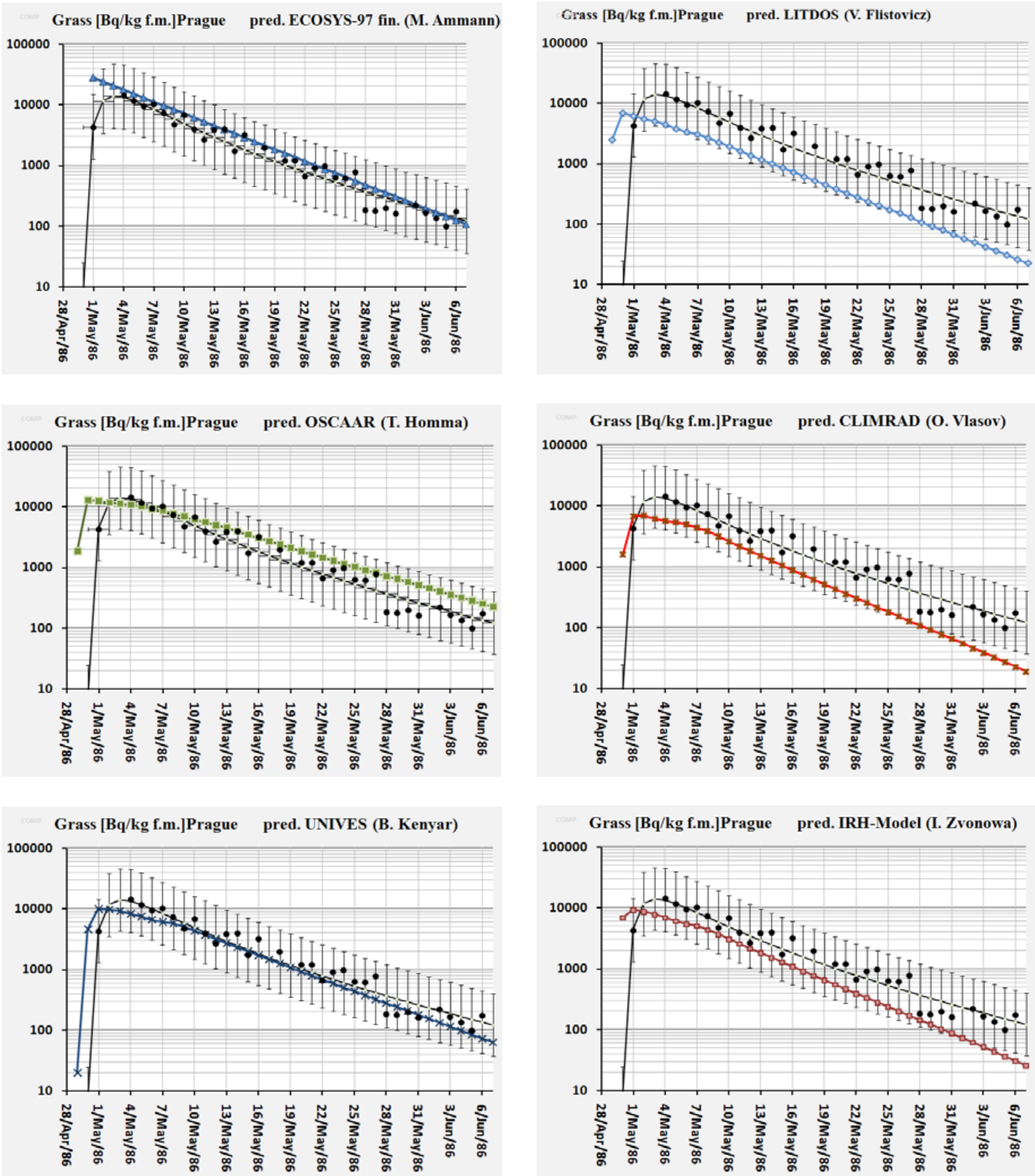


Fig. 4.52. Examples of models predictions ^{131}I concentration in grass versus measured values performed by modellers: ECOSYS-97 (M. Ammann), LIETDOS (V. Flistovich; T. Nedveckaite), OSCAAR (T. Homma), UNIVES (B. Kanyár), CLIMRAD (O. Vlasov) and IRH-model (I. Zvonova). Black dots present measurements values, whereas the thin line shows the extrapolation curve fitted to measurements with LSQ method.

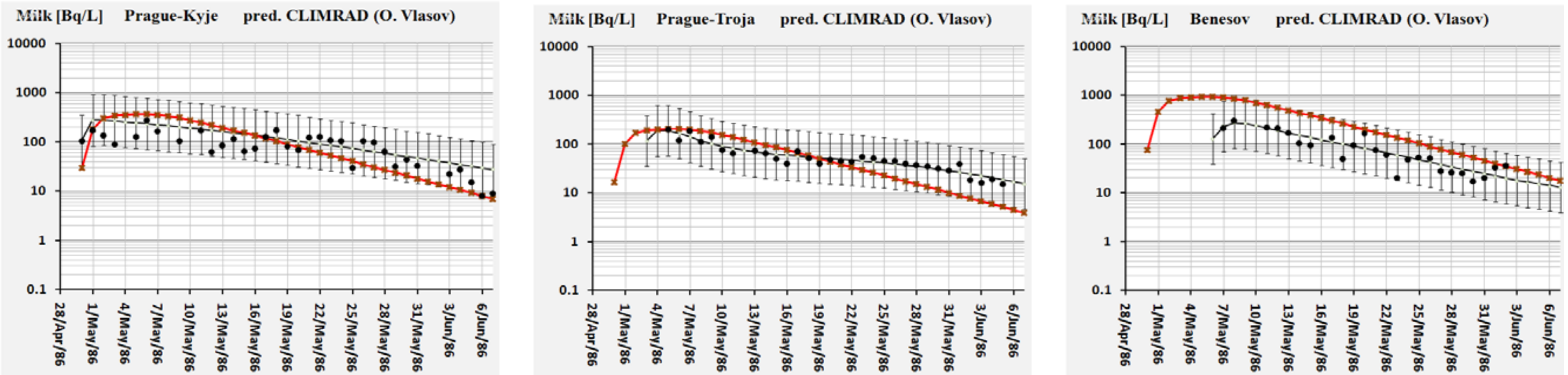


Fig. 4.53. Predictions for collective farm PRAGUE-KYJE, PRAGUE-TROJA, BENESOV by model CLIMRAD (O. Vlasov).

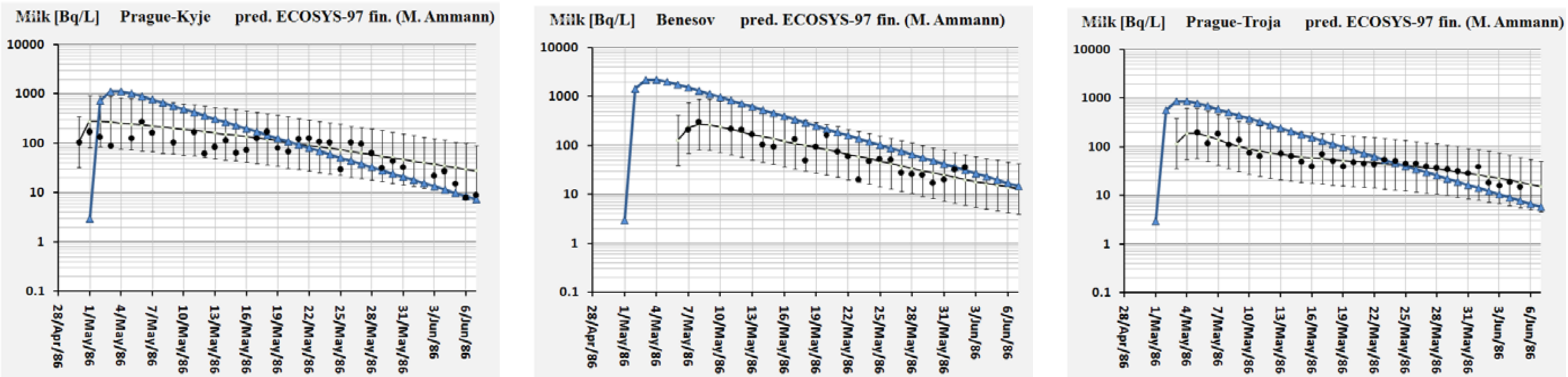


Fig. 4.54. Predictions for collective farm PRAGUE-KYJE, PRAGUE-TROJA, BENESOV by model ECOSYS-97 (M. Ammann).

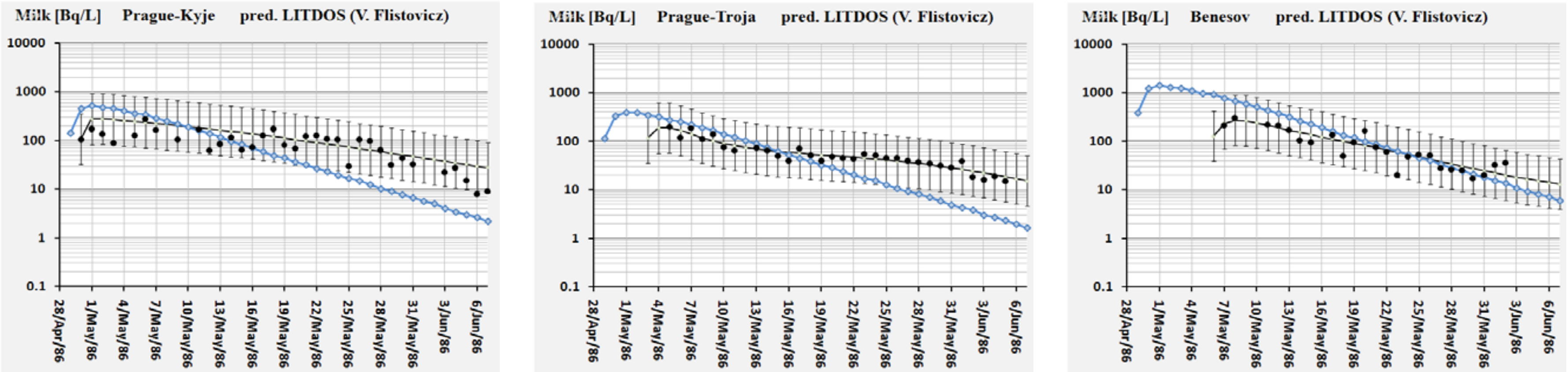


Fig. 4.55. Predictions for collective farm PRAGUE-KYJE, PRAGUE-TROJA, BENESOV by model LITDOS(V. Flistovich; T. Nedveckaite).

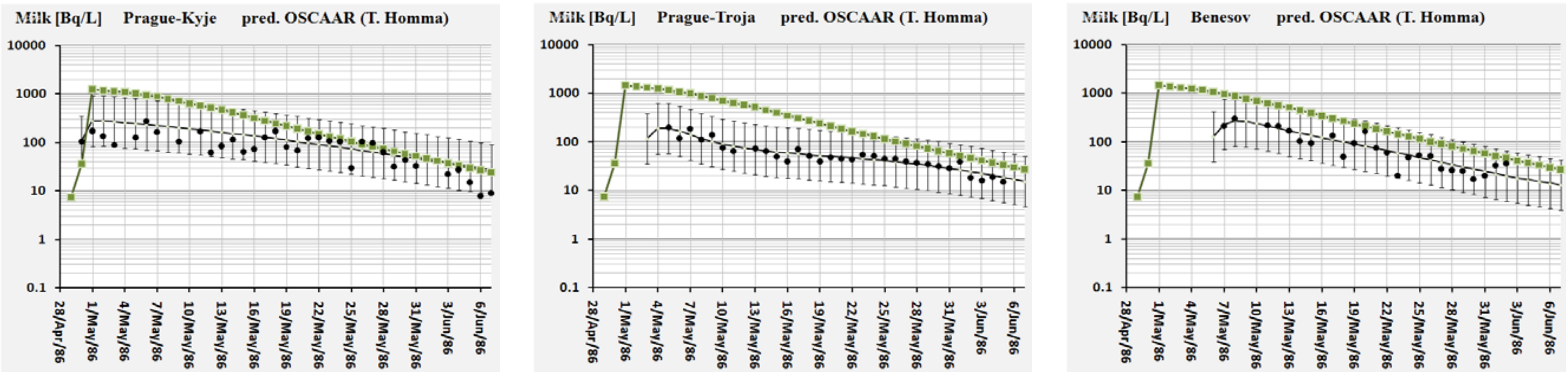


Fig. 4.56. Predictions for collective farm PRAGUE-KYJE, PRAGUE-TROJA, BENESOV by model OSCAAR(T. Homma).

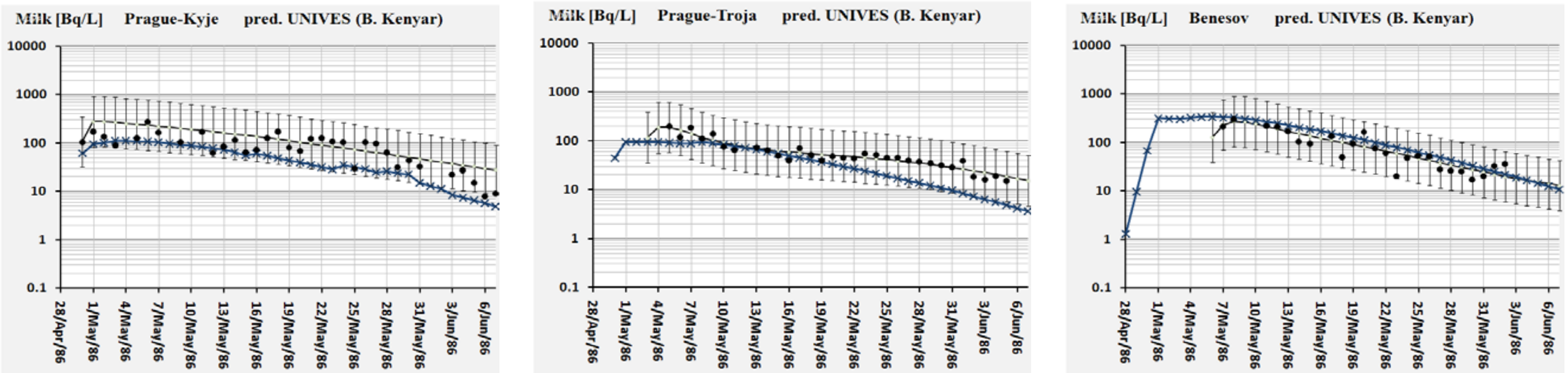


Fig. 4.57. Predictions for collective farm PRAGUE-KYJE, PRAGUE-TROJA, BENESOV by model UNIVES (B. Kenyar).

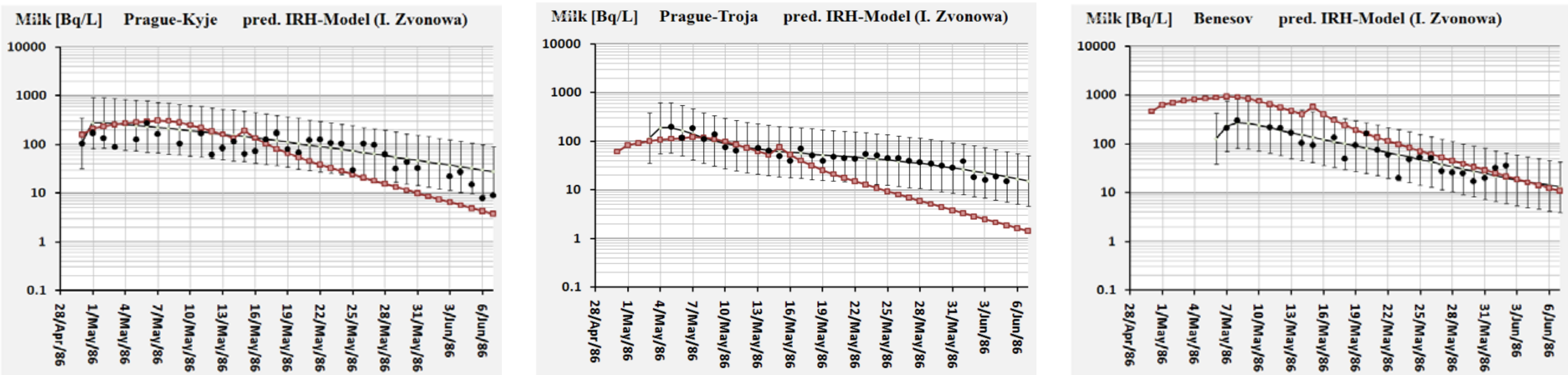


Fig. 4.58. Predictions for collective farm PRAGUE-KYJE, PRAGUE-TROJA, BENESOV by model IRH-Model (I. Zvonowa).

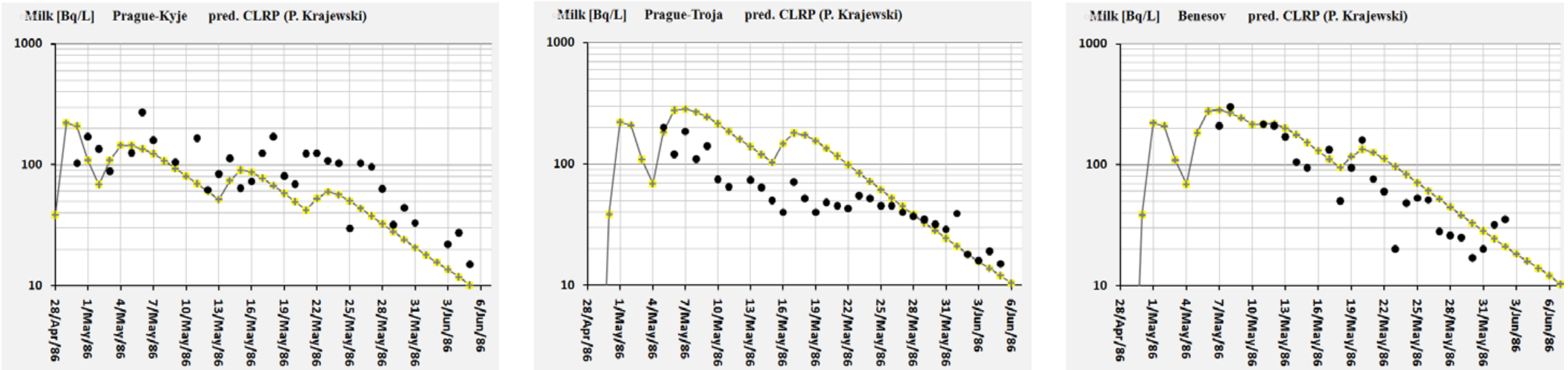


Fig. 4.59. Predictions for collective farm PRAGUE-KYJE, PRAGUE-TROJA, BENESOV by model CLRP (P. Krajewski).

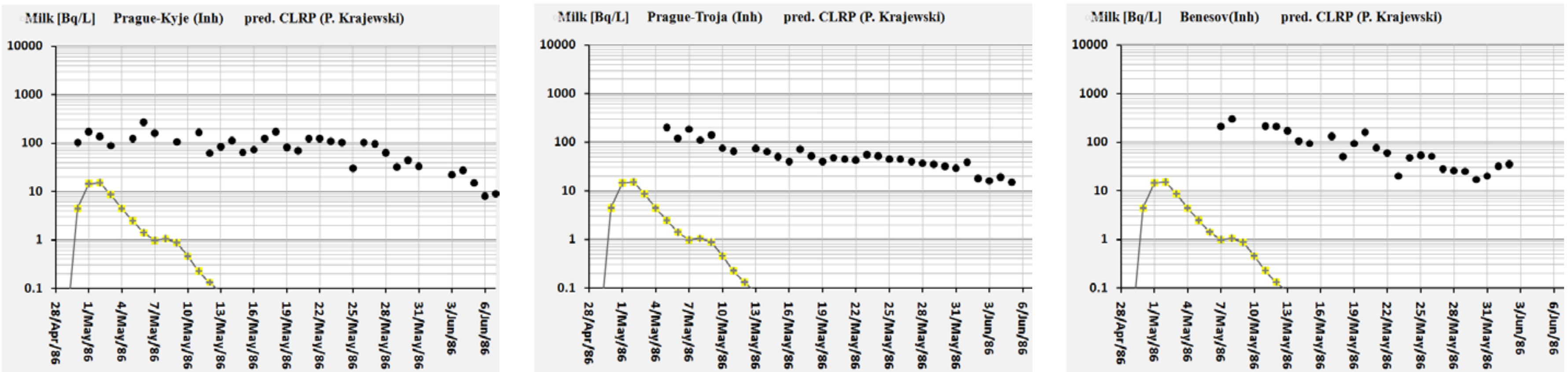


Fig. 4.60. Predictions of ^{131}I in milk for collective farm PRAGUE-KYJE, PRAGUE-TROJA, BENESOV due to inhalation of contaminated air (yellow lines) compared with measured values.

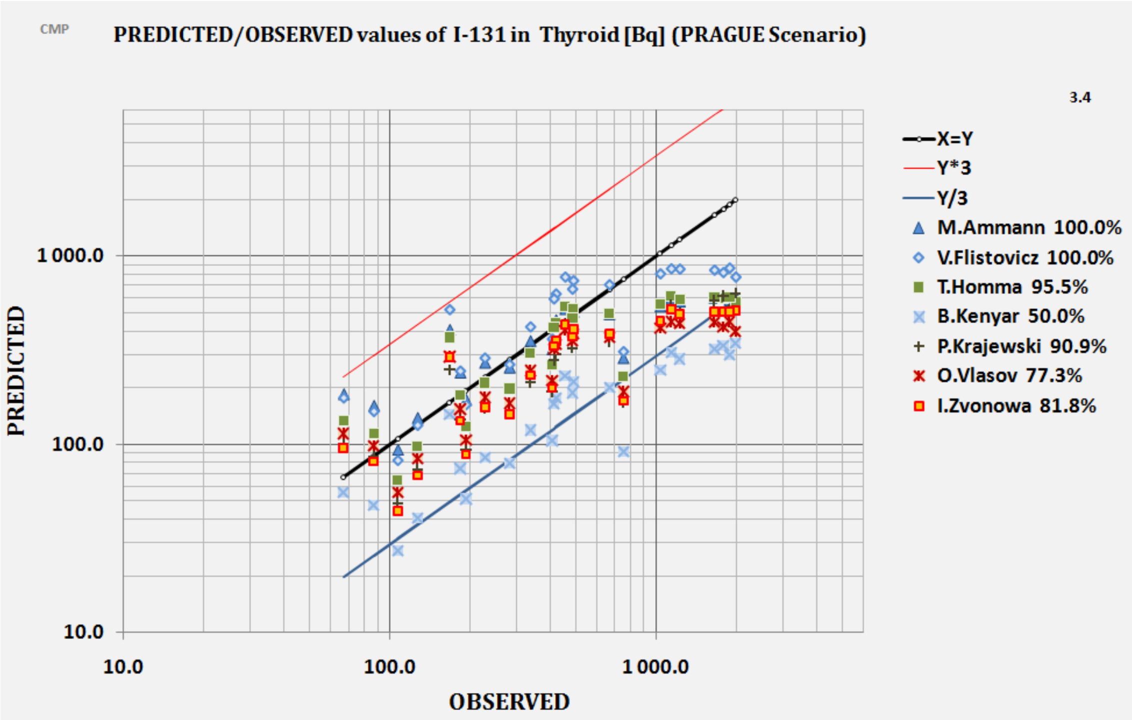


Fig. 4.61. Comparison of predicted versus observed ^{131}I content in thyroid for inhabitants of PRAGUE (Adults). Straight lines represent: predicted equal to observed values, order of magnitude bounds. Percentage values next to modeller's name are the percentage of predictions within the one order of magnitude measured value.

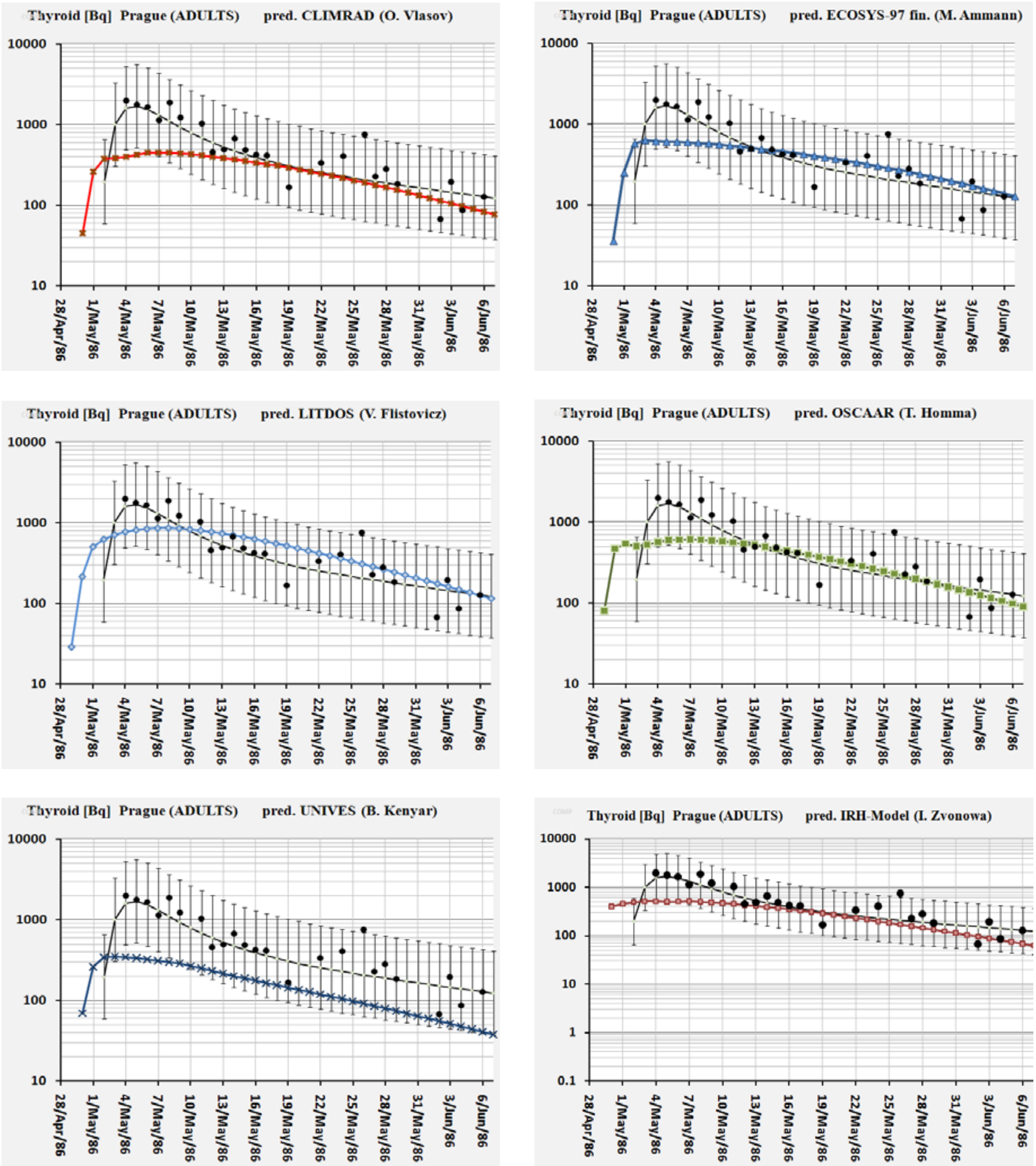
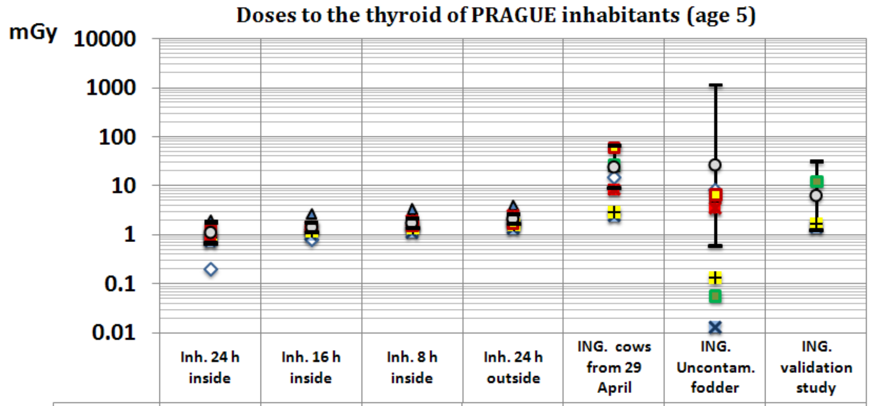
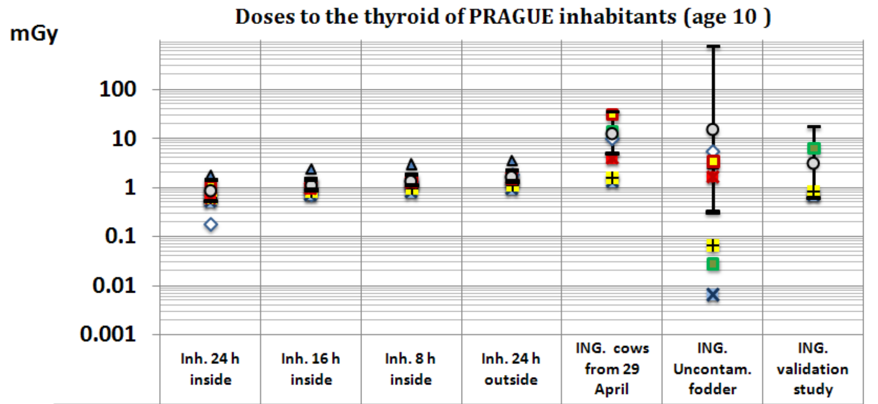


Fig. 4.62. Predictions of ^{131}I thyroid content for Prague inhabitants (Adults) performed by particular models versus observed data. Black dots denote measurements values, gray-thin-line shows polynomial fit to measurements by LSQ method.



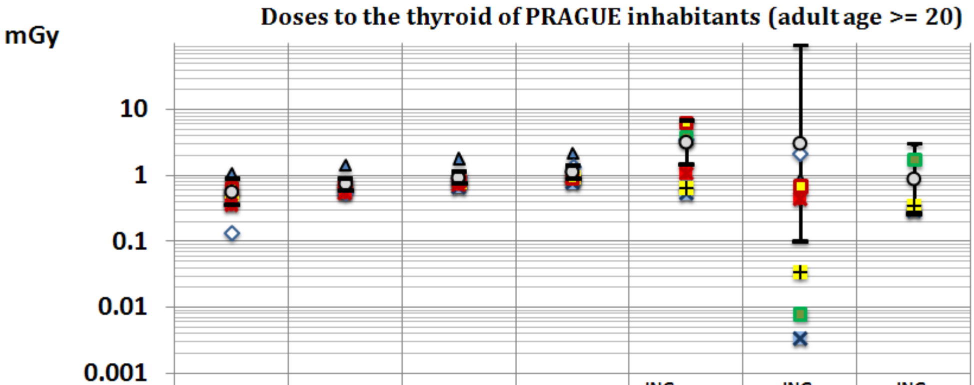
	Inh. 24 h inside	Inh. 16 h inside	Inh. 8 h inside	Inh. 24 h outside	ING. cows from 29 April	ING. Uncontam. fodder	ING. validation study
M.Ammann	1.98	2.64	3.31	3.97	24.67	5.96	
V.Flistovicz	0.20	0.78	1.37	1.96	14.66	8.05	
T.Homma	1.20	1.40	1.50	1.65	27.00	0.06	12.00
B.Kenyar	0.72	0.99	1.12	1.32	2.40	0.01	1.40
P.Krajewski	0.86	1.19	1.34	1.58	2.88	0.13	1.68
O.Vlasov	0.94	1.42	1.91	2.40	8.27	3.42	
I.Zvonowa	1.20	1.40	1.50	1.65	60.50	6.50	
Logn AVG	1.11	1.41	1.72	2.08	24.36	26.22	6.19
L95 AVG	0.66	1.11	1.37	1.64	8.89	0.59	1.22
U95 AVG	1.85	1.81	2.16	2.63	66.78	1170.92	31.45

Fig. 4.63. Thyroid dose assessments for inhabitants of Prague - critical group of children (5 years old) for two extreme cases – when no fresh fodder was consumed by cattle and when cattle were in pasture from the beginning of the accident.



	Inh. 24 h inside	Inh. 16 h inside	Inh. 8 h inside	Inh. 24 h outside	ING. cows from 29 April	ING. Uncontam. fodder	ING. validation study
M.Ammann	1.74	2.32	2.90	3.48	12.51	3.02	
V.Flistovicz	0.18	0.70	1.23	1.75	9.52	5.37	
T.Homma	1.00	1.20	1.30	1.45	14.00	0.03	6.20
B.Kenyar	0.51	0.69	0.78	0.92	1.30	0.01	0.68
P.Krajewski	0.61	0.83	0.94	1.10	1.56	0.07	0.82
O.Vlasov	0.60	0.92	1.23	1.55	3.87	1.61	
I.Zvonowa	1.00	1.20	1.30	1.45	30.67	3.29	
Logn AVG	0.86	1.13	1.39	1.68	12.79	15.28	3.20
L95 AVG	0.52	0.85	1.06	1.27	4.72	0.31	0.59
U95 AVG	1.44	1.49	1.81	2.21	34.64	762.28	17.54

Fig. 4.64. Thyroid dose assessments for inhabitants of Prague - critical group of children (10 years old) for two extreme cases – when no fresh fodder was consumed by cattle and when cattle were in pasture from the beginning of the accident



	Inh. 24 h inside	Inh. 16 h inside	Inh. 8 h inside	Inh. 24 h outside	ING. cows from 29 April	ING. Uncontam. fodder	ING. validation study
▲ M.Ammann	1.06	1.41	1.76	2.12	3.48	0.84	
◇ V.Flistovicz	0.13	0.53	0.93	1.33	3.49	2.11	
■ T.Homma	0.63	0.72	0.81	0.90	3.80	0.01	1.70
✕ B.Kenyar	0.44	0.58	0.66	0.77	0.53	0.00	0.29
+ P.Krajewski	0.53	0.70	0.79	0.92	0.64	0.03	0.35
■ O.Vlasov	0.36	0.55	0.74	0.93	1.09	0.45	
□ I.Zvonowa	0.63	0.72	0.81	0.90	6.27	0.67	
○ Logn AVG	0.57	0.75	0.93	1.13	3.15	3.09	0.89
– L95 AVG	0.37	0.60	0.76	0.90	1.47	0.10	0.27
– U95 AVG	0.90	0.92	1.14	1.41	6.75	94.67	2.98

Fig. 4.65. Thyroid dose assessments for inhabitants of Prague for two extreme cases – when no fresh fodder was consumed by cattle and when cattle were in pasture from the beginning of the accident.

CHAPTER 5. SUMMARY AND CONCLUSIONS

- Radioiodine releases are important for most radiation accidents (large and small). Because data on the results of these releases are often incomplete, models for estimating ^{131}I transport and exposure are essential in dose reconstruction efforts.
- The three scenarios, i.e., PLAVSK, MAZOVIA, PRAGUE described the Chernobyl contamination of ^{131}I and served as the basis for calculations of atmospheric transport, deposition, and doses to humans from internal exposure pathways.
- Most of the attention by IWG participants was focused to estimate ^{131}I deposition at several specified locations, then pasture and milk contamination. The primary exposure pathway in terms of contribution to human doses was ingestion of contaminated milk and inhalation of contaminated air.
- Particularly, owing to validation study programs, numerous reviewed and better quality data sets are prepared that now will be available for present and future generations of modellers.
- Some of these data may also be useful for derivation of parameter values for radioecological models., to test radioecological models, decision making systems, and national computer codes for assessment of the radiation exposure from environmental releases of ^{131}I.
- Participation in the IWG scenarios exercise gave modellers a unique experience in modelling various short term countermeasures. These countermeasures included: administration of stable iodine in form of solution (so called "Lugol liquid") to children and teenagers up to 16 years of age, putting grazing animals on stored feed, followed by the banning of potentially contaminated milk, milk products and leafy vegetables. Modellers learned that countermeasures (especially rapidly introduced) are complex and their effects are hard to predict. They are characterized by several important factors: social and economic situation, efficiency of emergency response system, public concern about radiation and transparency of public information.
- In addition, this kind of exercises may provide feedback to the site characterization. For instance, all modellers underestimated the ^{131}I concentration in milk for several location in the Plavsk district and this has led to the conclusion that the reported time of milk cow start grazing for that location was wrong.
- The inhomogeneous character of the radioactive contamination within the test areas and application of various countermeasures caused serious difficulties for modellers.
- The most difficult problems that arose during the course of the scenarios' calculations were as follows:
  - (a) Constant isotopic ratio ^{131}I/^{137}Cs provided fairly good approximation of ^{131}I deposition, however inhomogeneous ^{137}Cs deposition and relatively short time of rains during the cloud passage indicates that the radioactive fallout for areas specified in scenarios can be classified as mixed (dry and wet) and a regional approach might be applied with a more complex relationship of ^{131}I deposition to ^{137}Cs deposition.
  - (b) Resident time of ^{131}I on the pasture grass, described by so called weathering constant need to be replaced by more complex model that would include changeable weathering conditions.

(c) Model for grass interception fraction in a case of mixed (dry and wet) radioiodine fallout need to be carefully revised.
(d) Uncertainty associated with the prediction of ^{131}I concentration in air based on deposition data depends on partition of airborne radioiodine into different forms (particulate, elemental, organic) during the passage of radioactive cloud over the area of interest as well as meteorological conditions.
(e) The time when cows from collective farms were put on a pasture seems to be the most important factor of mispredictions of ^{131}I concentration in milk and consequently ingestion doses. It needs to be carefully considered.

— In general, although IWG was dealing with areas of assessment modelling for which the capabilities are not yet well established; there is remarkably improvement in models performance comparing with previous radioiodine scenarios [30–32]. Among the issues that arose during the exercises are several that may be appropriate subjects for future investigation:

— Predictions of the various models were in majority within a factor of ten of the observations; discrepancies between the estimates of average doses to thyroid produced by most participants not exceeded a factor of ten, reflecting differences in approaches or selection of parameter values for the deposition-to-dose calculations.

— Surprisingly, estimated doses did differ by two orders of magnitude when the professionals attempted to evaluate effectiveness of applied countermeasures using different methods and conceptual approaches, for instance: when modeller tried to evaluate effectiveness of fresh fodder ban in Prague scenario. .

— In general, the differences among the model predictions are rather due to differences in the interpretation of the scenario description than due to differences in modelling approach. While the predictions for the inhalation pathway are quite similar, greater variations between the ingestion pathway are observed. These differences are mainly caused by different interpretation of the current situation. For example, some modellers considered the different time of start milk cows grazing made different assumption about the surface contamination of the hay (produced with grass collected before radioactive cloud arrival).

— Some radioecological computer codes are not able to calculate radioiodine thyroid burden, and calculate ingestion doses based on predicted intakes. Such a nonflexible structure for the computer code excludes possibility to validate code's predictions based on monitoring data of radioiodine in thyroid and makes code useless in cases where assessment of effectiveness of stable iodine tablets administration is in the required emergency plan.

— IWG participants have been asked to perform uncertainty analysis of predictions by quantifying the uncertainty range of the best estimate values at the 95% confidence intervals. The approaches used varyied from the expert judgment to complex Monte Carlo simulations. According to their experience and familiarity with the code, and also their knowledge of the scenario, modellers defined different uncertainty ranges for the same endpoints. Some of them defined very narrow uncertainty ranges much lower than scatter of measurement data because of neglecting the contribution of essential factors as changeability of iodine metabolic parameters, deposition unhomogeneity or various behavior of public members. Others defined very broad uncertainty ranges (two orders of magnitude) expressed their personal judgment and lack of confidence on the input information.

CHAPTER 6. RECOMMENDATIONS AND SUGGESTIONS FOR FUTURE WORK

Several major points and recommendations can be made from the experience from three scenarios exercise:

- Recommended codes for radioecological assessment of radioiodine impact should be flexible enough, providing users the capability to start calculations from the most appropriate starting point determined by scenario. The possibility to calculate thyroid burden and thyroid blocking should be included.
- The emergency response system could only apply the decision support model of greater complexity when sufficient input information is provided. Use of complicated models without confident and adequate input information might lead to unreliable radioecological assessment.
- In the case of a radiological situation that differs from the scenarios used for model development, the intercomparison studies are essential. Model predictions should always be compared with real data or if not available, with the results of other modellers. Comparison of results among several assessors provides an opportunity to explain discrepancies, reduce mistakes that could occur due to the inexperience of the user with the code, errors in the code, and errors in unit conversion. It also enables clarification of interpretation of the radiological situation.
- Inclusion of uncertainty estimates for model predictions is essential for describing the level of confidence that should be placed in a prediction. Uncertainties about the model inputs or parameter values should reflect incompleteness, or uncertainties of the input data. In general, use of standard procedures for uncertainty assessment (if possible) would be very helpful in the comparison of modellers’ predictions and test data.
- In emergency circumstances, it may be foreseen that in reality, the rapid introduction of countermeasures (distribution of stable iodine, transfer of animals to stored feed, restrictions of consumption contaminated food) cannot be arranged or planned and also there are no means to make items compulsory but only to raise the level of public recognition. Therefore, the requirements of emergency response preparedness prompt validated methodology for realistic dose assessment, and dose uncertainty, moreover the justification of different variants of protective action. It requires firm analysis to ensure safety threshold. Therefore, it is strongly recommended to involve several groups of independent experts in the doses assessments process.
- Exceptionally, when only limited amount of relevant input data is available, a conservative approach can be considered as reasonable for situations.

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APPENDIX I. “SCENARIO P” – PLAVSK SCENARIO DESCRIPTION VALIDATION OF ENVIRONMENTAL MODELS USING DATA FROM CHERNOBYL FALLOUT IN THE PLAVSK AGRICULTURAL AREA

I.1. Background

The Plavsk district, in the Tula region of Russia, was chosen as the scenario area. The Plavsk district is located about 200 km south of Moscow. The population under consideration consists of about 30 000 people, working mainly in agricultural production. The area was significantly contaminated with radionuclides on 29–30 April 1986 from the same Chernobyl cloud which contaminated the Bryansk region one day before. The district belongs to the Tula-Kaluga-Orel radioactive “spot” created due to the Chernobyl accident at the Russian territory. Dynamics of the cloud movement, meteorological conditions of the fallout, isotopic composition, and soil contamination levels with deposited radionuclides are reviewed in this scenario description. The maximum ^{137}Cs soil contamination density of 0.5 MBq km^2 is located directly in the town of Plavsk, at the center of the Plavsk district. The Plavsk area did not receive primary attention in Russia with regard to population radiation protection, compared with the Bryansk region, because the contamination level was lower (maximum in Novozybkov district of the Bryansk region is above 2 MBq km^2) and the dominating soil (chernozem) fixed cesium radionuclides, which diminished internal exposure from 1987 on and no protective measures were applied in this area in the early period after the accident. About ninety thyroid cancers in former children and teenagers (at the time of the accident) were registered in 1991–2000 in the Tula region.

Measurements of local people on ^{131}I content in thyroid glands and spectrometric measurements of ^{131}I concentration in local milk began on 14 May 1986. Data of these measurements together with some meteorological data and results of inhabitant’s interviews about their life style and food habits are available for the scenario aimed at testing of models for thyroid dose estimations in population affected by radioiodine fallout.

I.2. Introduction

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 of different age groups in specified locations.

The exercise consists of two tasks:

- 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
- 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.

I.3. Assessment tasks

I.3.1. General

The following subsections contain descriptions of the calculation endpoints required in this test scenario. The first group consists of quantities for which measurements exist and against model predictions can be tested, the second group consists of quantities (e.g. radiation doses) which can only be predicted but not tested. For each quantity, a 95% confidence interval (2.5% and 97.5% lower and upper bound estimates, respectively) should be given to quantify the expected uncertainty of the results. It is anticipated that these values will be subjective confidence intervals, given the nature of the data provided for this scenario. For the quantities requested in Section I.3.2, modellers are required to estimate the arithmetic mean for the time period specified and for the specified location. Annex I includes the template tables for predictions, additionally the template Excel tables are provided. Participants are kindly asked to fill up Excel file templates tables rather than Word format templates tables but both forms are acceptable.

I.3.2. Calculations for model testing

The following ends points have been specified:

I.3.2.1. Deposition of ^{131}I

Estimate the average ^{131}I deposition calculated on the date 10 May 1986 for the settlements specified below.

I.3.2.2. ^{131}I concentration in milk

Estimate an arithmetic mean[8] of ^{131}I concentration in milk (Bq L^{-1}) for the period 27 April–30 May 1986 for 18 collective farms and the ^{131}I concentrations of composite milk samples taken daily from the Plavsk Town dairy. Estimate the integrated ^{131}I concentration in milk (Bq d L^{-1}) for the period 27 April–30 May 1986 in locations specified below. Determine the ratio of ^{131}I milk concentration on 30 May (Bq L^{-1}) to the ^{137}Cs deposition (kBq m^{-2}) in the specified locations. See template tables in Section I-1.2 in Annex I.

Table I.1. Names of 18 collective farms and Plavsk town (see Figure I.3).

Number	**Name**
1	Krasnogor'e
2	Za Mir
3	Im. Safonova
4	Plavskij
5	Vpered k kommunizmu
6	Im. Luk'janova
7	Gorbachevskij
8	Tul'skaja niva (NIISH)
9	Im. K. Marksa
10	Rossia
11	Kollektivist
12	Kommunar
13	Druzhba
14	im.XXII parts'ezda
15	Udarnik
16	Ol'hi
17	Skorodnoe
18	Novo-Nikol'skij
	Plavsk town

[8] Daily values.

Table I.2. Test age groups of rural and urban populations.

Settlement	Location/collective farm	Age in 1986
Plavsk	Town of Plavsk	New born 0 1–2 3–7 8–12 Adults
Jusupovo	Za Mir	1–3
Rakhmanovo	Im. Safonova	1–3 Adults
Jur'evo	Plavskij	0–2
Krekshino	Vpered k kommunizmu	0–3 Adults
Oktjabrskai	Vpered k kommunizmu	0–2 8–10 2
Nikolskoe	Im. Luk'janova	0–3
Molochnye Dvory	Tul'skaja niva	6–11 Adults
Bolshie Ozerki	Rossija	1–3
Urusovo	Druzhba	1–3
Sorochinka	Im.XXII parts'ezda	9–12
Diktatura	Udarnik	0–3
Ol'hi	Ol'hi	0–3 Adults
Gremjachevo	Skorodnoe	0–3 Adults
Skorodnoe	Skorodnoe	0–3 Adults
Novo-Nikol'skoe	Novo-Nikol'skij	2–3 Adults

Table I.3. Dose coefficients for thyroid from inhalation and ingestion.

Pathway	Child 1 y	Child 5 y	Child 10 y	Child 15 y	Man
Inhalation (Sv/Bq) [I.1]	2.5×10^{-6}	1.5×10^{-6}	$7.4E\times10^{-7}$	4.8×10^{-7}	3.1×10^{-7}
Ingestion (Sv/Bq) [I.2]	3.6×10^{-6}	2.1×10^{-6}	1.0×10^{-6}	6.8×10^{-7}	4.3×10^{-7}

I.3.2.3. ^{131}I thyroid burden

Estimate the arithmetic mean of ^{131}I thyroid content (Bq) for test age groups of rural population of urban population (Plavsk town) living in collective farms/locations specified in Table I.2 of rural and urban populations.

I.3.3. Calculations for model comparison

I.3.3.1. Reconstruction the mean ^{131}I concentration in air (Bq m^{-3})

Estimate the mean ^{131}I concentration in ground level air from 27 April to 15 May 1986 and partitioning of radioiodine in to particulate, reactive gaseous and organic phases (see template tables in Section I-2.1 in Annex I).

I.3.3.2. ^{131}I concentration in animal feeds

Estimate the mean ^{131}I concentration in pasture vegetation for the period 27 April–30 May 1986 in 18 specified location. Estimate the integrated ^{131}I concentration in grass (Bq d kg^{-1} fresh weight) for the period 27 April–30 May 1986 (see template tables in Section I-2.2 in Annex I).

I.3.3.3. Human ^{131}I intake

Estimate the mean ^{131}I intake per day (Bq d^{-1}) in for rural and urban (Plavsk town) population for the age groups of rural population and urban population (Plavsk town) living in collective farms/locations farms as specified (see template tables in Section I-2.3 in Annex I) This task is focused for model comparison to identify discrepancies in model predictions for ^{131}I thyroid burden (when different iodine thyroid retention functions would be applied[9] as well as predictions of ingestion doses.

I.3.4. Predictions of doses

I.3.4.1. Ingestion dose

Estimate the mean dose to thyroid from ingestions (committed equivalent dose to thyroid) (mSv) for the rural population living in settlements, presented in Table I.6 and for urban population (Plavsk town) for six different age groups,, i.e., “new born”, age 1–2 in 1986, age 3–7 in 1986, age 8–12 in 1986, and adult (age 20 in 1986) (see template tables in Annex I).

I.3.4.2. Inhalation dose

Estimate the mean dose to thyroid from inhalation (committed equivalent dose to thyroid) (mSv). For models with the flexibility to modify dose coefficients, the use of the coefficients for the dose predictions of six different age groups shown in Table I.3 is recommended.

I.4. Input information

I.4.1. General information

I.4.1.1. Geographical position and administrative division

The Tula region is situated to the north of the Mid-Russian eminence (height, up to 293 m above sea level); its area is 25 700 km^2 [I.3]. The region borders with Moscow, Ryazan, Lipetsk, Orel and Kaluga regions (see Figure I.1). The regional center, Tula city, is 190 km south of Moscow. The Chernobyl Nuclear Power Plant is 665 km away from the regional center, the city of Tula, and 540 km from the nearest border of the region. There are 23 administrative districts in the territory of the region. A map of the administrative divisions of the region showing the location of the Plavsk district is provided in Figure I.2. The Plavsk district is situated in the southern part of the Tula region; its area is 1020 km^2 [I.3]. The administrative center of the district, the town of Plavsk, is situated 60 km south of the regional center, the city of Tula. There are no other cities or towns in the territory of the district. The lands in the Plavsk district in 1986 were distributed among 18 collective farms, which were the main state suppliers of agricultural products. The borders of the collective farms in the Plavsk region in 1986 are shown in Figure I.3.

[9] For modellers who are able only estimate intake (for instance using RODOS FCM), the EXCEL worksheet which can calculate thyroid burden from intakes based on Jonson Model or ICRP model would be provided).

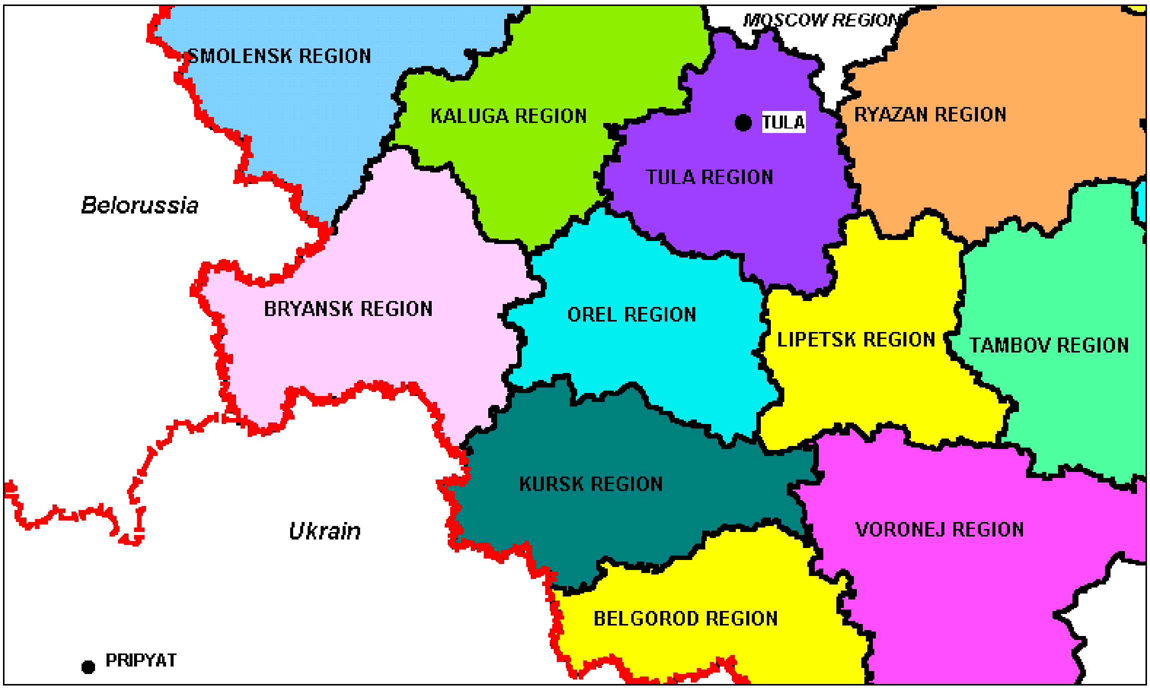


Fig. I.1. Location of the Tula region on the map of the European part of Russia.

1	ChERNSKIJ
2	KAMENSKIJ
3	BELEVSKIJ
4	SUVOROVSKIJ
5	ALEKSINSKIJ
6	ZAOKSKIJ
7	JaSNOGORSKIJ
8	VENEVSKIJ
9	LENINSKIJ
10	KIREEVSKIJ
11	DUBENSKIJ
12	SchEKINSKIJ
13	NOVOMOSKOVSKIJ
14	UZLOVSKIJ
15	ODOEVSKIJ
16	PLAVSKIJ
17	ARSEN'EVSKIJ
18	JeFREMOVSKIJ
19	TEPLO OGAREVSKIJ
20	VOLOVSKIJ
21	BOGORODICKIJ
22	KIMOVSKIJ
23	KURKINSKIJ

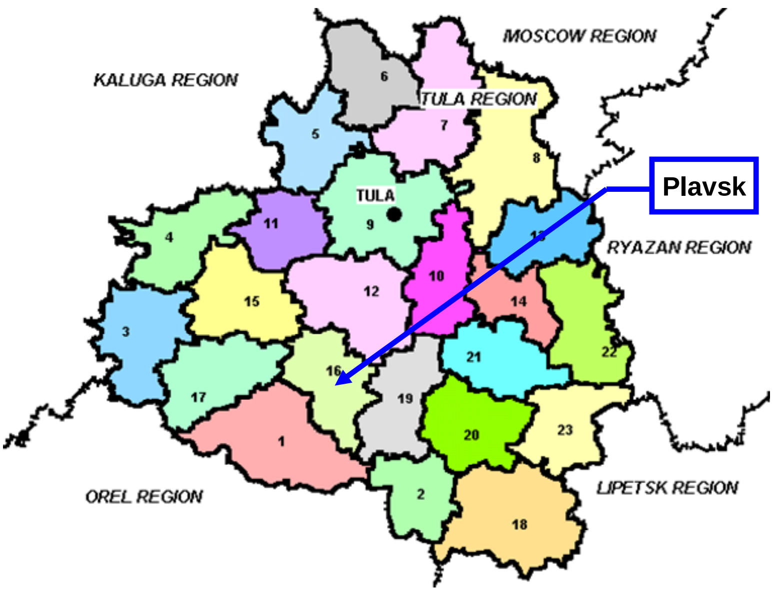


Fig. I.2. Map of the administrative districts of the Tula region. District number 16 is the area of interest, the Plavsk district.

1	KRASNOGOR'E
2	ZA MIR
3	IM. SAFONOVA
4	PLAVSKIJ
5	VPERED K KOMMUNIZMU
6	IM. LUK'JANOVA
7	GORBACHEVSKIJ
8	TUL'SKAJA NIVA
9	IM. K. MARKSA
10	ROSSIJA
11	KOLLEKTIVIST
12	KOMMUNAR
13	DRUZHBA
14	IM.XXII PARTS'EZDA
15	UDARNIK
16	OL'HI
17	SKORODNOE
18	NOVO NIKOL'SKIJ

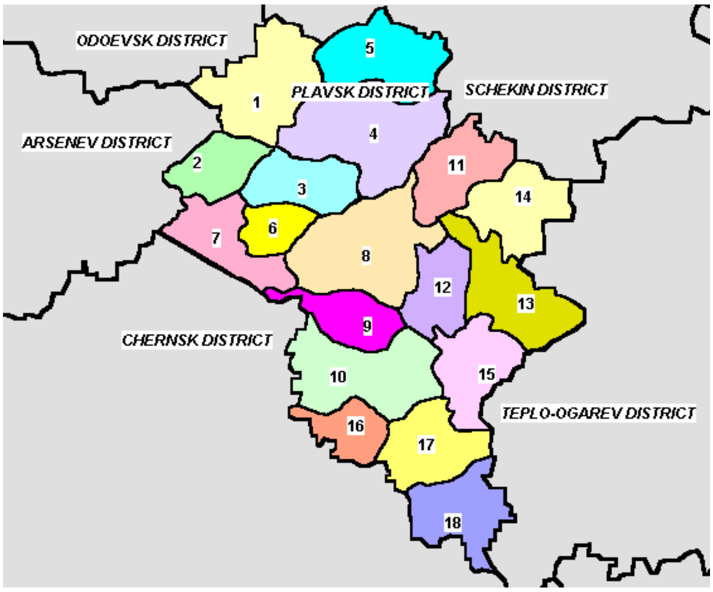


Fig. I.3. Map of the collective farms in the Plavsk district.

I.4.1.2. Climatic conditions

The climate in the Tula region is moderately continental, with a moderately cold winter and warm summer. The climate formation is considerably influenced by the atmospheric circulation. The major influence of the sea air masses is observed in winter and autumn. During the warm period of the year there are mostly west, northwest, north and south-easterly winds; in the colder period there are south-western and south winds.

The average annual temperatures vary between +3.5 and +4.8°C. The average temperature in June is +19°C, in January, –10°C. The highest temperature in July was +38°C in the Efremovsky district. From November until March the average monthly temperature is below zero. The period with temperatures above zero lasts for 220–225 days, and the period when the temperature is more than +10°C, when the agricultural plants grow, lasts for about 135–140 days. The vegetation period of trees and grasses lasts for 170–180 days, from mid-April until the middle of October [I.4].

Within the region there falls, on average, quite a lot of precipitation yearly: 550 mm in the northwest and 500 mm in the east, a bit less to the southeast. The greatest quantity of precipitation falls during the summer months (June and July), the lowest quantity, in winter, such that the summer precipitation quantity exceeds the winter amount by almost twice. In autumn there is more precipitation than in winter.

The average depth of the snow coverage in winter is between 30 and 40 cm; depending on the weather conditions, it varies from 10–90 cm.

As for the climate, the region can be divided into two parts: the north-western one, which is a little damper, has a milder winter and cooler summer, and the south-eastern one, which is less damp and has a hotter summer and a cold winter. Plavsk district is situated in the south part of the Tula region.

I.4.1.3. Hydrologic characteristics

Water resources in the Plavsk district are defined by the rivers Plava, Lokna, and Plavitsa, and by other small rivers and streams; there are also several lakes and ponds. The length of the river Plava is 89 km from the source to its release into the river Upa, which is the main river of the region. The Plava River is the longest tributary of the Upa River. The Upa has a length of 345 km; the catchment area is 9500 km^2. The bed of the river is moderately winding, starting from the middle flow; it is 20–75 m wide, and 1.2–3.5 m deep. The flow speed is 0.1–0.5 km s^{-1}, and the flood valley is 0.5–1.5 km wide [I.4].

More than 1600 rivers and streams flow on the territory of the Tula region; their cumulative length is about 11 000 km. Of the river network, 79.8% belongs to the Volga basin and 29.2% to the Don basin [I.4].

All the rivers of the region drain unevenly during the course of a year: 74% of the yearly draining falls in the springtime. The icy regime lasts for 3.5–4.5 months. The ice breaks usually by the end of March or the beginning of April. The water rise during the spring flood varies between 2–3 m and 4–10 m, depending on the weather conditions and the thickness of the snow cover. River valleys usually get covered with water. The rivers' feed is mostly from the melting snow, with great floods in springtime and low water levels in summer [I.4].

Local ecologists note the bad quality of water in small rivers, which is the result of irresponsible economic activity [I.5–I.8]. According to Berdantceva et al. [I.6], the absence or bad functioning of depuration (purification) establishments, the river bed is full of garbage, black mud on the bottom, and rotten smell of water were noted in living settlements.

The surface waters are usually not used as sources of drinking water supply for people, although the Plava river is considered to be one of the cleanest rivers of the Tula region. Ground water is used as drinking water.

I.4.1.4. Ground water

In the subsoil of the district there are about 28 watery levels: the upper water level, 7 levels in quaternary rocks, 2 in neogene rocks, 3 in mesozoic rocks, 9 in paleozoic rocks, and 6 in devonic rocks [I.5]. The 20 upper levels form the complex of the surface watery horizons. Waters from the devonic rocks are used most widely for centralized potable water supply for agricultural, industrial and home use. Some single outputs of waters in the areas of the superficial deposit are used by people for home-use water supply. Water extracting units here are improved springs and wells with a depth of 1–10 m.

I.4.1.5. Mineral composition

The mineral composition of surface watery horizons is very variable. The mineralization of waters changes in the range from 0.1 to 1.8 g L^{-1} (the prevalent values are from 0.2 to 0.4 g L^{-1}). The value of general hardness varies from 1.4 to 27.1 mg-eq L^{-1}. The water types are mostly hydrocarbonic calcium and sulphur-hydrocarbonic calcium ones. The nitrate content usually lies between 2 and 6 mg L^{-1}; it rarely reaches 19-24 mg L^{-1}. The ammonia content was found as ions from traces to 28 mg L^{-1}. The summary iron increase is observed, up to 31–56 mg L^{-1} (where the prevalent values are 0.7–3.0 mg L^{-1}). The value of oxidized iron (ferrous oxide, FeO) does usually not exceed 1 mg L^{-1}, reaching in some single cases 12.5–31.0 mg L^{-1} [I.5, I.6].

The Plavsk watery horizon contains fresh waters with the prevalent mineralization of 0.3–0.5 L^{-1}. As with the mineral content, waters here are mostly hydrocarbonic with magnesium and calcium. In some small areas their anion content changes into hydrocarbonic with sulphates and sulphurous. In this territory there are well developed, low-mineralized, very hard (over 20 mg-eq. L^{-1}) waters with a high content (0.7–1.6 g L^{-1}) of sulphates. The typical characteristic of waters from the Plavsk horizon is the higher content of strontium sulphates, over 4–8 mg L^{-1} [I.5]. The Plavsk horizon is one of the main sources of people's water supply.

I.4.1.6. Soils

The soils in the Plavsk region are mostly leached (alkaline) and poor black soils; alluvial soils are also frequent. Insignificant areas in the flood plains of rivers have light-gray forest soils [I.4]. Humus content is from 4 to 16%. The surface of the observed territory represents a sloping, wavy erosive plain.

In 1986, the Plavsk district had an area of 102 500 hectares. 81% was fertile black soil, 5% dark-grey forest soil, and 2.7% grey forest soils. Some 85 700 hectares were used by 17 collective farms of the district. 92.7% of the area is used for agriculture. The rest of it consisted of forests, marshes and water basins. Among the agricultural land, 84.6% are ploughed fields, and about 15% are occupied by grass fields and meadows. Of the soils, 97% had neutral or close to neutral reaction. Only 3% of soils had a slightly acid reaction.

I.4.1.7. Forests

The Tula region occupies the northern part of the steppe-forest zone. About 11% of the region's territory is covered with woods. The greatest number of woods is in the northern and northwestern parts of the region, where forests cover more thn 25%.

The main part of the forest contains mixed forests, where birch, aspen and oak prevail. Coniferous forests are present only in the Oka River valley. These forests are predominantly composed of pine trees. Mushrooms as *Boletus edulis*, *Leccinium* types, *Lactarius* types, *Russula* types and *Tricholoma* types, which are consumed by the local population, grow in the conditions of the investigated zone.

Forest areas in the Tula region alternate with steppe areas, which are now changed considerably from human activities, and much of the natural vegetation has not been conserved. Nowadays almost all these spaces are cultivated. There are common protective wooded lines between agricultural territories. Woods occupy an insignificant part of the territory of the study area.

I.4.1.8. Industry and agriculture

The Plavsk district is mostly agricultural. Mineral resources here are clays and building carbonic rocks. The industry consists of 9 enterprises, of which the biggest ones are the mechanics factory "Smytchka", distillery, auto repairing and ventilator. In the town of Plavsk there is also a milk factory.

The agriculture is specialized in meat and dairy production, cereals, maize, potatoes, and sugar beets. This specialization determines the structure of crop areas, where the fodder crops predominate: root-crops and perennial and annual herbs. The vegetation is characterised by high productivity. In the agricultural production the grounds are used as pastures for cattle.

The harvest of basic agricultural products in 1986 included the following (1 quintal = 100 kg):

- spring rye, 21 quintal/hectare;
- barley, 20 quintal/hectare;
- grains, 18-20 quintal/hectare on average;
- sugar beets, 40 quintal/hectare;
- potatoes, 64 quintal/hectare;
- fodder tubers, 73 quintal/hectare; and
- hay (natural grass meadows), 8.4 quintal/hectare.

I.4.2. Environmental measurements after Chernobyl accident

I.4.2.1. Meteorological data for the first days after the accident

The meteorological data for weather conditions from 27 April to 15 May 1986 were obtained from 8 meteorological and one agro-meteorological station. The location of the weather observation points is shown in Figure I.4.

Data for the direction and speed of the wind from 27 April to 15 May 1986 are reported in Table I.4, according to the results of measurements at 6 meteorological stations. The data were taken 8 times a day at 3-h intervals. Data were registered at the moment of control, meaning that the instrument's indications were written down at the moment of observation: at 00:00, 03:00, 06:00, 09:00, 12:00, 15:00, 18:00, and 21:00. Table I.4 presents the prevalent wind directions for the first and second halves of a day, and also the range of registered values of the wind speed in the same time intervals.

The study period was characterized by a great variety of wind directions. In the first days after the accident, there were mostly southwestern winds in the Tula region. On 29 April 1986 and half of 30 April, southeastern and eastern wind directions were registered. Then the wind changed to the north-northeastern direction, which remained until 7 May 1986. On 7–8 May 1986, the wind direction was mostly northwestern, then northern again, and then northeastern. Only on 12–13 May was there registered a wind from the southwestern direction, from the area of the accident. So it can be seen, that the first transport of radioactively contaminated air masses from the place of the accident was possible on 29–30 April 1986. The second possibility for that was on 12–13 May, but by that time the releases from the reactor were already over.

In the research works analysing the transport of air masses during the Chernobyl accident, it was concluded that radionuclides that were released from the reactor on 27 April 1986 were first carried to the north and northeast, and then they turned to the east, northeast and southeast, where they fell out with precipitation, forming the Bryansk-Byelorussia-Kaluga-Tula spot [I.9–I.11]. In the official methodical indications for calculating the effective doses and thyroid radiation doses for the Russian population, it was accepted, based on the available information, that the contamination of the Plavsk district started 3.5 ± 0.2 days after the accident, and it reached the maximal level 4.3 ± 0.2 days later [I.12]. Thus the radioactive cloud passed through the Tula region from the second half of the day on 29 April, until 07:00–10:00 on 30 April 1986. Additional evidence for these dates is given by measurements of the gamma dose rate in air; its sudden increase over the background values was recorded on 29 April 1986 in the town of Plavsk.

Number	Meteostations
1	TULA
2	UZLOVAYA
3	SUVOROV
4	BELEV
5	CHERN
6	PLAVSK
7	VOLOVO
8	JEFREMOV
9	ALEKSIN (AGRO METEO POST)

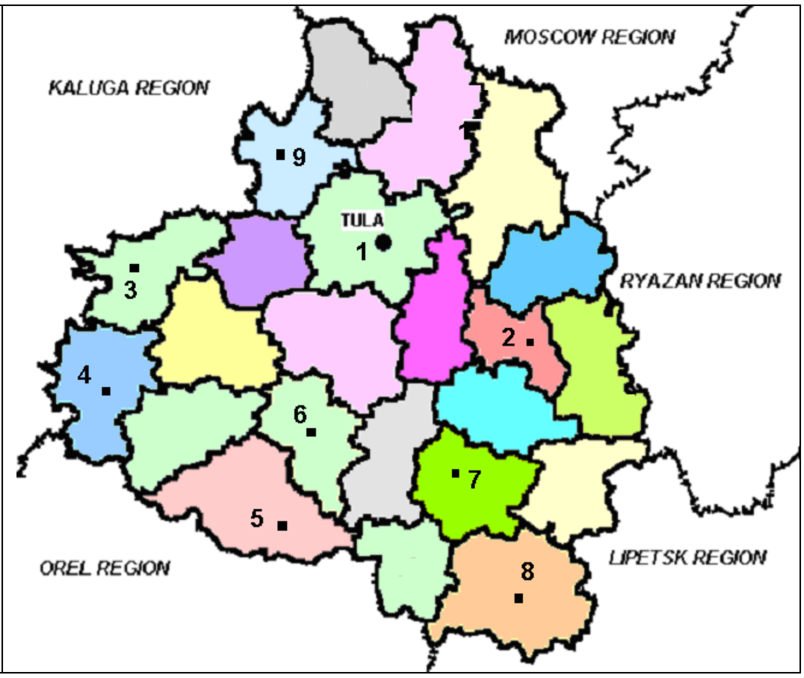


Fig. I.4. Locations of the weather observation points in the Tula region.

Table I.5 shows data for precipitation, which was recorded 4 times a day: at 06:00, 09:00, 18:00 and 21:00. The precipitation was collected within the following time intervals: 21:00 of the previous day until 06:00, 06:00–09:00, 09:00—18:00 and 18:00–21:00. It can be seen that on 29 April, during the transit of the radioactive cloud, there were rains of different intensity in most of the Tula region. It is known that the $^{131}I/^{137}Cs$ ratio in depositions depend on type of fallout – wet or dry. The spots of high contamination with ^{137}Cs were found after wet deposition. But ratio $^{131}I/^{137}Cs$ inversely depend on rains precipitations [I.13, I.14]. Rains were in all districts that were later nominated as contaminated areas on 29 April 1986. One can assume that wet fallout took place in all Plavsk district.

The average daily temperatures of the air are provided for 9 observation points from 27 April to 15 May 1986 (Table I.6). During the first days after the accident, the weather was warm, with an average daily temperature of 10–17°C. On 1–6 May 1986 the temperature suddenly decreased down to an average daily temperature of 2–3°C, with hoarfrosts at night times. On 7–10 May the average air temperature was above 10°C. On 11–12 May 1986, the temperature decreased again to 8-9°C, and after that warm weather with a temperature of about 15°C settled on the territory.

Data for the minimal and maximal soil temperatures from 20 April to 15 May 1986 (Table I.7) also confirm the presence of two periods of temperature decrease with night hoarfrosts on soil, during the periods 1–7 May and 11–12 May 1986, which influenced the developmental process of the vegetation. Data on the relative humidity in the air of the town of Plavsk from 26 April to 15 May 1986 are presented in Table I.8.

Table I.4. Wind direction and speed (m s^{-1}) in the Tula region from 27 April to 15 May 1986.

Date	Tula		Volovo		Yefremov		Uzlovaya		Suvorov		Plavsk	
	Direction[a]	**Speed**[b]	**Direction**	**Speed**	**Direction**	**Speed**	**Direction**	**Speed**	**Direction**	**Speed**	**Direction**	**Speed**
27 Apr.	ENE/SE	3-7/9-10	SE/SE	2-7/3-8	SE/SE	1-6/2-6	E/SSE	3-4/1-10	E/E	1-2/1-7	SE/SSE	2-3/7-8
28 Apr.	ESE/SSE	3-6/3-10	SE/S	2/6/03	SE/SSW	1-3/1-4	SE/SE	3-6/1-5	NE/N	1-2/1-5	ESE/SE	2-4/1-8
29 Apr.	SW/WSW	2-6/2-6	SSW/WNW	2-3/2-3	SSW/W	2/4/01	S/SW	0-2/1-3	S/W	1-2/1-2	SSW/W	2-3/1-3
30 Apr.	WSW/NNE	2-3/3-6	NW/N	2-3/3-6	NNW/NNE	1-3/3-4	W/N	0-2/2-3	WSW/N	1-2/2-3	W/NNE	2/3/05
1 May	NNE/SE	3-5/4-6	NE/SE	2-4/2-4	NE/E`	2-4/2-3	NE/ESE	2-4/2-4	ENE/SE	2-4/1-2	NE/SE	2-4/1-2
2 May	NE/NNE	2-3/5-6	E/NE	2-4/4-5	ENE/NNE	1-2/2-4	SSE/NE	0-2/3-6	NE/N	1-3/3-5	E/NE	2-5/5-7
3 May	N/NNE	6-10/9-10	NNE/NNE	4-6/8-10	N/NE	5-6/8-9	N/NNE	7/11/11	N/N	4-5/5-7	NNE/NNE	6-10/9-10
4 May	NNE/NNE	7-9/5-10	NNE/NE	8-14/5-11	NNE/NE	7-9/7-10	NNE/NNE	11/8/10	N/N	4-7/4-5	NNE/NNE	7-14/6-10
5 May	NNE/NNE	5-7/6-12	NNE/NNE	4-8/3-8	NNE/NNE	4-6/2-8	NNE/N	3-10/4-13	N/N	3-7/2-5	N/NNE	4-9/2-8
6 May	N/NNE	4-6/4-8	NNE/NE	2-6/3-7	N/NE	2-7/3-7	NNE/NNE	3/2/06	N/N	2-4/2-5	NNE/NE	3-4/3-7
7 May	NNW/SSW	2-4/3-5	NNW/NNE	2-4/2-4	NNW/NNW	1-3/2-4	NNW/W	1-3/1-4	W/W	1-3/1-4	NNW/SW	23/-3
8 May	WSW/NNW	4-5/2-8	WNW/NW	2-4/3-6	WNW/NW	3/2/05	W/NW	1-5/1-6	W/NNW	2-3/1-5	W/NW	2-3/2-6
9 May	NE/NNE	2-4/2-4	NE/ENE	2-3/2-4	NE/E	2-3/2-3	NE/NE	2-3/0-2	ENE/ESE	1/2/02	E/E	2-4/34
10 May	NE/NNE	2-4/2-4	S/NE	1-3/3-4	E/NE	0-1/2-4	NE/NE	0-2/3-4	E/NE	0-1/2	NE/NE	1/2/03
11 May	NE/SE	2/4/03	ENE/ENE	2-4/0-2	ENE/ENE	2-3/1-3	ENE/E	2-3/1-2	ENE/W	1-3/1-3	E/E	4/5/02
12 May	SE/SW	3-4/3-4	S/SW	1/4/05	S/SSW	0-2/1-4	S/SW	1-3/2-4	SE/S	2-3/2-3	SSE/SSW	2-4/2-5
13 May	S/NW	2-4/2-4	SSW/SW	1-4/2-3	S/W	1/1/04	SW/NW	0-1/0-3	SE/SW	0-1/1-2	SW/NW	0-3/1-3
14 May	N/NE	0-4/1-4	NE/NNE	2/4/01	SW/NE	1-3/2-3	NW/E	1-2/1-3	W/N	2-3/1-2	NNW/NE	2-3/2-3
15 May	NE/WSW	0-2/2-5	NE/SSE	1/2/02	N/E	1-Jan	SSE/S	0/2-4	ESE/W	1-2/1-3	SE/SW	0-1/0-1

[a] Prevalent wind directions for the first and second halves of the day.

[b] Range of observed values of the wind speed for the first and second halves of the day.

Table I.5. Rainfall observations (mm) in the Tula region from 27 April to 15 May 1986.

Date	Sampling[a] time	Tula	Volovo	Yefremov	Uzlovaya	Suvorov	Plavsk	Chern	Belev	Alexin
27 Apr.	21:00p-18:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain
	18:00-21:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	1.0
28 Apr.	21:00p-06:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain
	06:00-09:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	2.8	No rain
	09:00-18:00	5.7	5.5	12.6	11.1	No rain	5.6	No rain	No rain	No rain
	18:00-21:00	1.4	No rain	No rain	No rain	1.0	No rain	1.2	No rain	1.4
29 Apr.	21:00p-06:00	0.2	No rain	No rain	No rain	No rain	0.3	No rain	No rain	No rain
	06:00-09:00	0.6	No rain	No rain	1.7	No rain	2.8	1.6	6.8	No rain
	09:00-18:00	0.6	0.7	4.1	12.6	No rain	6.3	No rain	No rain	No rain
	18:00-21:00	No rain	No rain	No rain	No rain	No rain	No rain	0.8	2.2	No rain
30 Apr.	21:00p-06:00	1.3	No rain	1.1	No rain	No rain	No rain	No rain	No rain	No rain
	06:00-09:00	No rain	No rain	No rain	1.6	No rain	No rain	No rain	No rain	No rain
	09:00-21:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain
1 May	21:00p-21:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain
2 May	21:00p-06:00	No rain	No rain	No rain	No rain	0.4	No rain	No rain	No rain	No rain
	06:00-09:00	No rain	No rain	No rain	No rain	No rain	No rain	3.1	7.6	No rain
	09:00-18:00	No rain	No rain	2.0	No rain	No rain	No rain	No rain	No rain	No rain
	18:00-21:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain
3 May	21:00p-21:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain
4 May	21:00p-06:00	No rain	No rain	2.2	No rain	No rain	No rain	No rain	No rain	No rain
	06:00-21:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain
5 May	21:00p-21:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain
6 May	21:00p-21:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain
7 May	21:00p-21:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain
8 May	21:00p-21:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain
9 May	21:00p-21:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain
10 May	21:00p-21:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain
11 May	21:00p-21:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain
12 May	21:00p-06:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain
	06:00-09:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	0.3	No rain
	09:00-21:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain
13 May	21:00p-09:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain
	09:00-18:00	No rain	4.4	No rain	No rain	No rain	No rain	No rain	No rain	No rain
	18:00-21:00	No rain	2.0	No rain	No rain	1.4	2.7	No rain	2.2	No rain
14 May	21:00p-06:00	0.7	0.5	No rain	1.4	No rain	0.5	No rain	No rain	No rain
	06:00-09:00	No rain	1.4	0.7	4.8	No rain	1.0	No rain	No rain	No rain
	09:00-18:00	No rain	0.3	No rain	No rain	No rain	No rain	No rain	No rain	No rain
	18:00-21:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain
15 May	21:00p-21:00	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain	No rain

[a] 21:00p denotes 21:00 of the previous day.

Table I.6. Average daily temperature in the air (°C).

Date	Tula	Volovo	Yefremov	Uzlovaya	Suvorov	Plavsk	Chern	Belev	Aleksin
27 Apr.	16.8	16.6	17.3	17.0	16.0	16.2	16.6	15.8	16.2
28 Apr.	14.7	13.9	14.0	14.4	14.0	14.0	14.2	13.5	15.4
29 Apr.	10.7	9.2	10.0	8.9	10.7	9.6	10.1	10.7	11.0
30 Apr.	12.6	12.5	13.7	11.8	13.3	13.0	14.4	14.2	12.6
1 May	8.8	7.5	8.2	8.0	8.2	8.1	8.5	9.1	8.6
2 May	9.0	6.9	7.0	8.3	8.5	7.9	7.9	8.8	9.5
3 May	7.8	6.8	7.6	7.0	7.6	7.6	7.4	8.1	7.8
4 May	6.7	6.3	7.0	6.4	7.1	6.9	6.8	7.1	6.6
5 May	3.7	1.8	3.2	2.8	3.2	2.8	2.8	3.9	4.1
6 May	6.4	4.1	3.9	5.3	5.9	5.3	5.0	5.9	6.2
7 May	10.3	7.8	7.6	8.9	10.6	9.6	9.1	10.6	10.4
8 May	16.1	15.5	16.3	15.2	16.1	15.8	16.3	16.2	14.9
9 May	14.4	13.8	15.4	13.2	14.1	14.5	14.8	15.0	15.0
10 May	10.9	11.9	13.8	11.0	12.6	12.6	13.1	12.1	12.6
11 May	8.5	7.3	8.5	7.4	8.6	8.3	9.0	10.2	8.2
12 May	9.0	9.0	9.7	10.1	8.8	8.8	9.2	9.3	8.0
13 May	13.0	12.6	13.1	13.2	11.8	12.7	12.0	11.1	12.2
14 May	14.7	12.9	13.6	13.9	14.4	14.2	14.1	14.7	14.8
15 May	14.5	15.1	16.2	14.8	14.6	14.9	15.0	14.4	13.9

Table I.7. Maximal and minimal daily temperature on the soil surface (°C).

Date	Yefremov		Suvorov		Uzlovaya		Tula		Volovo		Plavsk		Chern		Belev		Alexin	
	max.	**min.**	**max.**	**min.**	**max.**	**min.**	**max.**	**min.**	**max.**	**min.**	**max.**	**min.**	**max.**	**min.**	**max.**	**min.**	**max.**	**min.**
20 Apr.	11	4.7	13	7	9.1	4	10.3	5.4	10	4	10	6	12	5	10	6	15	6
21 Apr.	10.2	7.1	13	6	9	7.5	10.2	7.5	10	7	12	7	11	6	13	6	18	5
22 Apr.	13.7	7.3	12	6	16	6.9	15.8	7	13	6	13	7	13	6	9	5	18	5
23 Apr.	21.5	5.2	17	5	17.2	5	16.1	4.9	18	4	18	4	20	5	17	5	20	5
24 Apr.	33.4	4	24	4	25	3	29.7	0.7	27	2	29	1	25	1	20	2	26	3
25 Apr.	34.7	6.9	25	6	25.2	7	32	6.9	32	6	32	8	26	7	26	3	28	6
26 Apr.	35.1	3.5	27	6	24	5.6	35.9	4.4	34	5	33	5	30	5	28	5	30	7
27 Apr.	34	6.3	24	6	22	7.3	32	6	32	7	32	7	32	7	26	5	30	8
28 Apr.	32.1	6.5	27	8	21.7	7	32.2	8.1	32	6	36	6	38	7	24	6	28	8
29 Apr.	18.5	3	22	6	18.6	4.4	23.6	5.6	21	3	24	5	22	4	18	6	24	4
30 Apr.	27.8	4.8	28	6	26.3	5.2	27.4	5.1	27	4	28	5	33	5	27	5	28	5
1 May	32.5	1.8	30	2	24.5	2.5	24.9	2	28	-1	30	0	28	0	22	2	21	0
2 May	17.3	1.4	23	6	17	2.9	20.8	4.2	16	2	19	3	19	4	16	4	18	2
3 May	15	4.2	21	4	19.6	2	25.9	3.2	21	2	22	2	20	2	18	4	16	1
4 May	21.6	2.5	24	2	19.7	1.2	22	1.6	22	2	24	2	21	2	19	1	18	0
5 May	21.3	-2	18	-2	16.9	-1.5	18.6	-1.7	21	-3	23	-3	21	-3	15	-2	14	-2
6 May	15.4	-3.5	25	-1	16.8	-1.5	27.9	-1.6	22	-4	26	-2	23	-3	21	-2	19	-2
7 May	29.2	-4	29	-1	19.7	-2.5	30	-1	35	-4	32	-2	33	-4	26	-2	27	-1
8 May	37.8	4.5	34	7	33.5	2.9	36	5	42	5	38	5	37	5	35	4	30	4
9 May	42.7	7.5	33	9	35.7	6.2	34.7	7	37	6	41	6	33	6	41	7	28	4
10 May	35.3	3	34	6	27.3	4.4	35.3	3.4	40	1	39	3	33	3	35	2	24	4
11 May	39.2	1	30	2	31.1	-2.6	35.2	1	39	-1	36	1	31	0	31	2	19	0
12 May	41.4	-1.3	21	7	31.8	-3	31.2	0.7	35	-1	30	2	26	5	21	5	19	0
13 May	42.6	6	39	4	38	2	36.9	4	38	7	42	4	37	4	34	4	25	3
14 May	38.3	10.4	35	10	29.4	10	35.5	11.5	27	10	37	11	36	9	35	10	24	8
15 May	42.5	6.9	39	6	28.7	4	39	5.4	35	4	40	5	38	3	35	5	28	3

Table I.8. Relative humidity in the town of Plavsk (%).

Date	Time of day							
	00:00	03:00	06:00	09:00	12:00	15:00	18:00	21:00
26 April	65	68	72	56	30	21	22	36
27 April	58	54	65	43	25	22	21	35
28 April	45	55	59	50	42	86	83	91
29 April	84	93	96	96	94	82	69	84
30 April	90	91	96	78	63	60	60	73
1 May	78	84	91	78	61	44	45	64
2 May	79	87	88	74	64	52	58	77
3 May	76	89	84	55	38	45	50	63
4 May	72	78	77	43	34	34	33	34
5 May	43	54	58	66	42	34	38	52
6 May	59	67	62	46	29	20	16	32
7 May	46	43	48	35	19	32	32	47
8 May	56	61	72	50	28	28	29	50
9 May	60	70	68	54	33	29	28	42
10 May	51	59	68	46	36	35	38	46
11 May	43	50	56	26	23	18	21	37
12 May	44	48	53	47	55	53	51	57
13 May	54	75	83	75	58	52	44	88
14 May	90	92	94	87	71	47	45	63
15 May	81	91	94	63	40	43	41	52

Table I.9. Mean activity ratios of gamma-emitting radionuclides deposited after the Chernobyl accident for the "northeast trace" (derived from [I.10, I.15]).

Radionuclides[a]	Mean	Standard error (%)
^{134}Cs / ^{137}Cs	0.51	4.3
^{131}I / ^{137}Cs	3.34	19.5
(^{140}Ba + ^{140}La) / ^{137}Cs	0.64	24.0
(^{95}Zr + ^{95}Nb) / ^{137}Cs	0.13	27.0
^{103}Ru / ^{137}Cs	1.39	29.0
^{106}Ru / ^{137}Cs	0.47	15.7
^{133}I / ^{131}I	2.0	5.0
^{136}Cs / ^{137}Cs	0.26	8.0
^{132}Te / ^{137}Cs	15.8	30.0

[a] In general, the ratios apply to 10 May 1986; for the short-lived radionuclides ^{136}Cs, ^{133}I, and ^{132}Te they apply to 26 April 1986.

I.4.2.2. Isotopic composition of deposition

The activity deposited per unit area varied considerably even over short distances because of the intensive precipitation during the passage of the radioactive cloud. Unfortunately, detailed data about the precipitation are not available. In general, it was dry before 28 April 1986, and precipitation of different intensities during the passage of the radioactive cloud was observed 29 April 1986. Therefore, the radioactive fallout can be classified as mixed (dry + wet). For the deposition in Tula region, the largest part of the deposited activity was attached to aerosols.

The values of ratios of the surface activities of the radionuclides ^{134}Cs, ^{131}I, ^{140}Ba+^{140}La, ^{95}Zr+^{95}Nb, and ^{103}Ru to the surface activity of the reference radionuclide ^{137}Cs were determined on the basis of the data presented by Orlov et al. [I.10]. These ratios were estimated on the basis of measurement results fulfilled in May 1986. For the radionuclide ^{106}Ru, the value of this ratio was determined on the basis of data presented by Pitkevich et al. [I.15]. Estimation of the ratios of the activities of ^{136}Cs, ^{133}I and ^{132}Te to the activity of ^{137}Cs used observed data of the content of these radionuclides in air and on soil in other places and results of calculations of the ratios of their activities in the reactor up to the moment of the accident [I.15–I.19. Mean activity ratios of gamma-emitting radionuclides deposited after the Chernobyl accident to the surface activity of the reference radionuclide ^{137}Cs for the test area are presented in Table I.9on the date 10 May 1986. This values were estimated for Russian territories with wet fallouts. There were 4 points of soil sampling in May 1986 in Tula region [I.10]. Only one of them is located in the Plavsk district (town of Plavsk). It is very important for the goal of this scenario that there were meteorological stations in these settlements (Belev, Plavsk, Uzlovaja). One can assume that these radionuclide ratios correspond to wet deposition. There is lack of experimental data for dry deposition. These four points can be used for verification of model calculations of ^{131}I depositions as a range of possible values.

I.4.2.3. Ground contamination by ^{137}Cs

Table I.10 shows the surface contamination levels by ^{137}Cs in the particular settlements of Plavsk district and the average levels of contamination on the territories of the collective farms in the study area. Each value of ^{137}Cs soil contamination in a settlement is an arithmetic mean of some real measurements that are distributed approximately log-normally with geometric standard deviation GM= 1.3–1.6 depending on number of measurements. Averages for farms are calculated from all available data of ground contamination with ^{137}Cs for settlements involved in a collective farm territory, as simple arithmetic means (denoted as $\overline{X}$) with standard deviation SD. The 95% confidence intervals for each collective farm are included. All data on the density of the surface contamination of territories are counted for the date of the radioactive fallout, considered as 26 April 1986, according to data from the Russian Hydrometeorological Committee [I.20] (with some correction for 2001). Figure I.5 shows a scheme of the territory's contamination with radioactive fallout of ^{137}Cs in the Plavsk district, counted for 26 April 1986.

Table I.10. Average soil contamination with ^{137}Cs (kBq m^{-2}) at the date of the accident (26 April 1986) in collective farms of the plavsk district.

Farm N#	Collective farm	Average ^{137}Cs in 1986 (kBq m^{-2}) $\overline{X}$	±	S	95% Confidence Interval Lower Bound	Upper Bound	N	Local administration	Settlements involved in the collective farm	^{137}Cs in 1986 (kBq m^{-2})
1	Krasnogor'e	169	±	53	127	233	6	Chastinskij	Chastoe	169
									Djukovo	83
									Ivanovka	230
									Krasnogor'e	206
									Sorochinka	136
									Leski	189
2	Za Mir	442	±	42	405	484	5	Jusupovskij	Arsen'evo	449
									Jusupovo	369
									Lunino	469
									Streshnevo	474
									Vitcinskie Vyselki	450
3	Im. Safonova	485	±	91	417	567	6	Samozvanovskij	Novaja Slobodka	439
									Rahmanovo	361
									Rozhdestveno 1	616
									Rozhdestveno 2	562
									Zarech'e	480
									Orlikovo	451
4	Plavskij	278	±	49	251	309	11	Prigorodnyj	Akulovo	238
									Akulovskie Vyselki	341
									Jur'evo	272
									Jur'evskij	250
									Krasnaja Niva	247
									Krasnyj	246
									Prigorodnyj	295
									Sinjavino	368
									Sinjavinskie Vyselki	282
									Srednij	316
									Volhonschino	205
5	Vpered k kommunizmu	137	±	40	114	167	11	Oktjabr'skij	Aleksandrovka	197
									Aleksandrovskij	152
									Kosaja Guba	76
									Kozhuhovo	152
									Krasnoe	152
									Krasnoe Zarech'e	111
									Krekshino	159
									Krutoe	111
									Oktjabr'skij	189
									Pen'kovo	80
									Vasilevka	130
6	Im. Luk'janova	364	±	31	334	396	4	Gorbachevskij	Lokna	349
									Nikol'skoe 1	386
									Nikol'skoe 2	327
									Voejkovo	393
7	Gorbachevskij	248	±	106	183	342	7	Gorbachevskij	Gorbachevka	171
									Gorbachevo	157
									Mihajlovskoe	334
									Novaja Lokna	436
									Rumjancevskij	244
									Seleznevo	246
									Sovetskij	147
8	Tul'skaja niva (NIISH)	273	±	76	217	350	4	Samozvanovskij	Krasnaja Lokna	230
									Molochnye Dvory	302
									Petrovka	193
									Svobodnyj Serp	365
9	Im. K. Marksa	123	±	18	107	144	4	Samozvanovskij	Samozvanovka	125
									Samozvanovka (St)	127
									Savvateevka	99
									Shosse	142
10	Rossia	100	±	22	8 2	125	5	Bol'sheozerskij	Bol'shie Ozerki	118
									Jasnyj	83
									Kobylinskij Hutor	70
									Korobanovka	115
									Spasskoe	115

Table I.10. (Continued)

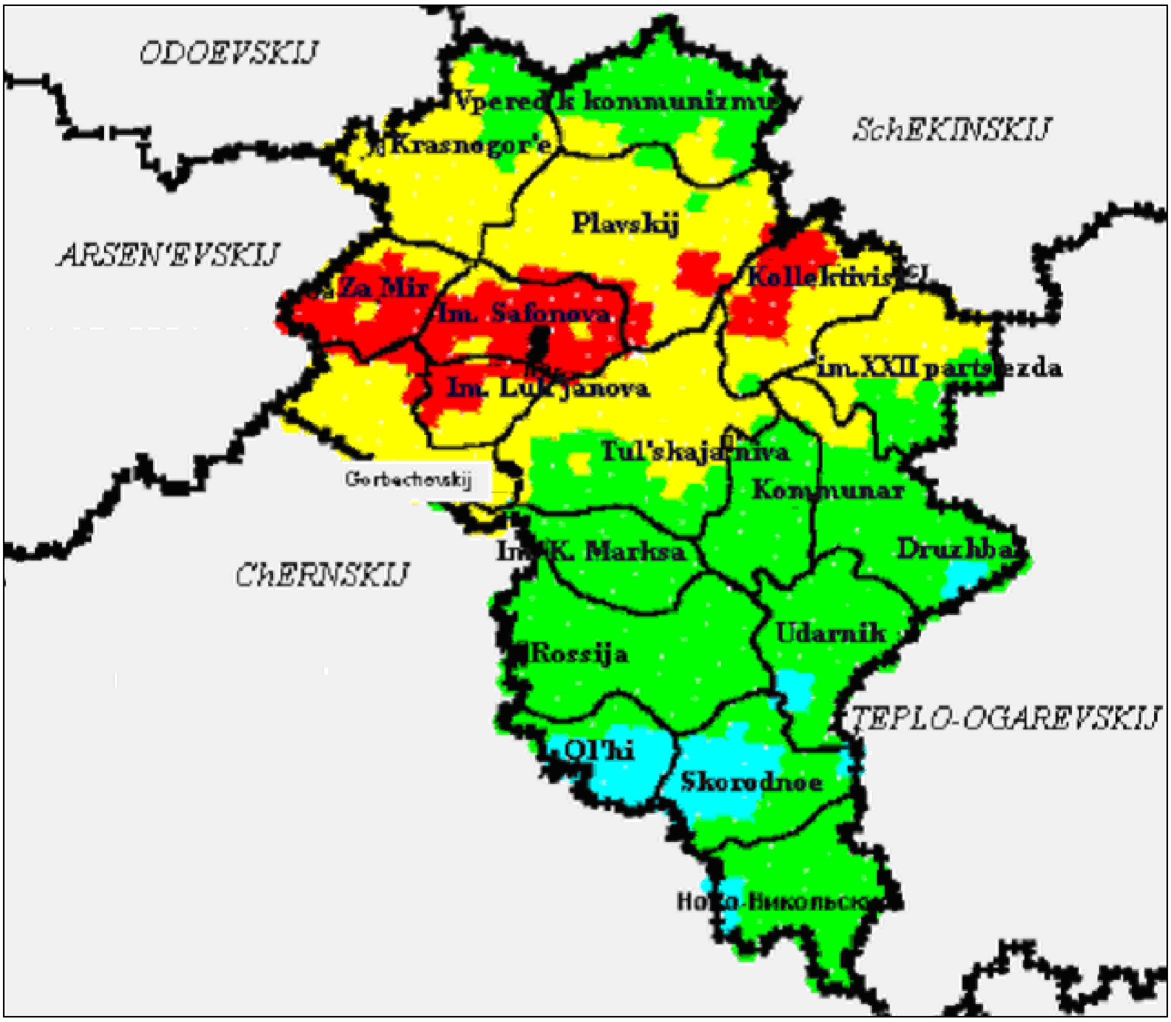
Farm N#	Collective farm	Average ^{137}Cs in 1986 (kBq m^{-2}) $\bar{X}$	±	S	95% Confidence Interval Lower Bound	Upper Bound	N	Local administration	Settlements involved in the collective farm	^{137}Cs in 1986 (kBq m^{-2})
11	Kollektivist	358	±	123	253	531	5	Kamyninskij	Guba	176
									Kamynino	291
									Nizhnie Marmyzhi	439
									Novoselki	407
									Srednie Marmyzhi	477
12	Kommunar	112	±	7	106	119	4	Mescherinskij	Ivanovskoe 1	106
									Ivanovskoe 2	115
									Ivanovskoe 3	120
									Vasil'evskoe	107
13	Druzhba	110	±	33	89	142	12	Mescherinskij	Baburino	86
									Esipovo	104
									Gubarevka	125
									Ivanovskoe	103
									Krasnoe	152
									Ljapunovka	142
									Mescherino	112
									Nikol'skoe	119
									Ostrovki	34
									Pochinino	100
									Tjurinka	93
									Urusovo	154
14	im.XXII parts'ezda	196	±	17	180	214	4	Sorochinskij	Bohino	214
									Bonjakovo	175
									Pervoe Maja	190
									Sorochinka	205
15	Udarnik	66	±	23	44	106	4	Diktaturskij	Chebyshovka	74
									Diktatura	84
									Sokovnino	73
									Zhadomo	33
16	Ol'hi	27	±	13	16	46	3	Novozhukovskij	Novoe Zhukovo	18
									Ol'hi	41
									Staroe Zhukovo	21
17	Skorodnoe	18	±	8	10	36	4	Novozhukovskij	Gremjachevo	26
									Juzhnyj	7
									Skorodnoe	17
									Suhotinka	23
18	Novo-Nikol'skij	54	±	15	42	71	7	Novonikol'skij	Krasnyj Oktjabrj	43
									Lidinka	70
									Novoe Arhangel'skoe	62
									Novonikol'skoe	56
									Pavlovka	55
									Strojka	65
									Zapol'nyj Ol'hovec	26

Table I.11. Average soil contamination with ^{137}Cs (kBq m^{-2}) at the date of the accident (26 April 1986) in urban areas of the Plavsk district.

Location	Local administration	^{137}Cs in 1986 (kBq m^{-2})
Gorbachevo (r.s)	Gorbachevskij	453
Town of Plavsk	District center	475

Table I.12. Height of natural grasses (cm).

Meteostation	Vegetation type	Dates (1986) 20 April	30 April	10 May	20 May
Volovo	clover	–	5	8	11
	bonfire grass	–	5	8	11
Plavsk	various grasses	–	4	6	11



>37 kBq/m^2 ; 37–185 kBq/m^2 ; 185–370 kBq/m^2 ;
370–555 kBq/m^2 ; > 555 kBq/m^2

Fig. I.5. Scheme of soil contamination with ^{137}Cs in the Plavsk district.

I.4.3. *Important agriculture information*

I.4.3.1. Yield of the pasture at the time of accident

The presence of two periods of temperature decrease with night hoarfrosts on soil, during 1–7 May and 11–12 May 1986 had influenced the developmental process of the vegetation. The height of natural grasses was measured at two observation points. The data from 20 April to 20 May 1986 are shown in Table I.12. One can consider that such grass growth rate was characteristic for all Plavsk district. Haymaking usually begins in the middle of June when the height of natural grass is about 30 cm. The measurements indicate that yield of 10 cm height grass varied from 0.05 to 0.09 kg m^{-2} dry weight (18% of dry matter contents) depending on the kind of grass and agricultural practices.

I.4.3.2. Pasturing of milk cattle

The date when pasturing started for milk cattle is very important for estimating the internal exposure dose. Everywhere in Russia it is usual to keep the milk cattle outdoors during summer time. The internal radiation dose for the population during the first days after the accident depended significantly upon whether the milk cattle were already at pasture or were still in the cowshed. Agro-meteorological service supposed that grazing of cows can be started when air temperature was stabilized above 10ºC.

Milk contamination increased greatly after the cows were brought to pasture. Estimation of thyroid doses for the population from the radioisotopes of iodine depended directly on the radioactive contamination of the area the cattle were brought to pasture.

A question about the beginning date of pasturing was included in the questionnaire during the poll of the Tula population in the spring of 1987 (described above). Table I.13 gives the summarized answers of inhabitants concerning the beginning date for pasturing private cows in the spring of 1986 in the Tula region. Besides the 559 people indicating the date of the beginning of pasture, 400 more people among the 1774 participants of the poll answered that the cows were first put on pasture in May. It is necessary to comment on the procedure of pasturing private cows in Russian villages. Private cows of a village are collected in the morning into a herd that is grazed by a herdsman engaged collectively by the owners of the cows, or by the owners of the cows themselves alternated by turns. Small towns with populations under 5–10 thousand inhabitants have many private houses, where people lead a rural lifestyle, and some of them keep their own cattle, including cows.

In 1995–1996 a poll was carried out among the directors of collective farms concerning the dates of the beginning of the grazing period for collective and private herds in 1986. The comparison of answers about the grazing of private cows, received from the individual polls and from the polling of directors from the same settlements, showed a good agreement. This permitted the use of the answers of the collective farm directors for estimating the dates of private and public cattle grazing in 1986. Figure I.6 provides the distributions of answers about the dates of the beginning of pasturing for private and public milk cattle, which were received from the individual questioning and from the answers of the collective farms directors from Plavsk and bordering districts. The greatest number of answers gave dates of 5 May and 10 May 1986. This was the range of the dates when the cattle pasturing started in the southern districts of the Tula region. The dates of the beginning of cattle pasturing in the farms of the Plavsk district, received from the answers of their directors, are shown in Table I.14. It can be seen that the pasture season for private cows started between 4 and 11 May 1986; for the public herd it started between 8 and 25 May 1986. It is necessary to keep in mind that the beginning of the pasture season depended not only on the weather conditions, but also on the presence of fodder to be used by cattle still in the cowshed.

I.4.3.3. Cows consumption rate

During the pasture period cows eat 40–45 kg/day of fresh grass. Transfer of cattle in grazing regime goes on gradually, beginning from 2 hours in first day, then increasing time of grazing during 7–10 till full day. During transfer period cows receive mixed fodder, hay and silage depend on their availability in a farm. During stall keeping of cattle they should receive not less than 10 kg of hay, 25–30 kg of rich fodder, 2.5–3 kg of mixed fodder.

Table I.13. Dates of the beginning of milk cattle pasturing from private farms in the spring of 1986 in the Tula region (data from individual questioning of inhabitants).

District and settlement	**Dates**	**Number of answers**	**% of answers in district**
Arsen’evsky, villages	1-2 May	152	0.40
	4-5 May	72	0.19
	9-11 May	146	0.39
	After 11 May	7	0.02
Belevsky, town of Belev	25-29 April	5	0.15
	3-6 May	10	0.30
	9-10 May	5	0.15
	14-15 May	9	0.27
	After 15 May	4	0.12
Plavsky, town of Plavsk	5 May	5	0.07
	9-10 May	37	0.54
	12 May	1	0.015
	15 May	18	0.27
	17-20 May	6	0.09
	After 20 May	1	0.015
Teplo-Ogarevsky,	Before 26 April	1	0.01
village of Naryshkino	1 May	2	0.03
	9-11 May	78	0.96

Table I.14. Dates of the beginning of pasturing collective and private cattle at farms of the Plavsk district in 1986 (data from answers of farm directors).

Number of the farm	**Name of the collective farm**	**Collective cattle**	**Private cattle**
Sovkhoz	Krasnogorie	15 May 1986	9 May 1986
Kolkhoz	Za Mir	18 May 1986	7 May 1986
Kolkhoz	Im. Safonova	18 May 1986	10 May 1986
Sovkhoz	Plavsky	15 May 1986	10 May 1986
Kolkhoz	Vperiod k Kommunizmu	24 May 1986	5 May 1986
Kolkhoz	Im. Lukianova	15 May 1986	6 May 1986
Sovkhoz	Gorbachevsky	25 May 1986	6 May 1986
Sovkhoz	Tul'skaja niva	Approximately 20-25 May	
Kolkhoz	Im. Karl Marx	20 May 1986	8 May 1986
Kolkhoz	Rossia	16 May 1986	7 May 1986
Kolkhoz	Kollektivist	8 May 1986	4 May 1986
Kolkhoz	Kommunar	16 May 1986	10 May 1986
Sovkhoz	Druzhba	10 May 1986	7 May 1986
Kolkhoz	22 Partsjezda	15 May 1986	10 May 1986
Sovkhoz	Udarnik	8 May 1986	6 May 1986
Sovkhoz	Olkhi	13 May 1986	7 May 1986
Sovkhoz	Skorodnoie	11 May 1986	4 May 1986
Sovkhoz	Novo-Nicolsky	25 May 1986	11 May 1986

(a)

(b)

(c)

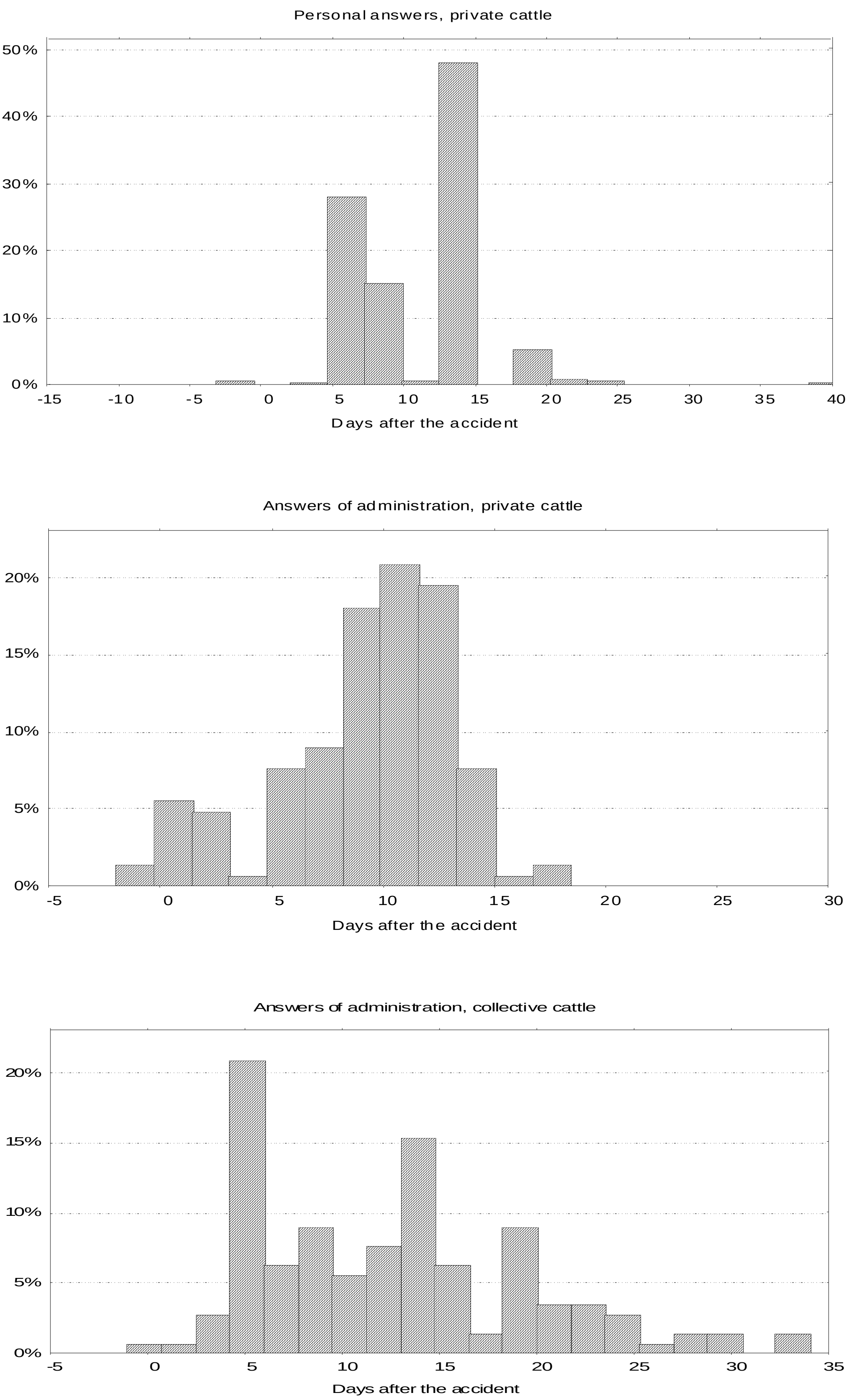


Fig. I.6. Distribution of answers about the date that cattle pasturing began, according to (a) personal answers about private cows; (b) answers of farm directors about private cows; and (c) answers of farm directors about common (collective) cattle.

Average productivity of natural grass meadows in Tula region was estimated as 8.4 quintal/hectare of hay, that is mean about 40-45 quintal/hectare of fresh mass (0.4–0.45 kg/m^2). About 100–129 m^2 of pasture could provide one day's grass ratio for a cow.

According to data on milk production during 1997–2000, average mean productivity of cows in May differs from 5 L per day in first dates to 7 L per day at the last days of month.

I.4.3.4. Distribution of milk production

There is no data about the spatial distribution of the milk production in the Plavsk test area, i.e., contribution to milk that appeared in the shops of Plavsk town from particular collective farms. It would be important to evaluate average ^{131}I milk concentration in Plavsk town). For the scenario exercise, the modellers are asked to assume equal contribution from all collective farms to milk plant in Plavsk town.

I.4.4. Population information

I.4.4.1. Demography

The population of the Tula region includes 1.79 million people, and its density is 69.6 people per km^2. The urban population includes 1 434 600 people (81.3%), and the rural population 329 000 people (18.7%). With respect to the density of population, the region takes second place in the Russian Federation after the Moscow region.

There are 29 700 people living in the Plavsk district. According to the data of the census in 1989, the population of the town of Plavsk was 16 400 persons, and the rural population of the district was 13 300 people [I.21]. Table I.15 provides data on sex and age of the population of the Tula region, according to the census of 1989 [I.21].

I.4.4.2. Food consumption rates

In April–May 1987 in the Plavsk, Arsenievsky and Teplo-Ogaryovsky districts of the Tula region, a dispensary control of children in the most contaminated living settlements was carried out; it was accompanied by measurements of the cesium radionuclide content in the body, and interviews about the diet and activities in summer and autumn of 1986. Altogether, 1774 questionnaires with answers were received; 1219 of them were from the inhabitants of the town of Plavsk, 58 from the inhabitants of the town of Belev, and 497 from the rural population. Among others, there was a question about the daily milk consumption rate. Based on these data it can be concluded that the amount of milk consumption is different for the rural and urban populations. Almost 100% of the villagers in 1986 consumed milk from their private farms. In the town of Plavsk, only 11% of the population consumed private milk; the others bought milk in the shops. Table I.16 provides the average milk consumption by age for the rural and urban populations, estimated from the questionnaire. Unfortunately, questionnaire data were not available for all the age groups. As people in the middle part of Russia have similar lifestyles and diets, the data for the missing age groups, or for age groups with a low number of measurements, were replaced by the data from a similar questioning of the inhabitants of the Bryansk region, which was carried out in the spring of 1986.

For the same reason, we consider it to be possible to use for Plavsk population the diet that was obtained from the questionnaires from the Bryansk region population for the pre-accident period. Consumption of basic foods apart from milk is shown in Table I.17 for adults [I.22]. Data on a diet of children are not available.

Table I.15. Age and sex distribution of the urban and rural populations of the Tula region (%).

Age group (years)	Urban population			Rural population		
	Men	Women	Both	Men	Women	Both
0–2	1.9	1.8	3.8	2.0	2.0	4.0
3–5	1.9	1.8	3.8	1.9	1.9	3.8
6–9	2.5	2.4	4.8	2.5	2.4	4.8
10–15	3.8	3.7	7.5	3.5	3.4	6.9
16–19	2.6	2.5	5.1	2.1	1.6	3.7
20–24	2.9	2.8	5.7	2.5	2.3	4.8
25–29	3.7	3.6	7.3	3.4	2.9	6.4
30–34	4.1	4.2	8.3	3.7	3.1	6.9
35–39	4.0	4.2	8.2	3.3	2.7	5.9
40–44	2.7	2.9	5.7	2.0	1.9	3.9
45–49	2.8	3.3	6.1	2.6	2.8	5.4
50–54	3.3	4.1	7.3	3.6	4.0	7.6
55–59	3.1	4.1	7.2	4.2	5.1	9.3
60–64	3.0	4.7	7.6	3.7	6.0	9.6
65–69	1.3	2.8	4.1	1.7	3.9	5.6
70–74	0.9	2.1	3.0	1.1	3.2	4.3
75–79	0.7	1.9	2.6	0.8	3.2	4.1
80–84	0.3	1.1	1.3	0.4	1.8	2.1
> 85	0.1	0.5	0.6	0.1	0.9	1.0
Total	45.5	54.5	100.0	45.1	54.9	100.0

Table I.16. Milk consumption rates by age for rural and urban inhabitants (l d^{-1}).

Age (years)	Number of individuals	Arithmetic mean ± st. dev.
	Rural population	
0 – < 0.25	10	0.01 ± 0.03
0.25 – < 0.5	20	0.38 ± 0.45
0.5 – < 0.75	11	0.33 ± 0.25
0.75 – < 1	22	0.45 ± 0.38
1–2	135	0.56 ± 0.34
3–7	250	0.60 ± 0.35
8–12	33	0.44 ± 0.28
13–17, male[a]	781	0.59 ± 0.57
13–17, female[a]	918	0.38 ± 0.47
> 17, male[a]	1508	0.71 ± 0.74
> 17, female[a]	2086	0.65 ± 0.58
	Urban population	
0 – < 0.25	16	0
0.25 – < 0.5	44	0.08 ± 0.14
0.5 – < 0.75	46	0.21 ± 0.25
0.75 – < 1	41	0.36 ± 0.20
1–2	350	0.40 ± 0.20
3–7	734	0.40 ± 0.20
8–12[a]	720	0.30 ± 0.25
13–17, male[a]	551	0.30 ± 0.35
13–17, female[a]	230	0.22 ± 0.22
> 17, male[a]	2236	0.30 ± 0.48
> 17, female[a]	3755	0.25 ± 0.33

[a] Values for these age groups are taken from the poll of the Bryansk population.

Table I.17. Food consumption rates for adult rural inhabitants (kg d^{-1}, mean ± st. Dev.) [I.22].

Sex	Meat	Potatoes	Vegetables	Bread[a]
Male	0.177 ± 0.099	0.64 ± 0.30	0.30 ± 0.11	0.39 ± 0.16
Female	0.170 ± 0.122	0.56 ± 0.22	0.27 ± 0.09	0.29 ± 0.12

[a] Made of imported flour.

I.4.5. Protective measures

No protective measures were performed in the territory of the test area.

I.5. Radioiodine ^{131}I measurements

I.5.1. ^{131}I concentration in milk measurements

90 samples of milk were measured from 15 to 30 of May 1986 in Plavsk district. From 2 to 6 milk samples were measured from 10 settlements where measurements of ^{131}I in thyroids of inhabitants were performed in period from May 15 to June 6, 1986. 4–6 milk samples were taken and measured in 6 other villages. 11 milk samples from the town of Plavsk are available.

For models testing purposes, there is possibility to add to this number of settlements some from neighboring districts, where dates of beginning grazing period for cattle were approximately the same. The modellers are asked to estimate dependence of ^{131}I concentration in milk in reference date (8 May 1986 or other) on ^{137}Cs soil contamination. For verification of this dependence all milk measurements in Tula region have to be used.

I.5.2. Direct measurements of ^{131}I content in human thyroid

I.5.2.1. Distribution of measurements with age groups and locations

Direct measurements of ^{131}I content in human thyroid were performed in the radiodiagnostic laboratory of the Tula regional hospital since May 13 till June 6, 1986, using diagnostic spectrometer with lead collimator in energy interval 300–450 keV.

In total, 648 people from 40 settlements of the Tula region were measured, where 390 persons were from rural settlements and 258 from urban settlements. Most of the measured people (459 persons) were living in the Plavsk district. Number of measurement, age of measured people and dates of measurements are presented in Table I.18. The ^{131}I content in the thyroid of people in the districts of the Tula region was being measured in the radioisotope laboratory of Tula regional hospital from 13 May–6 June 1986.

I.6. Spectrometric measurements of ^{131}I in milk samples

Spectrometric measurements of ^{131}I content in milk samples and other foods in Tula region were carried out from 14 May–12 June 1986 on the base of the regional sanitary-and-epidemiological station. For this purpose a spectrometer was used on the base of the crystal of NaI(Tl) ∅40 × 40 mm, as used to define the function of the thyroid gland. The detector was put inside the cylindrical leaden collimator in vertical position. The sample volume was 100 milliliters. 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. In total 1744 measurements of milk samples were performed.

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 ^{137}Cs 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 14–30 May 1986.

The mean effective period of ^{131}I activity reduction in milk from in the Tula region is determined as 4.2 days.

I.7. ^{131}I 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 13 May–6 June 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 × 40 mm in the energetic channel of ^{131}I: 300–450 keV [I.23, I.24]. 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 the detector was introduced into 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 [I.23, I.24]. 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 I.15. The results of ^{131}I activity measurements in the thyroid of people living in the district of interest for some measurements dates are reported in Table I.20.

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

I.7.1. Thyroid dose estimations

Thyroid dose estimations were made according to the model of ^{131}I intake to a human body shown at Figure I.7. Three main sources of ^{131}I intake in a human body are taken into account: inhalation of the radionuclide during the passage of the radioactive cloud; consumption of contaminated milk; other intake sources, of which the main are consumption of leaf vegetables and some other food products, mainly contaminated superficially. The value of radioiodine intake in the body of inhabitants is strongly influenced by the date of the beginning of dairy cattle pasturing and of termination of local milk consumption if any. With consideration for these main factors, we developed the schematic model of ^{131}I intake in the body of man in the post-accidental period. The parameters of this model were based upon the analysis of the Russian radiation monitoring data.

Table I.18. Settlements with direct measurements of ^{131}I in thyroids of inhabitants.

Settlement	Collective farm	N#	Number of measurements	Age in 1986	Date
PLAVSK	TOWN OF PLAVSK		34	0	14-16.05.1986
PLAVSK	TOWN OF PLAVSK		6	1-2	14.05.1987
PLAVSK	TOWN OF PLAVSK		18	3-7	14-16.05.1986
PLAVSK	TOWN OF PLAVSK		13	8-12	13.05.1986
PLAVSK	TOWN OF PLAVSK		70	adults	14-17.05.1986
JUSUPOVO	ZA MIR	2	6	1-3	19.05.1986
RAKHMANOVO	IM. SAFONOVA	3	6	2-3	21.05.1986
RAKHMANOVO	IM. SAFONOVA	3	3	adults	21.05.1986
JUR’EVO	PLAVSKIJ	4	7	1-2	19.05.1986
KREKSHINO	VPERED K KOMMUNIZMU	5	16	2-3	16.05.1986
KREKSHINO	VPERED K KOMMUNIZMU	5	17	adults	16.05.1986
OKTJABRSKAI	VPERED K KOMMUNIZMU	5	12	2	16.05.1986
OKTJABRSKAI	VPERED K KOMMUNIZMU	5	11	8-10	16.05.1986
OKTJABRSKAI	VPERED K KOMMUNIZMU	5	18	adults	16.05.1986
NIKOLSKOE	IM. LUK'JANOVA	6	6	1-3	19.05.1986
MOLOCHNYE DVORY	TUL'SKAJA NIVA	8	15	8-10	30.05.1986
MOLOCHNYE DVORY	TUL'SKAJA NIVA	8	4	adults	13-15.05.1986
BOLSHIE OZERKI	ROSSIJA	10	7	1	19.05.1986
BOLSHIE OZERKI	ROSSIJA	10	7	2-3	
URUSOVO	DRUZHBA	13	5	1-3	21.05.1986
SOROCHINKA	IM.XXII PARTS'EZDA	14	7	9-12	13.05.1986
DIKTATURA	UDARNIK	15	4	1	21.05.1986
DIKTATURA	UDARNIK	15	15	2-3	
OL'HI	OL'HI	16	6	2-3	17.05.1986
OL'HI	OL'HI	16	7	adults	17.05.1986
GREMJACHEVO	SKORODNOE	17	5	2-3	17.05.1986
GREMJACHEVO	SKORODNOE	17	6	adults	17.05.1986
SKORODNOE	SKORODNOE	17	5	2-3	17.05.1986
SKORODNOE	SKORODNOE	17	7	adults	17.05.1986
NOVO-NIKOL'SKOE	NOVO-NIKOL'SKIJ	18	12	2-3	17.05.1986
NOVO-NIKOL'SKOE	NOVO-NIKOL'SKIJ	18	15	adults	17.05.1986

Table I.19. Measured data of ^{131}I concentration in milk in the Plavsk agricultural area.

Collective Farm	**^{137}Cs kBq/m^2**	**14 05 86**			**15 05 86**			**19 05 86**			**22 05 86**			**27 05 86**		
		Samples values	**Average or ref. values**	**S.D.**	**Samples values**	**Average or ref. values**	**S.D.**	**Samples values**	**Average or ref. values**	**S.D.**	**Samples values**	**Average or ref. values**	**S.D.**	**Samples values**	**Average or ref. values**	**sd**
SKORODNOE	18	4407	**4407**	n.a.	nm	nm	nm	1536	**1536**	n.a.	981	**981**	*n.a.*	322 148	**235**	*123*
OL'HI	27	4052 8122	**6087**	*2878*	nm	nm	nm	1347	**1347**	n.a.	651	**651**	*n.a.*	315 189	**252**	*89*
NOVO-NIKOL'SKIJ	54	4917	**4917**	*n.a.*	nm	nm	nm	1084	**1084**	n.a.	1391	**1391**	*n.a.*	41 130	**85**	*63*
UDARNIK	66	nm	nm	nm	nm	nm	nm	nm	nm	nm	1117	**1117**	*n.a.*	723 525	**623**	*140*
ROSSIA	100	4718 3330	**4024**	*981*	nm	nm	nm	1077	**1077**	n.a.	673	**673**	*n.a*	673 511	**592**	*115*
DRUZHBA	110	5565	**5565**	*n.a*	nm	nm	nm	969 1210	**1090**	*170*	1735	**1735**	*n.a*	15 MDA	8	
KOMMUNAR	112	nm	nm	nm	nm	nm	nm	5672 2516	**4094**	*2232*	2309	**2309**	*n.a*	921 1240	**1080**	226
IM. K. MARKSA	123	nm	nm	nm	nm	nm	nm	1317	**1317**	*n.a.*	1499	**1499**	*n.a*	460 1499	**981**	735
VPERED K KOMMUNIZMU	137	nm	nm	nm	nm	nm	nm	241	**241**	*n.a.*	921	**921**	*n.a*	100	**100**	*n.a*
KRASNOGOR'E	169	4703	**4703**	*n.a*	nm	nm	nm	3378	**3378**	nm	nm	nm	nm	nm	**1413**	
IM.XXII PARTS'EZDA	196	nm	nm	nm	nm	nm	nm	3463 3774	**3619**	*220*	3898 2919	**3408**	*692*	1602 1454 1166	**1407**	*222*
GORBACHEVSKIJ	248	nm	nm	nm	nm	nm	nm	315	**315**	*n.a.*	19	**19**	*n.a*	470	**470**	*n.a*
TUL'SKAJA NIVA	273	nm	nm	nm	nm	nm	nm	93	**93**	*n.a.*	107	**107**	*n.a*	673	**673**	*n.a*
PLAVSKIJ	278	nm	nm	nm	nm	nm	nm	nm	nm	nm	5091	**5091**	*n.a*			
KOLLEKTIVIST	358	nm	nm	nm	nm	nm	nm	5221	**5221**	*n.a*	4225	**4225**	*n.a*	1010 2202	**1606**	*843*
IM. LUK'JANOVA	364	nm	nm	nm	nm	nm	nm	5014	**5014**	*n.a*	4755	**4755**	*n.a*	2253 2057	**2155**	*139*
ZA MIR	442	nm	nm	nm	nm	nm	nm	4751	**4751**	*n.a*	4318	**4318**	*n.a*		2110	
PLAVSK TOWN	475	6068	**6068**	*n.a*	7441 6109 6956	**6835**	*674*	2679	**2679**	*n.a*	3907 1251	**2579**	*187 8*	914 2128	1521	*858*
IM. SAFONOVA	485	nm	nm	nm	nm	nm	nm	nm	nm	nm	5099	**5099**	*n.a*	1758	**1758**	*n.a*

nm – no measurement in the specified day.
n.a.- single measurement.

Table I.20. Average activity of ^{131}I in thyroids of Tula inhabitants measured in May 1986 (kBq).

Collective farm	Settlement	σ137, kBq/m²	Date in 1986	Age in 1986, yr.	Mean	SD	Number of measurements
TOWN OF PLAVSK	PLAVSK TOWN	473	14 May	1-2	2.2	0.7	5
				3-7	5.1	4.1	7
				>17	5.4	3.8	18
			15 May	<1	5.1	5.9	28
				>17	4.6	4.1	39
			16 May	3-7	6.4	5.9	5
				>17	4.7	7.4	8
			5 Jun	<1	2.7	2.2	7
RUSSIA	BOLSHIE OSERKI	139	19 May	1-2	3.8	2.4	11
				3	2.7	2.1	3
UDARNIK	DIKTATURA	40	21 May	1-2	1.7	0.7	17
DRUZHBA	URUSOVO	152	21 May	1-2	4.1	4.8	5
SKORODNOE	GREMYACHEVO	26	17 May	2-3	3.0	1.8	4
				>17	3.4	3.2	5
	SKORODNOE	17	17 May	2	2.0	1.3	4
				>17	3.6	2.4	7
OL'HI	OL'HI	41	17 May	2-3	3.2	1.9	6
				>17	8.8	5.4	6
NOVO-NIKOL'SKIJ	NOVONIKOLSKOE	44	17 May	2-3	4.3	3.5	12
				>17	11	15	14
VPERED K KOMMUNIZMU	KREKSHINO	134	16 May	2-3	2.1	2.4	16
				>17	4.3	3.3	13
	OKTYABRSKY	168	16 May	2	1.9	1.9	12
			13 May	8-10	2.4	2.2	8
			16 May	>17	2.3	1.9	16
PLAVSKIJ	YURIEVO	318	19 May	1-2	6.9	5.5	7
TUL'SKAJA NIVA	MOLOCHNYE DVORY	322	13 May	8-10	4.2	3.1	12
				>17	1.9	1.8	4
IM. SAFONOWA	RAHMANOVO	350	21 May	1-2	5.7	2.9	6
IM.XXII PARTS'EZDA	COROCHINKA	145	13 May	9-12	3.6	1.1	7
ZA MIR	YUSUPOVO	336	19 May	1-2	9.5	14	5

Table I.21. Statistical parameters of the frequency distribution of the measured ^{131}I activity in thyroids of inhabitants who lived at radioactively contaminated areas of Russia. Standardised to arithmetic mean value.

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

Table I.22. Average thyroid dose, mGy, per 1 kBq/m² of soil contamination with ^{137}Cs in Tula region, Plavsk district.

Parameter	Age groups, years					
	<1	1–2	3–7	8–12	13–17	>17
Mean	0.76	0.57	0.33	0.19	0.14	0.11
SD	0.13	0.10	0.06	0.04	0.03	0.02
Count	96	96	96	96	96	96
Min	0.33	0.1	0.06	0.04	0.03	0.02
Max	1.11	0.83	0.51	0.28	0.2	0.16

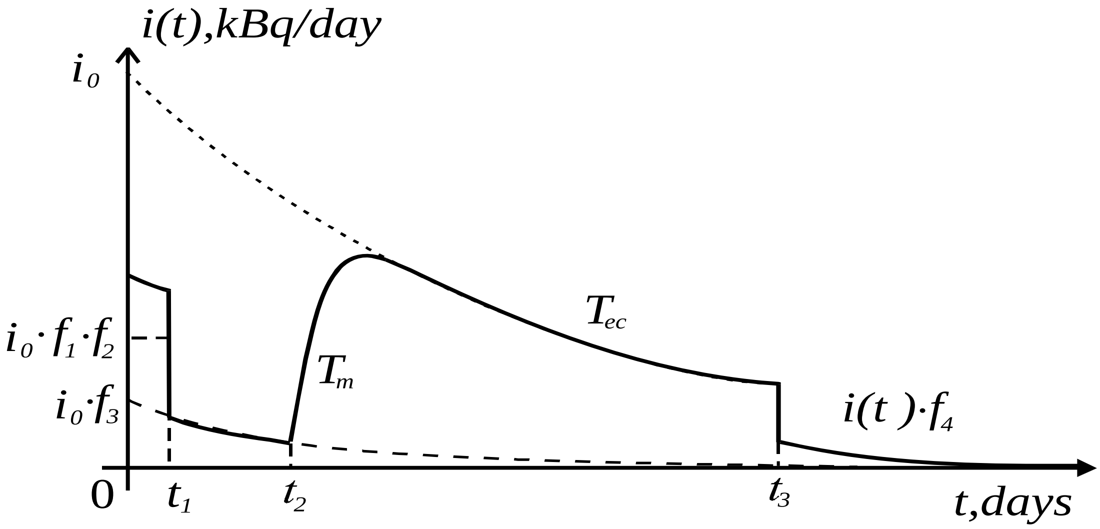


Fig. I.7. Model of [131]I intake into inhabitants of Russia after the Chernobyl accident [I.25, I.26].

Table I.23. Average thyroid dose, mGy estimated by scenario provider (I.Zvonova).

Collective farm	new born			age 1–2 in 1986			age 3–7 in 1986			age 8–12 in 1986			adult (age 20 in 1986).		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
SKORODNOE	**96**	32	192	**83**	28	166	**41**	14	82	**23**	8	46	**14**	5	28
OL'HI	**157**	52	314	**134**	45	268	**67**	22	134	**38**	13	76	**23**	8	46
NOVO-NIKOL'SKIJ	**233**	78	466	**200**	67	400	**100**	33	200	**56**	19	112	**34**	11	68
UDARNIK	**86**	29	172	**74**	25	148	**37**	12	74	**21**	7	42	**13**	4	26
ROSSIA	**165**	55	330	**141**	47	282	**71**	24	142	**39**	13	78	**24**	8	48
DRUZHBA	**196**	65	392	**168**	56	336	**84**	28	168	**47**	16	94	**29**	10	58
KOMMUNAR	**90**	30	180	**70**	23	140	**40**	13	80	**22**	7	44	**13**	4	26
K. MARKSA	**100**	33	200	**80**	27	160	**40**	13	80	**26**	9	52	**15**	5	30
VPERED K KOM.	**67**	22	134	**58**	19	116	**29**	10	58	**16**	5	32	**10**	3	20
KRASNOGOR'E	**130**	43	260	**111**	37	222	**56**	19	112	**31**	10	62	**19**	6	38
XXII PARTS'EZDA	**130**	43	260	**100**	33	200	**60**	20	120	**30**	10	60	**19**	6	38
GORBACHEVSKIJ	**798**	266	1596	**684**	228	1368	**342**	114	684	**192**	64	384	**141**	47	282
TUL'SKAJA NIVA	**66**	22	132	**57**	19	114	**28**	9	56	**16**	5	32	**10**	3	20
PLAVSKIJ	**300**	100	600	**258**	86	516	**129**	43	258	**70**	24	144	**44**	15	88
KOLLEKTIVIST	**278**	93	555	**208**	69	416	**119**	40	238	**67**	22	134	**41**	14	82
LUK'JANOVA	**260**	87	520	**200**	67	400	**110**	40	238	**70**	23	140	**40**	13	80
ZA MIR	**385**	128	770	**330**	110	660	**165**	55	330	**92**	31	184	**56**	19	112
PLAVSK TOWN	**220**	73	440	**188**	63	376	**94**	31	188	**44**	15	88	**18**	6	36
SAFONOVA	**326**	109	652	**280**	93	560	**140**	47	280	**78**	26	156	**48**	16	96

ANNEX I. FORMULARIES

I-1. Calculation for model testing

I-1.1. Deposition of ^{131}I

Table I-1. ^{131}I deposition in Plavsk district calculated on 10 May 1986 (kBq m^{-2}).

Farm number	Collective farm	Average	95% Confidence Interval	
			Lower Bound	Upper Bound
1	KRASNOGOR'E			
2	ZA MIR			
3	IM. SAFONOVA			
4	PLAVSKIJ			
5	VPERED K KOMMUNIZMU			
6	IM. LUK'JANOVA			
7	GORBACHEVSKIJ			
8	TUL'SKAJA NIVA (NIISH)			
9	IM. K. MARKSA			
10	ROSSIA			
11	KOLLEKTIVIST			
12	KOMMUNAR			
13	DRUZHBA			
14	IM.XXII PARTS'EZDA			
15	UDARNIK			
16	OL'HI			
17	SKORODNOE			
18	NOVO-NIKOL'SKIJ			

I-1.2. ^{131}I concentration in milk

Table I-2. Average ^{131}I concentration in milk for specified locations (Bq l^{-1} fresh weight).

Daily averages	1- KRASNOGOR'E			2- ZA MIR			3 - IM. SAFONOVA		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 ….. ….. 30 05 86									
Milk Integrals∗									
Milk ratio to ^{137}Cs**									

∗ For the period 27 April–30 May 1986.
** Determine the ratio of ^{131}I milk concentration on 30 May (Bq L^{-1}) to the ^{137}Cs deposition in the particular location of collective farm (kBq m^{-2}).

Table I-3. Average ^{131}I concentration in milk for specified locations (Bq l^{-1} fresh weight).

Daily averages	4 – PLAVSKIJ			5 - VPERED K KOMMUNIZMU			6 - IM. LUK'JANOVA		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 ….. ….. 30 05 86									
Milk Integrals∗									
Milk ratio to ^{137}Cs **									

∗ For the period 27 April–30 May 1986.
** Determine the ratio of ^{131}I milk concentration on 30 May (Bq L^{-1}) to the ^{137}Cs deposition in the particular location of collective farm (kBq m^{-2}).

Table I-4. Average ^{131}I concentration in milk for specified locations (Bq l^{-1} fresh weight).

Daily averages	7 - GORBACHEVSKIJ			8 - TUL'SKAJA NIVA (NIISH)			9 - IM. K. MARKSA		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 …… …… 30 05 86									
Milk Integrals∗									
Milk ratio to ^{137}Cs **									

∗ For the period 27 April–30 May 1986.
** Determine the ratio of ^{131}I milk concentration on 30 May (Bq L^{-1}) to the ^{137}Cs deposition in the particular location of collective farm (kBq m^{-2}).

Table I-5. Average ^{131}I concentration in milk for specified locations (Bq l^{-1} fresh weight).

Daily averages	10 - ROSSIA			11 - KOLLEKTIVIST			12 - KOMMUNAR		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 ….. ….. 30 05 86									
Milk Integrals∗									
Milk ratio to ^{137}Cs **									

∗ For the period 27 April–30 May 1986.
** Determine the ratio of ^{131}I milk concentration on 30 May (Bq L^{-1}) to the ^{137}Cs deposition in the particular location of collective farm (kBq m^{-2}).

Table I-6. Average ^{131}I concentration in milk for specified locations (Bq l^{-1} fresh weight).

Daily averages	13 - DRUZHBA			14 - IM.XXII PARTS'EZDA			15 - UDARNIK		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 …… ……. 30 05 86									
Milk Integrals∗									
Milk ratio to ^{137}Cs **									

∗ For the period 27 April–30 May 1986.
** Determine the ratio of ^{131}I milk concentration on 30 May (Bq L^{-1}) to the ^{137}Cs deposition in the particular location of collective farm (kBq m^{-2}).

Table I-7. Average ^{131}I concentration in milk for specified locations (Bq l^{-1} fresh weight).

Daily averages	16 - OL'HI			17 - SKORODNOE			18 - NOVO-NIKOL'SKIJ		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 …. …. 30 05 86									
Milk Integrals∗									
Milk ratio to ^{137}Cs **									

∗ For the period 27 April–30 May 1986.
** Determine the ratio of ^{131}I milk concentration on 30 May (Bq L^{-1}) to the ^{137}Cs deposition in the particular location of collective farm (kBq m^{-2}).

Table I-8. Average ^{131}I concentration in milk for specified locations (Bq l^{-1} fresh weight).

Daily averages	PLAVSK TOWN		
	Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound
27 04 86 ….. ….. 30 05 86			
Milk Integrals∗			
Milk ratio to ^{137}Cs **			

∗ For the period 27 April–30 May 1986.
** Determine the ratio of ^{131}I milk concentration on 30 May (Bq L^{-1}) to the ^{137}Cs deposition in the particular location of collective farm (kBq m^{-2}).

I-1.3. ^{131}I thyroid burden

Table I-9. Predictions of ^{131}I thyroid burden for inhabitants of collective farm "ZA MIR" (Bq).

COLECTIVE FARM "ZA MIR" (JUSUPOVO)*			
Daily averages	**age 1–3 in 1986**		
	Arithmetic mean	**95% Confidence interval**	
		Lower Bound	**Upper Bound**
27 04 86 …. ….. 30 05 86			

* Settlement's name in parenthesis.

Table I-10. Predictions of 131i thyroid burden for inhabitants of collective farm "IM. SAFONOVA" (Bq).

COLECTIVE FARM "IM. SAFONOVA" (RAKHMANOVO)*						
Daily averages	**age 2–3 in 1986**			**adult (age 20 in 1986)**		
	Arithmetic mean	**95% Confidence interval**		**Arithmetic mean**	**95% Confidence interval**	
		Lower Bound	**Upper Bound**		**Lower Bound**	**Upper Bound**
27 04 86 ….. ….. 30 05 86						

* Settlement's name in parenthesis.

Table I-11. Predictions of ^{131}I thyroid burden for inhabitants of collective farm "PLAVSKIJ" (Bq).

COLECTIVE FARM "PLAVSKIJ" (JUR'EVO)*			
Daily averages	**age 1–2 in 1986**		
	Arithmetic mean	**95% Confidence interval**	
		Lower Bound	**Upper Bound**
27 04 86 …. …. 30 05 86			

* Settlement's name in parenthesis.

Table I-12. Predictions of ^{131}I thyroid burden for inhabitants of collective farm "IM. LUK'JANOVA" (Bq).

COLLECTIVE FARM IM. LUK'JANOVA (NIKOLSKOE)*			
Daily averages	**age 1–3 in 1986**		
	Arithmetic mean	**95% Confidence interval**	
		Lower Bound	**Upper Bound**
27 04 86 30 05 86			

* Settlement's name in parenthesis.

Table I-13. Predictions of ^{131}I thyroid burden for inhabitants of collective farm "TUL'SKAJA NIVA" (Bq).

COLLECTIVE FARM "TUL'SKAJA NIVA" (MOLOCHNYE DVORY)*						
Daily averages	age 8–10 in 1986			adult (age 20 in 1986)		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 ……. ……. 30 05 86						

* Settlement's name in parenthesis.

Table I-14. Predictions of ^{131}I thyroid burden for inhabitants of collective farm "ROSSIJA" (Bq).

COLLECTIVE FARM "ROSSIJA"(BOLSHIE OZERKI)*						
Daily averages	age 1 in 1986			age 2–3 in 1986		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 ….. ….. 30 05 86						

* Settlement's name in parenthesis.

Table I-15. Predictions of ^{131}I Thyroid burden for inhabitants of collective farm "DRUZHBA" (Bq).

COLLECTIVE FARM "DRUZHBA" (URUSOVO)*			
Daily averages	age 1–3 in 1986		
	Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound
27 04 86 …. …. 30 05 86			

* Settlement's name in parenthesis.

Table I-16. Predictions of ^{131}I Thyroid burden for inhabitants of collective farm "IM.XXII PARTS'EZDA" (Bq).

COLLECTIVE FARM „IM.XXII PARTS'EZDA" (SOROCHINKA)*			
Daily averages	age 9–12 in 1986		
	Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound
27 04 86 …. …. 30 05 86			

* Settlement's name in parenthesis.

Table I-17. Predictions of ^{131}I thyroid burden for inhabitants of collective farm "UDARNIK" (Bq).

COLLECTIVE FARM "UDARNIK" (DIKTATURA)*						
Daily averages	age 1 in 1986			age 2–3 in 1986		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86						
….						
….						
30 05 86						

* Settlement's name in parenthesis.

Table I-18. Predictions of ^{131}I thyroid burden for inhabitants of collective farm "OL'HI" (Bq).

COLLECTIVE FARM "OL'HI" (OL'HI)*						
Daily averages	age 2–3 in 1986			adult (age 20 in 1986)		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86						
….						
….						
30 05 86						

* Settlement's name in parenthesis.

Table I-19. Predictions of ^{131}I thyroid burden for inhabitants of collective farm "SKORODNOE" (Bq).

Daily averages	COLLECTIVE FARM "SKORODNOJE" (GREMJACHEVO)*						COLLECTIVE FARM "SKORODNOJE" (SKORODNOJE)*					
	age 2–3 in 1986			adult (age 20 in 1986).			age 2–3 in 1986			adult (age 20 in 1986).		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86												
….												
….												
30 05 86												

* Settlement's name in parenthesis.

Table I-20. Predictions of ^{131}I thyroid burden for inhabitants of collective farm "NOVO-NIKOL'SKIJ" (Bq).

COLLECTIVE FARM "NOVO-NIKOL'SKIJ" (NOVO-NIKOL'SKIJ)*						
Daily averages	age 2–3 in 1986			adult (age 20 in 1986)		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86						
….						
….						
30 05 86						

* Settlement's name in parenthesis.

Table I-21. Predictions of ^{131}I thyroid burden for inhabitants of collective farm "VPERED K KOMMUNIZMU KRESHINO" (Bq).

COLLECTIVE FARM "VPERED K KOMMUNIZMU" (KRESHINO)*						
Daily averages	age 2–3 in 1986			adult (age 20 in 1986)		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 ….. ….. 30 05 86						

* Settlement's name in parenthesis.

Table I-22. Predictions of ^{131}I thyroid burden for inhabitants of collective farm "VPERED K KOMMUNIZMU OKTJABRSKAI" (Bq).

Daily averages	COLLECTIVE FARM "VPERED K KOMMUNIZMU" (OKTJABRSKAI)*								
	age 2 in 1986			age 8–10 in 1986			adult (age 20 in 1986)		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 ….. ….. 30 05 86									

* Settlement's name in parenthesis.

Table I-23. Predictions of ^{131}I thyroid burden for inhabitants of "TOWN OF PLAVSK" (Bq).

TOWN OF PLAVSK															
Daily averages	new born			age 1–2 in 1986			age 3–7 in 1986			age 8–12 in 1986			adult (age 20 in 1986).		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 …. …. 30 05 86															

* Settlement's name in parenthesis.

I-2. Calculation for model comparison

I-2.1. The mean ^{131}i concentration in ground level air and contribution of the radioiodine phases, i.e., particulate, reactive gaseous and organic phases (optional).

Table I-24. The mean ^{131}I concentration in ground level air (Bq m^{-3}).

Daily averages	1- KRASNOGOR'E						2- ZA MIR					
	Arithmetic mean	95% Confidence interval		radioiodine phases			Arithmetic mean	95% Confidence interval		radioiodine phases		
		Lower Bound	Upper Bound	parti - culate	reactive gaseous I_2	organic CH_3I		Lower Bound	Upper Bound	parti - culate	reactive gaseous I_2	organic CH_3I
27 04 86												
….												
….												
15 05 86												

Table I-25. The mean ^{131}I concentration in ground level air (Bq m^{-3}).

Daily averages	3 - IM. SAFONOVA						4 - PLAVSKIJ					
	Arithmetic mean	95% Confidence interval		radioiodine phases			Arithmetic mean	95% Confidence interval		radioiodine phases		
		Lower Bound	Upper Bound	parti - culate	reactive gaseous I_2	organic CH_3I		Lower Bound	Upper Bound	parti - culate	reactive gaseous I_2	organic CH_3I
27 04 86												
….												
….												
15 05 86												

Table I-26. The mean ^{131}I concentration in ground level air (Bq m^{-3}).

Daily averages	5 - VPERED K KOMMUNIZMU						6 - IM. LUK'JANOVA					
	Arithmetic mean	95% Confidence interval		radioiodine phases			Arithmetic mean	95% Confidence interval		radioiodine phases		
		Lower Bound	Upper Bound	parti - culate	reactive gaseous I_2	organic CH_3I		Lower Bound	Upper Bound	parti - culate	reactive gaseous I_2	organic CH_3I
27 04 86												
….												
….												
15 05 86												

Table I-27. The mean ^{131}I concentration in ground level air (Bq m^{-3}).

Daily averages	7 - GORBACHEVSKIJ						8 - TUL'SKAJA NIVA (NIISH)					
	Arithmetic mean	95% Confidence interval		radioiodine phases			Arithmetic mean	95% Confidence interval		radioiodine phases		
		Lower Bound	Upper Bound	parti - culate	reactive gaseous I_2	organic CH_3I		Lower Bound	Upper Bound	parti - culate	reactive gaseous I_2	organic CH_3I
27 04 86												
….												
….												
15 05 86												

Table I-28. The mean ^{131}I concentration in ground level air (Bq m^{-3}).

Daily averages	9 - IM. K. MARKSA						10 - ROSSIA					
	Arithmetic mean	95% Confidence interval		radioiodine phases			Arithmetic mean	95% Confidence interval		radioiodine phases		
		Lower Bound	Upper Bound	parti - culate	reactive gaseous I_2	organic CH_3I		Lower Bound	Upper Bound	parti - culate	reactive gaseous I_2	organic CH_3I
27 04 86												
….												
….												
15 05 86												

Table I-29. The mean ^{131}I concentration in ground level air (Bq m^{-3}).

Daily averages	11 - KOLLEKTIVIST						12 - KOMMUNAR					
	Arithmetic mean	95% Confidence interval		radioiodine phases			Arithmetic mean	95% Confidence interval		radioiodine phases		
		Lower Bound	Upper Bound	parti - culate	reactive gaseous I_2	organic CH_3I		Lower Bound	Upper Bound	parti - culate	reactive gaseous I_2	organic CH_3I
27 04 86												
….												
….												
15 05 86												

Table I-30. The mean ^{131}I concentration in ground level air (Bq m^{-3}).

Daily averages	13 - DRUZHBA						14 - IM.XXII PARTS'EZDA					
	Arithmetic mean	95% Confidence interval		radioiodine phases			Arithmetic mean	95% Confidence interval		radioiodine phases		
		Lower Bound	Upper Bound	parti - culate	reactive gaseous I_2	organic CH_3I		Lower Bound	Upper Bound	parti - culate	reactive gaseous I_2	organic CH_3I
27 04 86												
….												
….												
15 05 86												

Table I-31. The mean ^{131}I concentration in ground level air (Bq m^{-3}).

Daily averages	15 - UDARNIK						16 - OL'HI					
	Arithmetic mean	95% Confidence interval		radioiodine phases			Arithmetic mean	95% Confidence interval		radioiodine phases		
		Lower Bound	Upper Bound	parti - culate	reactive gaseous I_2	organic CH_3I		Lower Bound	Upper Bound	parti - culate	reactive gaseous I_2	organic CH_3I
27 04 86												
….												
….												
15 05 86												

Table I-32. The mean ^{131}I concentration in ground level air (Bq m^{-3}).

Daily averages	17 - SKORODNOE						18 - NOVO-NIKOL'SKIJ					
	Arithmetic mean	95% Confidence interval		radioiodine phases			Arithmetic mean	95% Confidence interval		radioiodine phasES		
		Lower Bound	Upper Bound	parti - culate	reactive gaseous I_2	organic CH_3I		Lower Bound	Upper Bound	parti - culate	reactive gaseous I_2	organic CH_3I
27 04 86												
….												
….												
15 05 86												

Table I-33. The mean ^{131}I concentration in ground level air (Bq m^{-3}).

Daily averages	TOWN PLAVSK					
	Arithmetic mean	95% Confidence interval		radioiodine phases		
		Lower Bound	Upper Bound	particulate	reactive gaseous I_2	organic CH_3I
27 04 86 …. …. 15 05 86						

I-2.2. *^{131}I concentration in vegetation*

Table I-34. Average ^{131}I concentration in grass for specified locations (Bq kg^{-1} fresh weight).

Daily averages	1- KRASNOGOR'E			2- ZA MIR			3 - IM. SAFONOVA		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 …. …. 30 05 86									
Integrals∗									

∗ For the period 27 April–30 May 1986.

Table I-35. Average ^{131}I concentration in grass for specified locations (Bq kg^{-1} fresh weight).

Daily averages	4 – PLAVSKIJ			5 - VPERED K KOMMUNIZMU			6 - IM. LUK'JANOVA		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 …. …. 30 05 86									
Integrals∗									

∗ For the period 27 April–30 May 1986.

Table I-36. Average ^{131}I concentration in grass for specified locations (Bq kg^{-1} fresh weight).

Daily averages	7 - GORBACHEVSKIJ			8 - TUL'SKAJA NIVA (NIISH)			9 - IM. K. MARKSA		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 …. …. 30 05 86									
Integrals∗									

∗ For the period 27 April–30 May 1986.

Table I-37. Average ^{131}I concentration in grass for specified locations (Bq kg-1 fresh weight).

Daily averages	10 - ROSSIA			11 - KOLLEKTIVIST			12 - KOMMUNAR		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 …. …. 30 05 86									
Integrals∗									

∗ For the period 27 April–30 May 1986.

Table I-38. Average ^{131}I concentration in grass for specified locations (Bq kg^{-1} fresh weight).

Daily averages	13 - DRUZHBA			14 - IM.XXII PARTS'EZDA			15 - UDARNIK		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 …. …. 30 05 86									
Integrals∗									

∗ For the period 27 April–30 May 1986.

Table I-39. Average ^{131}I concentration in grass for specified locations (Bq kg^{-1} fresh weight).

Daily averages	16 - OL'HI			17 - SKORODNOE			18 - NOVO-NIKOL'SKIJ		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 …. …. 30 05 86									
Integrals∗									

∗ For the period 27 April–30 May 1986.

I-2.3. ^{131}I intakes

Table I-40. Predictions of average ^{131}I intake per day for inhabitants of collective farm "ZA MIR" (Bq d^{-1}).

COLECTIVE FARM "ZA MIR" (JUSUPOVO)*			
Daily averages	age 1–3 in 1986		
	Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound
27 04 86 …. ….. 30 05 86			

* Settlement's name in parenthesis.

Table I-41. Predictions of average ^{131}I intake per day for inhabitants of collective farm "IM. SAFONOVA" (Bq d^{-1}).

COLECTIVE FARM "IM. SAFONOVA" (RAKHMANOVO)*						
Daily averages	age 2–3 in 1986			adult (age 20 in 1986)		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 ….. ….. 30 05 86						

* Settlement's name in parenthesis.

Table I-42. Predictions of average ^{131}I intake per day for inhabitants of collective farm "PLAVSKIJ" (Bq d^{-1}).

COLECTIVE FARM "PLAVSKIJ" (JUR'EVO)*			
Daily averages	age 1–2 in 1986		
	Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound
27 04 86 …. …. 30 05 86			

* Settlement's name in parenthesis.

Table I-43. Predictions of average ^{131}I intake per day for inhabitants of collective farm "IM. LUK'JANOVA" (Bq d^{-1}).

COLLECTIVE FARM IM. LUK'JANOVA (NIKOLSKOE)*			
Daily averages	age 1–3 in 1986		
	Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound
27 04 86 …. …. 30 05 86			

* Settlement's name in parenthesis.

Table I-44. Predictions of average ^{131}I intake per day for inhabitants of collective farm "TUL'SKAJA NIVA" (Bq d^{-1}).

COLLECTIVE FARM "TUL'SKAJA NIVA" (MOLOCHNYE DVORY)*						
Daily averages	age 8–10 in 1986			adult (age 20 in 1986)		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86 ……. ……. 30 05 86						

* Settlement's name in parenthesis.

Table I-45. Predictions of average ^{131}I intake per day for inhabitants of collective farm "ROSSIJA" (Bq d^{-1}).

COLLECTIVE FARM "ROSSIJA"(BOLSHIE OZERKI)*						
Daily averages	age 1 in 1986			age 2–3 in 1986		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86						
…..						
…..						
30 05 86						

* Settlement's name in parenthesis.

Table I-46. Predictions of average ^{131}I intake per day for inhabitants of collective farm "DRUZHBA" (Bq d^{-1}).

COLLECTIVE FARM "DRUZHBA" (URUSOVO)*			
Daily averages	age 1–3 in 1986		
	Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound
27 04 86			
….			
….			
30 05 86			

* Settlement's name in parenthesis.

Table I-47. Predictions of average ^{131}I intake per day for inhabitants of collective farm "IM.XXII PARTS'EZDA" (Bq d^{-1}).

COLLECTIVE FARM „IM.XXII PARTS'EZDA" (SOROCHINKA)*			
Daily averages	age 9–12 in 1986		
	Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound
27 04 86			
….			
….			
30 05 86			

* Settlement's name in parenthesis.

Table I-48. Predictions of average ^{131}I intake per day for inhabitants of collective farm "UDARNIK" (Bq d^{-1}).

COLLECTIVE FARM "UDARNIK" (DIKTATURA)*						
Daily averages	age 1 in 1986			age 2–3 in 1986		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86						
….						
….						
30 05 86						

* Settlement's name in parenthesis.

Table I-49. Predictions of average ^{131}I intake per day for inhabitants of collective farm "OL'HI" (Bq d^{-1}).

COLLECTIVE FARM "OL'HI" (OL'HI)*						
Daily averages	age 2–3 in 1986			adult (age 20 in 1986)		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86						
….						
….						
30 05 86						

* Settlement's name in parenthesis.

Table I-50. Predictions of average ^{131}I intake per day for inhabitants of collective farm "SKORODNOE" (Bq d^{-1}).

Daily averages	COLLECTIVE FARM "SKORODNOJE" (GREMJACHEVO)*						COLLECTIVE FARM "SKORODNOJE" (SKORODNOJE)*					
	age 2–3 in 1986			adult (age 20 in 1986).			age 2–3 in 1986			adult (age 20 in 1986).		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86												
….												
….												
30 05 86												

* Settlement's name in parenthesis.

Table I-51. Predictions of average ^{131}I intake per day for inhabitants of collective farm "NOVO-NIKOL'SKIJ" (Bq d^{-1}).

COLLECTIVE FARM "NOVO-NIKOL'SKIJ" (NOVO-NIKOL'SKIJ)*						
Daily averages	age 2–3 in 1986			adult (age 20 in 1986)		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86						
….						
….						
30 05 86						

* Settlement's name in parenthesis.

Table I-52. Predictions of average ^{131}I intake per day for inhabitants of collective farm "VPERED K KOMMUNIZMU KRESHINO" (Bq d^{-1}).

COLLECTIVE FARM "VPERED K KOMMUNIZMU" (KRESHINO)*						
Daily averages	age 2–3 in 1986			adult (age 20 in 1986)		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86						
…..						
…..						
30 05 86						

* Settlement's name in parenthesis.

Table I-53. Predictions of average ^{131}I intake per day for inhabitants of collective farm "VPERED K KOMMUNIZMU OKTJABRSKAI" (Bq d^{-1}).

Daily averages	COLLECTIVE FARM "VPERED K KOMMUNIZMU" (OKTJABRSKAI)*								
	age 2 in 1986			age 8–10 in 1986			adult (age 20 in 1986)		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86									
…..									
…..									
30 05 86									

* Settlement's name in parenthesis.

Table I-54. Predictions of average ^{131}I intake per day for inhabitants of "TOWN OF PLAVSK" (Bq d^{-1}).

Daily averages	TOWN OF PLAVSK														
	new born			age 1–2 in 1986			age 3–7 in 1986			age 8–12 in 1986			adult (age 20 in 1986)		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86															
….															
….															
30 05 86															

* Settlement's name in parenthesis.

I-2.4. Mean doses to thyroid from inhalation

Table I-55. ^{131}I mean doses to thyroid from inhalation – committed equivalent dose to thyroid (mSv).

Collective farm	new born			age 1–2 in 1986			age 3–7 in 1986			age 8–12 in 1986			adult (age 20 in 1986)		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
KRASNOGOR'E															
ZA MIR															
IM. SAFONOVA															
PLAVSKIJ															
VPERED K KOMMUNIZMU															
IM. LUK'JANOVA															
GORBACHEVSKIJ															
TUL'SKAJA NIVA (NIISH)															
IM. K. MARKSA															
ROSSIA															
KOLLEKTIVIST															
KOMMUNAR															
DRUZHBA															
IM.XXII PARTS'EZDA															
UDARNIK															
OL'HI															
SKORODNOE															
NOVO-NIKOL'SKIJ															
PLAVSK TOWN															

I-2.5. Mean doses to thyroid from ingestion

Table I-56. ^{131}I mean doses to thyroid from ingestion - committed equivalent dose to thyroid (mSv).

Collective farm	new born			age 1–2 in 1986			age 3–7 in 1986			age 8–12 in 1986			adult (age 20 in 1986)		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
KRASNOGOR'E															
ZA MIR															
IM. SAFONOVA															
PLAVSKIJ															
VPERED K KOMMUNIZMU															
IM. LUK'JANOVA															
GORBACHEVSKIJ															
TUL'SKAJA NIVA (NIISH)															
IM. K. MARKSA															
ROSSIA															
KOLLEKTIVIST															
KOMMUNAR															
DRUZHBA															
IM.XXII PARTS'EZDA															
UDARNIK															
OL'HI															
SKORODNOE															
NOVO-NIKOL'SKIJ															
PLAVSK TOWN															

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APPENDIX II. “SCENARIO W” – MAZOVIA SCENARIO DESCRIPTION VALIDATION OF ENVIROMNEMTAL MODELS USING DATA FROM CHERNOBYL AIR POLLUTION IN THE MAZOVIA AREA

II.1. Background

The Working Group on Iodine (IWG) which has been established in the framework of the EMRAS programme continues some of the work of previous international comparison and validation studies that were aimed at increasing confidence in methods and models for the assessment of radiation exposure related to the environmental releases. The main activity of the IWG will be to carry out environmental modeling exercises on radioiodine to test and compare model predictions with environmental data and to compare modeling approaches and model predictions among several assessors.

In 2004, the main objective of the exercise which had been carried out by IWG was to evaluate the performance of the participating models in dose reconstruction exercises in cases when ^{137}Cs (^{129}I) tracer is used to estimate the deposition of ^{131}I;

Nine experts in environmental modeling participated in the Plavsk Scenario, dealing with areas of assessment modeling for which the capabilities are not yet well established. The following problems were identified to be most in need of attention:

(1) Constant isotopic ratio $^{131}I/^{137}Cs$ gives fairly good approximation of ^{131}I deposition, providing that the radioactive fallout can be classified as wet; for other cases approaches should be applied with more complex relationships ^{131}I deposition to ^{137}Cs deposition.
(2) Model for grass interception fraction in a case of mixed (dry and wet) radioiodine fallout need to be carefully considered.
(3) Uncertainty associated with prediction of ^{131}I concentration in air over the particular location strongly depends on partition of airborne radioiodine into different forms (particulate, elemental, organic).
(4) The lack of knowledge about the correct time when cows were put on a pasture seems to be the most important factor of mispredictions of ^{131}I concentration in milk and related ingestion doses.

In general, one could observe the remarkably improvement in models’ performance comparing with previous radioiodine scenarios. Predictions of the various models were within a factor of three of the observations; discrepancies between the estimates of average doses to thyroid produced by most participants not exceeded a factor of ten.

The second most important issue of IWG model validation study is to assess the applicability of the models to countermeasure response. Scenario W gives the opportunity to check models performance in a case of an assessment of the effectiveness of short-term protective measures that had been applied in the MAZOVIA province in Poland in order to reduce the exposure of the thyroid gland. These countermeasures included: application of stable iodine agent for thyroid blocking and fresh milk consumption and pasturage ban.

However, the question about effectiveness of these countermeasures still remains important, not only from the point of view of the uncertainty of estimates of radiation doses to thyroid, and probability of induced thyroid cancers for population due to the Chernobyl accident, but especially from the point of view regarding elaboration of consistent and effective emergency plans in a case of any radioiodine releases to the environment.

Such plans might also require a high quality monitoring system which ensures completeness and the site specific relevance of the collected data as well as validated decision support models.

The dose assessment professionals, could find an opportunity to examine their skills, methods and conceptual approaches for the specified level of the assessment, when applied countermeasures need to be evaluated with respect of their real usefulness. The data provided by this exercise enable the risk manager to identify the most important sources of uncertainty with respect to the radiological assessments involving ^{131}I in the risk reduction measures context. This could heldp to identify improvements of the current emergency response system.

II.2. Introduction

II.2.1. General descriptions of the Mazovia Province

The Mazovia Province (Polish: Wojewodztwo Mazowieckie) Mazovia, in Poland, was selected as the scenario area (see Figure II.1). This province is the largest and most populated of the sixteen Polish administrative regions or voivodships. It covers an area of 35 598 km² in eastern-central Poland, equal to over 11% of Poland's territory, and contains nearly 5.1 million inhabitants and consists of 42 counties. Most Mazovians are urban residents (64%), greater Warsaw being the largest urban centre (over 2.8 million).

Its principal cities are Warsaw (population 1.6 million) in the centre, Radom (230 000) in the south, Plock (130 000) in the west, Siedlce (75 000) in the east, and Ostroleka (55 000) in the north.

The region's main river is the Vistula with its right-bank tributaries: the Narew and the Bug. As the region has almost no natural lakes, two artificial lakes, the Zegrze Lake on the outskirts of Warsaw and the Wloclawek Lake between Wloclawek and Plock, play a major role. Besides Warsaw, the national capital, Mazovia's major cities include Radom, Plock, Siedlce, Ciechanow and Ostroleka.

At the same time, Mazovia supports the country's largest rural population (1.8 million), as much as 67% of the area of the province is under cultivation, accounting for 13% of Poland's total acreage of agricultural land. Mazovia is a horticultural and orcharding centre. The expansion of agriculture is encouraged by the closeness of Warsaw's vast market. The region's agricultural production is the basis for the food-processing sector. Even so, much of Mazovia's agricultural potential remains unused. Small farms continue to prevail.

II.2.2. Chernobyl plume over Mazovia Province

The origin of contaminated air, which moved up to Poland at probably 28 April 1986 00:00 GMT[10] (see Figures II.2 and II.3) was unknown, however just preliminary spectrometric measurements (performed in CLOR 28 April 1986 10:10–13:15) of particulates collected on filters indicated that there were fission products and the following analysis suggested it was caused by a reactor accident. It was confirmed by presence of ^{134}Cs and small contribution of the elements of boiling point above 1500°K, which usually occur in a greater amount in fallout after nuclear weapons explosions. The gamma spectrometric measurements of airborne

[10] 28 April 1986 at 07:00 monitoring station Mikolajki reported 700 fold higher global beta in air.

particulates activity collected on filters allowed identifying of above twenty artificial radionuclides, the presence of Xenonium-133 in air was also evident. In addition, investigations of physic-chemical phases of ^{131}I were carried out by filtration of air trough out the filter set with fiber medium, charcoal and charcoal impregnated paper. About 59 ± 12 % of the particulate radioactive iodine was collected during the few days of measurement, later the percentage of airborne particulate decreased. Particularly, elevated levels of airborne ^{131}I during the first hours of 28 April 1986 (above 100 Bq m^3) threatened that thyroid doses to children could have exceeded 50 mSv. In the late afternoon of 28 April 1986 the message about Chernobyl nuclear power plant accident was revealed by western media. On 29 April 1986 about 06:00 (after all night discussions) the Governmental Commission for Assessment of Nuclear Radiation and Prophylactic Measures was created which recommended (on 29 April 1986 11:00) to introduce countermeasures in order to diminish children thyroids exposure to radioiodine. These countermeasures included: administration of stable iodine in form of solution (so called "Lugol liquid") to children and teenagers up to 16 of age, consumption ban of milk from cows fed with green fodder, and cows' pasturage limitation. The distribution of stable iodine liquid started in the evening hours of 29 April 1986 and was continued in 30 April 1986 (when 75% of children population get stable iodine) as well as in the first days of May, depending on resources in particular districts. Generally, in the distribution of "Lugol liquid" the kindergartens, schools, pharmacies and medical centres were engaged. Regarding diet restrictions (milk and milk product and leafy vegetables) as well as cows' pasturage ban there are no means to make items compulsory but only to raise the level of public recognition.

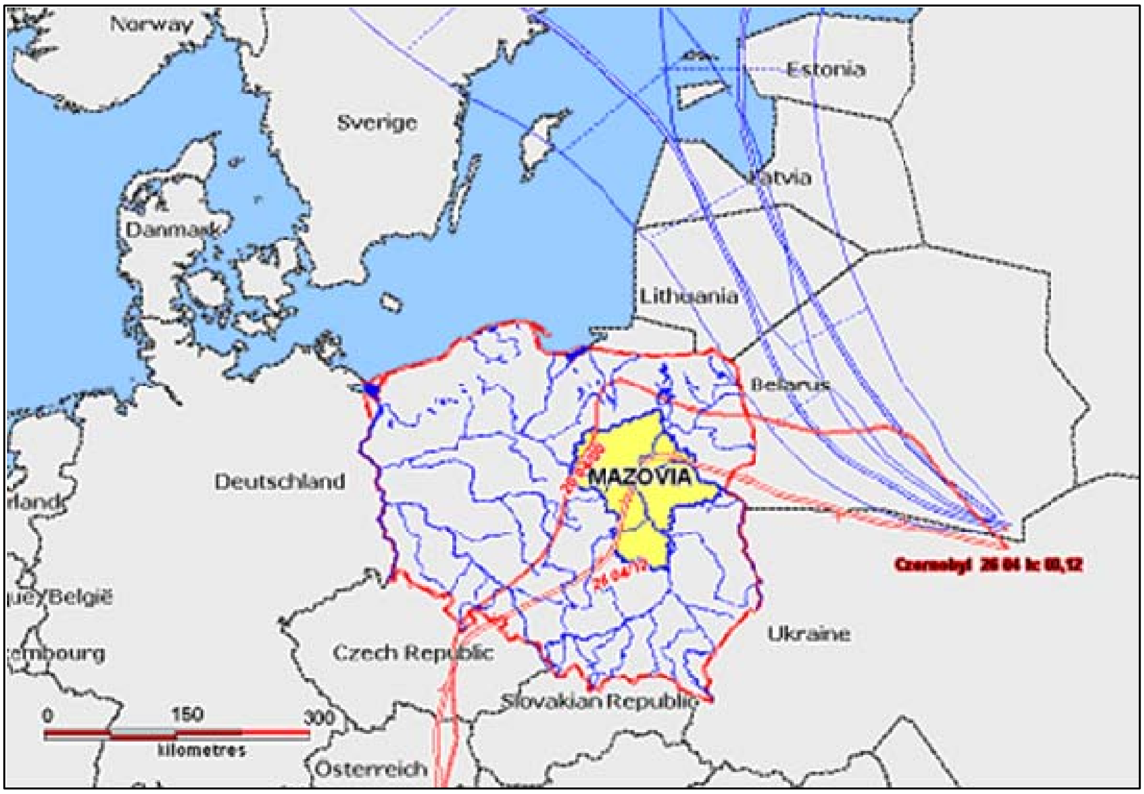

Fig. II.1. Location of the Mazovia province in Europe.

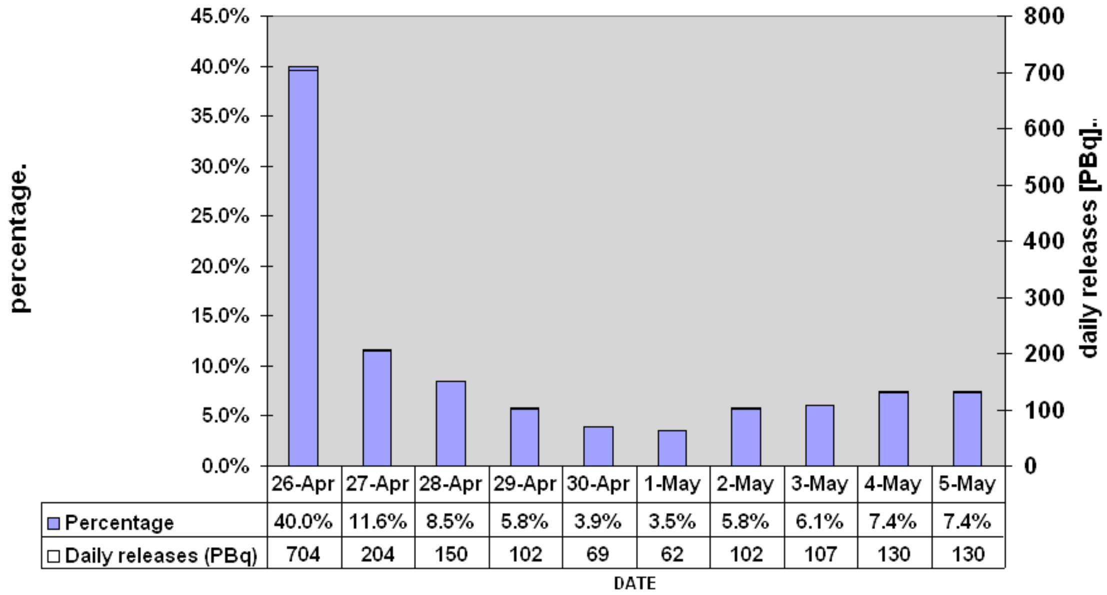

Fig. II.2. Estimated daily releases of ^{131}I during the accident [II.1, II.2].

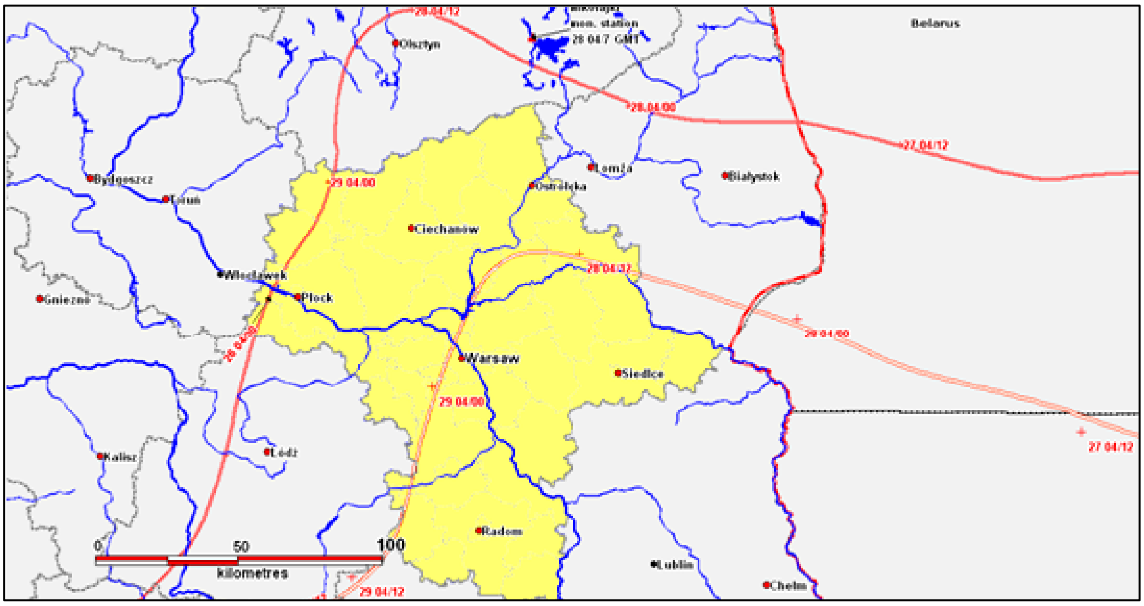

Fig. II.3. Passage of contaminated air over Mazovia province after Chernobyl accident.

II.3. Assessment tasks

II.3.1. General

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; for various countermeasures variants; and
(2) a model comparison in which calculation of model integrated air concentration, predictions of the mean inhalation and ingestion dose to the thyroid for different age groups 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 suggested starting point of calculation is evaluation of deposition of ^{131}I over the Mazovia province on the basis of provided ^{131}I airborne concentrations. The models that would not be able to use air data, could reconstruct ^{131}I deposition applying ^{137}Cs content in soil (provided in Tables II.23–II.25) although with awareness of higher uncertainty.

The following subsections contain descriptions of the calculation endpoints required in this test scenario. The first group consists of quantities for which measurements exist and against model predictions can be tested, the second group consists of quantities (e.g. radiation doses) which can only be predicted but not tested. For each quantity, a 95% confidence interval (2.5% and 97.5% lower and upper bound estimates, respectively) should be given to quantify the expected uncertainty of the results. It is anticipated that these values will be subjective confidence intervals, given the nature of the data provided for this scenario. For the quantities specified in Section II.3.2, modellers are required to estimate the arithmetic mean for the time period specified and for the specified location. Annex II includes the template tables for predictions, additionally the template Excel tables are provided. Participants are kindly asked to fill up Excel file templates tables rather than Word format templates tables but both forms are acceptable.

II.3.2. Calculations for model testing

II.3.2.1. ^{131}I concentration in milk for particular variants of countermeasures specified

— **Cows pasturage limitation**

Estimate an arithmetic mean of daily samples values of ^{131}I concentration in milk (Bq L^{-1}) during the period 27 April–31 May 1986 for collective farm (named FALENTY) situated near Warsaw where it was reported that cows had been kept in cowshed during the whole period (see Figure II.4). Estimate the integrated ^{131}I concentration in milk (Bq d L^{-1}) for the period 27 April–31 May 1986 in location specified above. (See template Table II-1 in Annex II.)

— **Average milk from big dairy**

Estimate an arithmetic mean of daily values of ^{131}I concentration in milk (Bq L^{-1}) for the period 27 April–31 May 1986 of composite milk samples taken daily from the WARSAW Town dairy. Estimate the integrated ^{131}I concentration in milk (Bq d L^{-1}) for the period 27 April–31 May 1986 in location specified above. (See template Table II-1 in Annex II.)

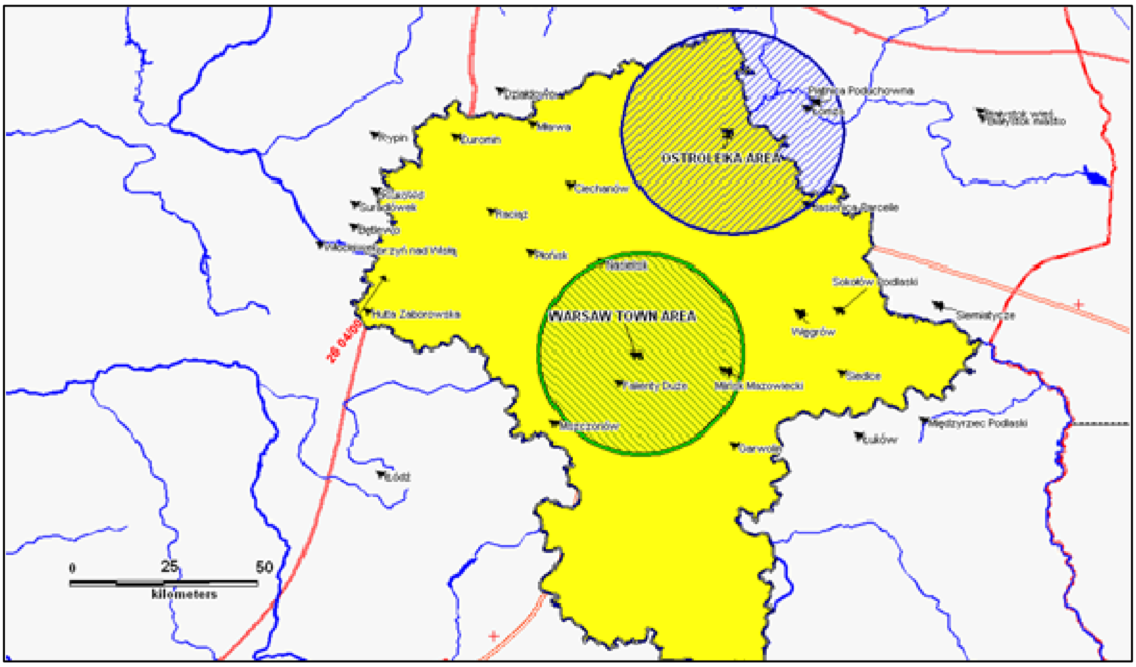

Fig. II.4. Localization of Warsaw town area and Ostroleka area in the Mazovia province. Milk sampling places during 28 April–31 May1986.

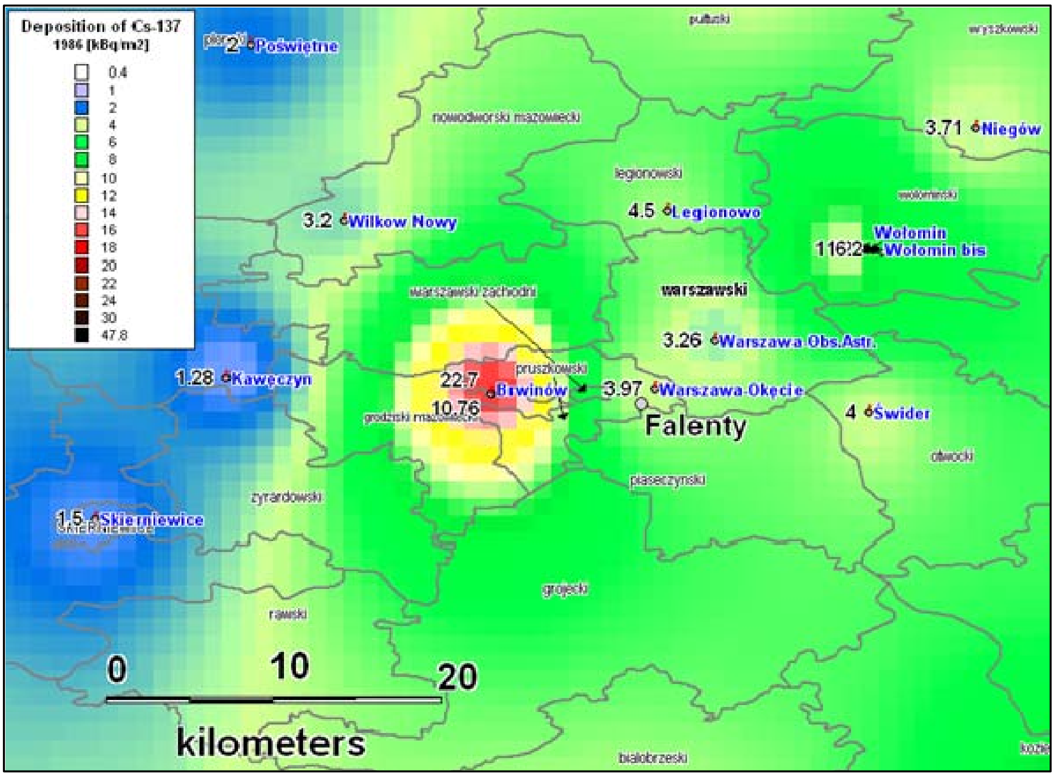

Fig. II.5. Location of Falenty Dairy- about 2.5 km from Warsaw-Okecie Airport. Sampling points and ^{137}Cs deposition are presented.

— **No pasture limitation**

Estimate an arithmetic mean of daily values of ^{131}I concentration in milk (Bq L^{-1}) for the period 27 April–30 May 1986 of composite milk samples taken daily from the OSTROLEKA dairy. It was reported that most of the private farms in this area suffer from shortage of uncontaminated hay. See section Estimate the integrated ^{131}I concentration in milk (Bq d $^{L-1}$) for the period 27 April–31 May 1986 in location specified above. (See template Table II-1 in Annex II.)

II.3.2.2. ^{131}I thyroid burden

Estimate an arithmetic mean of ^{131}I thyroid content (Bq) for test age groups of urban population (Warsaw town) and rural population (Ostroleka area) during the period 27–31 May 1986. The proposed age groups were selected to provide good statistics for model validation purposes as follows:

Warsaw inhabitants (see Tables II-2 to II-4 in Annex II):

- Children at the age from 3 to 10, who had been given a stable iodine dose of 30 mg on 29 April 1986, 12:00;
- Children at the age from 3 to 10 who had been given a stable iodine dose of 30 mg on 30 April 1986, 12:00;
- Teenagers at the age from 10 to 17 who had been given a stable iodine dose of 60 mg on 29 April 1986, 12:00;
- Teenagers at the age from 10 to 17 who had been given a stable iodine dose of 60 mg on April 1986, 12:00;
- Adults at the age 20 who had not taken any stable iodine dose,
- Adults at the age 20 who had voluntary taken a stable iodine dose of 60 mg on 29 April 1986, 12:00;
- Adults at the age 20 who had voluntary taken a stable iodine dose of 60 mg on 30 April 1986, 12:00.

Ostroleka area inhabitants (see Tables II-5 to II-7 in Annex II):

- Children at the age from 3 to 10, who had been given a stable iodine dose of 30 mg on 29 April 1986, 12:00;
- Children at the age from 3 to 10 who had been given a stable iodine dose of 30 mg on 30 April 1986, 12:00;
- Teenagers at the age from 10 to 17 who had been given a stable iodine dose of 60 mg on 29 April 1986, 12:00;
- Teenagers at the age from 10 to 17 who had been given a stable iodine dose of 60 mg on April 1986, 12:00;
- Adults at the age 20 who had not taken any stable iodine dose;
- Adults at the age 20 who had voluntary taken a stable iodine dose of 60 mg on 29 April 1986, 12:00;
- Adults at the age 20 who had voluntary taken a stable iodine dose of 60 mg on 30 April 1986, 12:00.

II.3.3. Calculations for model comparison

II.3.3.1. Integrated air concentration of ^{131}I

In the scenario, both original measurement record data from two air sampling stations (A and B) are presented (see Tables II.16 to II.19) as well as the average daily air concentrations of ^{131}I are provided in order to make easier calculations of subsequent endpoints of the scenario. The latter data have been evaluated by authors of Scenario; however different approach could be developed by other participants.

To compare the starting point of the predictions, the participants are asked to provide the total integrated ^{131}I air concentration and contributions of the radioiodine phases (expressed as ratio of appropriate integrals) see Table II-8 in Annex II.

II.3.3.2. ^{131}I concentration in pasture grass

Estimate an arithmetic mean of ^{131}I in grass in two test location (Warsaw town, Ostroleka area) in the subsequent days of ^{131}I deposition, i.e., from 27 April to 25 May 1986. Note that initially there were no rains in places the grass samples had been taken.

II.3.3.3. Inhalation dose

This point may give an opportunity for the dose assessment professionals to examine their skills, methods and conceptual approaches for the specified level of the assessment, when applied countermeasures need to be evaluated with respect of their real practicability.

Estimate the mean dose to thyroid from inhalation (committed equivalent dose to thyroid in mSv) for the specified age groups at various variants of countermeasures applied in two locations, i.e., Warsaw town and rural Ostroleka area. To simplify the interpretation of the predictions of various models, the same building filtration factors and residence time should be assumed for different dates of taking stable iodine dose. One could consider different dynamic of contaminated plume for pre-selected location (see Tables II-10 and II-11 in Annex II).

For models, not designed with the fixed set of dose conversion factors, the use of the factors for the dose predictions of six different age groups is recommended (see Table II.1).

II.3.3.4. Ingestion dose

Estimate the dose to thyroid from ingestion (committed equivalent dose to thyroid in mSv) for the specified age groups for various variants of countermeasures applied in two locations, i.e., Warsaw town and rural Ostroleka area. In this case, the countermeasures involve a combination of pasturage limitation as well as administration of stable iodine at different time. The most probable dates of putting cows on a pasture has been selected. For the sake of model comparison transparency, participants would be asked to make assumption, that whole milk is consumed by representatives of the particular age groups (see Tables II-12 and II-13 in Annex II).

For models not designed with the fixed set of dose conversion factors, the use of the following factors for the dose predictions of six different age groups is recommended (see Table II.2).

Table II.1. Thyroid dose coefficients for inhalation.

Pathway	Child 1 y	Child 5 y	Child 10 y	Child 15 y	Man
Inhalation[II.3] [Sv/Bq]	2.5×10^{-6}	1.5×10^{-6}	7.4×10^{-7}	4.8×10^{-7}	3.1×10^{-7}

Table II.2. Thyroid dose coefficients for ingestion.

Pathway	Child 1 y	Child 5 y	Child 10 y	Child 15 y	Man
Ingestion [II.4] [Sv/Bq]	3.6×10^{-6}	2.1×10^{-6}	1.0×10^{-6}	6.8×10^{-7}	4.3×10^{-7}

II.4. Input information

II.4.1. Environmental data

II.4.1.1. Agriculture information

The Mazovian Voivodship (in Polish Wojewodztwo Mazowieckie) covers an area of 35 598 km² in eastern-central Poland, equal to over 11% of Poland’s territory, and contains nearly 5.1 million inhabitants and consists of 42 counties. Most Mazovians are urban residents (64%), greater Warsaw being the largest urban centre (over 2.8 million).

At the same time, Mazovia supports the country’s largest rural population (1.8 million), as much as 67% of the area of the province is under cultivation, accounting for 13% of Poland’s total area of agricultural land.

II.4.1.2. Distribution of milk production

From point of view Scenario requirements only milk production might be useful if one could evaluate contributions of particular areas to the average milk contamination in Warsaw. Table II.5 presents selected information about milk production and usage of pasturing land in particular counties of Mazovia province. These data have been taken from Polish Central Statistical Office on the basis of agricultural census in 1989. There is no data about the distribution of milk production over Mazovia province, only information that milk in Warsaw is predominantly delivered by following counties: grodziski mazowiecki, grójecki, legionowski, minski, nowodworski mazowiecki, otwocki, piaseczynski, pruszkowski, pultuski, warszawski, warszawski zachodni, wolominski, wyszkowski. It does not excluded possibility of occurrence milk from other sites on Warsaw market.

II.4.1.3. Yield of the pasture at the time of accident

In 1986, there was a hot spring with temperatures of about 20°C and it stimulated the growth, especially of pasture grass that reached about 60–75% of its maximum biomass at end of April 1986.

The yield was about 0.4 kg m^{-2} fresh weight. Based on data of Central Statistical Office, one can assume that the average yield of grass for MAZOWIA region was 0.5 ± 0.05 kg m^{-2}. There are no remarkable differences during the years 1989–1993 among other neighboring regions (see Table II.3 and Figure II.6.

The yield of the pasture for intensively cultivated areas (nutrition usage) is less important because these areas are harvested (three times per year) for winter pasture storage (see Table II.4).

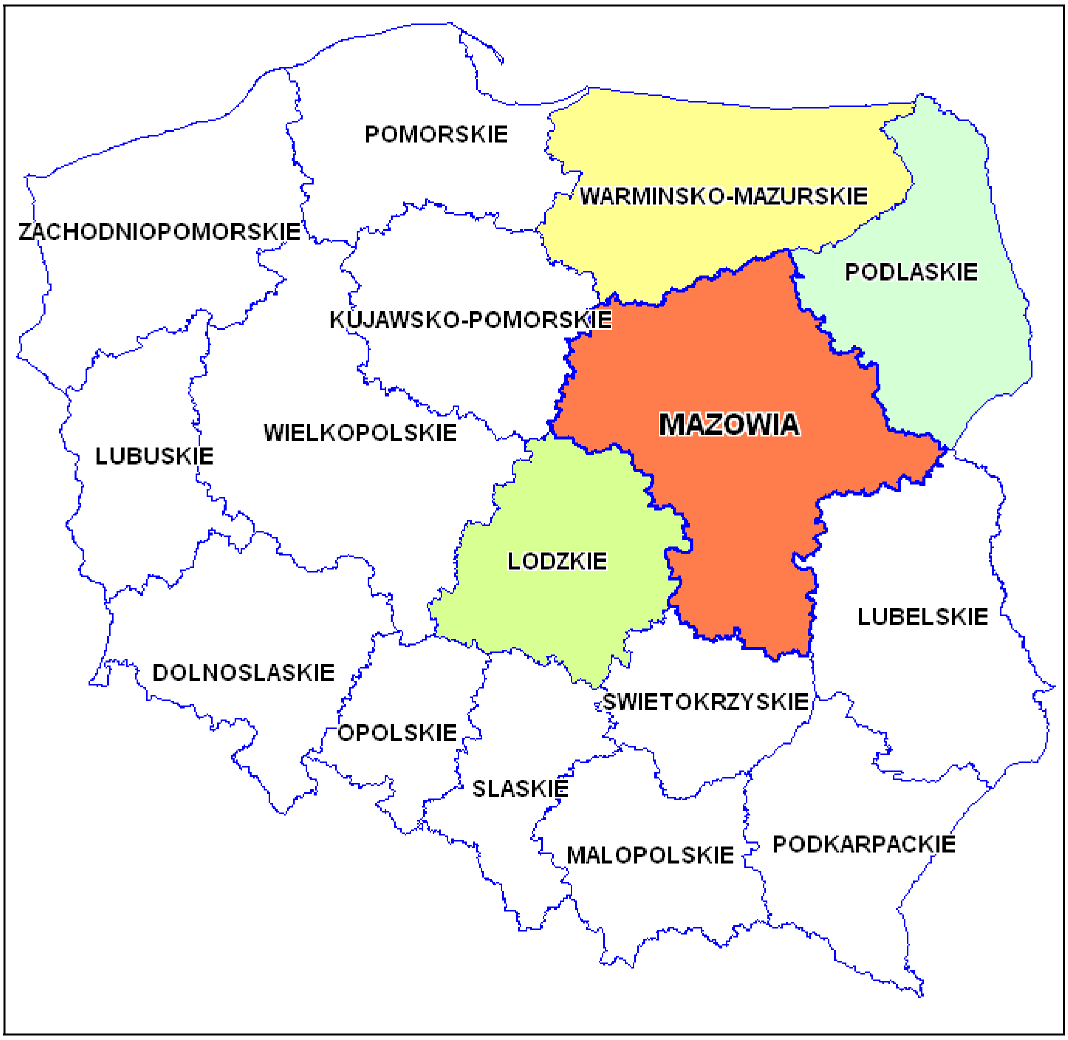

Fig. II.6. Mazovia region and neighboring regions specified in Tables II.3 and II.4.

Table II.3. Average yield of extensively cultivated grass (kg m^{-2}) in the particular regions of Poland.

Region	**Yield of grass (dry mass) meadows (extensively cultivated)**						
	1989 [kg/m^2]	**1990** [kg/m^2]	**1991** [kg/m^2]	**1992** [kg/m^2]	**1993** [kg/m^2]	**Average** [kg/m^2]	***SD*** [kg/m^2]
Lodzkie	0.50	0.46	0.55	0.53	0.41	0.49	*0.06*
Mazowia	0.52	0.43	0.56	0.51	0.48	0.50	*0.05*
Podlaskie	0.52	0.38	0.56	0.45	0.46	0.47	*0.07*
Warminsko-Mazurskie	0.53	0.42	0.55	0.46	0.49	0.49	*0.05*
Total						0.49	*0.01*

Table II.4. Average yield of intensively cultivated grass (kg m^{-2}) in the particular regions of Poland.

Region	Yield of grass (dry mass) pasturing land (intensively cultivated)						
	1989	**1990**	**1991**	**1992**	**1993**	**Average**	***SD***
	[kg/m^2]	**[kg/m^2]**	**[kg/m^2]**	**[kg/m^2]**	**[kg/m^2]**	**[kg/m^2]**	**[kg/m^2]**
Lodzkie	1.81	1.76	1.96	1.82	1.54	1.78	*0.15*
Mazowia	1.71	1.50	1.74	1.61	1.48	1.61	*0.12*
Podlaskie	2.22	1.82	2.33	1.87	1.98	2.04	*0.22*
Warminsko-Mazurskie	2.18	1.81	2.22	1.68	1.98	1.97	*0.23*
Total						1.85	*0.20*

Table II.5. Selected agricultural information by counties.

Counties name	Milk [thousants liters]	Number of cows	Meadows [ha]	Pasturing land [ha]
bialobrzeski	31855.6	9151	5628	4245
ciechanowski	64292.7	18469	8672	6271
garwolinski	78826.4	22644	11615	4048
gostyninski	26968.2	7747	4275	1886
grodziski mazowiecki	12894.0	3704	4025	2766
grojecki	37648.2	10815	7157	7004
kozienicki	30626.8	8798	6666	4255
legionowski	7059.7	2028	3107	1961
lipski	39183.4	11256	2827	1720
losicki	34149.7	9810	7676	4184
makowski	67425.7	19369	11511	6366
minski	65507.6	18818	15996	5639
mlawski	88956.4	25554	18985	10745
nowodworski mazowiecki	20549.0	5903	4417	4418
ostrolecki	178309.7	51222	40486	26064
OSTROLEKA	581.3	167	265	112
ostrowski mazowiecki	86248.1	24776	12567	6853
otwocki	20218.3	5808	7263	2529
piaseczynski	10036.0	2883	2372	2565
PLOCK	466.4	134	574	409
plocki	93878.7	26968	10058	7578
plonski	87184.5	25045	11821	5492
pruszkowski	3825.7	1099	1639	1051
przasnyski	88002.6	25280	15543	11171
przysuski	42239.8	12134	5777	4259
pultuski	48913.1	14051	8100	4586
RADOM	2099.1	603	488	260
radomski	82457.2	23687	10712	4319
SIEDLCE	414.2	119	223	103
siedlecki	98456.4	28283	24770	6857
sierpecki	58427.0	16784	8396	5707
sochaczewski	32193.3	9248	4745	4105
sokolowski	75912.7	21807	14244	5313
szydlowiecki	19953.7	5732	4591	2113
warszawski	4671.6	1342	1940	1204
warszawski zachodni	10063.9	2891	3691	1795
wegrowski	75634.2	21727	17640	7710
wolominski	46626.0	13394	12540	6187
wyszkowski	44192.7	12695	12069	4396
zurominski	67822.5	19483	11826	7695
zwolenski	37213.1	10690	2641	1589
zyrardowski	17812.8	5117	3665	2423

II.4.1.4. Cows consumption rate

During the pasture period, cows consume about 50 kg/day of fresh grasses. During stalled keeping of cattle they receive about 5 kg of hay, 5 -6 kg of cereals and 10 kg of mixed fodder (silage).

According to data on milk production in 1989 the average mean productivity of cows is 11.6 Liter per day.

II.4.1.5. Climatic conditions

Like most of Poland's territory, Mazovia has a temperate climate, intermediate between the continental and the Atlantic climates. In summer, temperatures are in the twenties, in winter they fall below 0°C. In 1986, there was hot spring with temperature of about 20°C and it stimulated the growth of pasture.

The climate formation is considerably influenced by the atmospheric circulation. The major influence of the sea air masses is observed in winter and autumn. During the warm period of the year there are mostly west, northwest, north and south-easterly winds; in the colder period there are south-western and south winds.

The average annual temperatures vary between +7.5 and +8°C. The period with temperatures above zero lasts for 220–225 days, and the period when the temperature is more than +10°C, when the agricultural plants grow, lasts for about 200 days. Within the region there falls, on average, quite a lot of precipitation yearly 600 mm.

In 1986 there was rater warm spring with temperature above 15°C and it intensifies pasture grass growing especially pasture grass that reached on end of April of about 60–75% its maximum biomass (see Figure II.7).

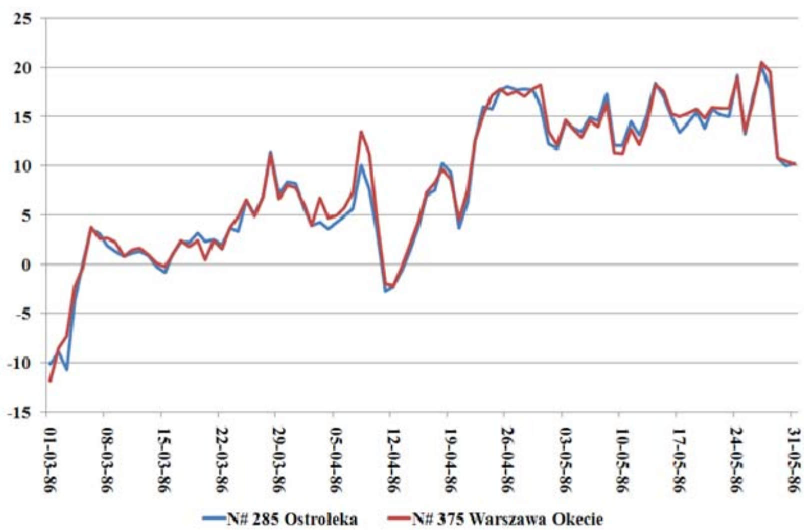

Fig. II.7. Average daily temperature in 1986 in Mazovia area.

Table II.6. Average daily temperature and total daily precipitation measured by meteorological stations in Warsaw and Ostroleka towns in the period 1 March – 15 April 1986. Location of Meteorological Stations is shown in Figure II.5 (Institute of Meteorology and Water Management data).

Average daily temperature °C			**Total daily precipitation [mm]**		
Date	**N# 285 Ostroleka**	**N# 375 Warszawa Okecie**	**DATE**	**N# 285 Ostroleka**	**N# 375 Warszawa Okecie**
01-03-1986	-10.1	-11.8	01-03-1986	no value	no value
02-03-1986	-8.9	-8.5	02-03-1986	no value	no value
03-03-1986	-10.7	-7.2	03-03-1986	no value	0
04-03-1986	-3.7	-2.3	04-03-1986	0.1	0.1
05-03-1986	0.1	-0.3	05-03-1986	1.6	1.8
06-03-1986	3.6	3.8	06-03-1986	0	0
07-03-1986	3.1	2.6	07-03-1986	0.2	0
08-03-1986	1.9	2.7	08-03-1986	no value	no value
09-03-1986	1.3	2.3	09-03-1986	no value	0
10-03-1986	0.8	0.8	10-03-1986	0	no value
11-03-1986	1.1	1.5	11-03-1986	no value	no value
12-03-1986	1.3	1.7	12-03-1986	no value	no value
13-03-1986	0.9	1	13-03-1986	no value	no value
14-03-1986	-0.2	0.1	14-03-1986	no value	no value
15-03-1986	-0.8	-0.2	15-03-1986	no value	0
16-03-1986	1	1	16-03-1986	no value	no value
17-03-1986	2.2	2.4	17-03-1986	no value	no value
18-03-1986	2.2	1.8	18-03-1986	no value	no value
19-03-1986	3.2	2.4	19-03-1986	no value	no value
20-03-1986	2.3	0.5	20-03-1986	no value	no value
21-03-1986	2.5	2.4	21-03-1986	no value	no value
22-03-1986	2	1.6	22-03-1986	no value	0
23-03-1986	3.7	3.8	23-03-1986	3.9	6
24-03-1986	3.3	4.8	24-03-1986	0.7	2.7
25-03-1986	6.5	6.6	25-03-1986	no value	no value
26-03-1986	5	4.9	26-03-1986	no value	0
27-03-1986	6.9	7	27-03-1986	no value	no value
28-03-1986	11.4	11.2	28-03-1986	no value	0
29-03-1986	7.2	6.7	29-03-1986	5.3	1.5
30-03-1986	8.4	8.1	30-03-1986	2.3	3.2
31-03-1986	8.2	7.8	31-03-1986	0.8	1.4
01-04-1986	5.7	6.1	01-04-1986	1.2	0.3
02-04-1986	3.9	4	02-04-1986	no value	0
03-04-1986	4.3	6.8	03-04-1986	0	no value
04-04-1986	3.6	4.7	04-04-1986	0	0
05-04-1986	4.3	5	05-04-1986	4.6	1.6
06-04-1986	4.9	5.8	06-04-1986	0.1	0
07-04-1986	5.6	7.3	07-04-1986	no value	0
08-04-1986	10.1	13.5	08-04-1986	no value	no value
09-04-1986	7.6	11.3	09-04-1986	no value	no value
10-04-1986	3.3	4.5	10-04-1986	13	3
11-04-1986	-2.7	-2	11-04-1986	2.2	0.5
12-04-1986	-2.2	-2.2	12-04-1986	no value	0
13-04-1986	-0.6	-0.1	13-04-1986	no value	no value
14-04-1986	1.3	1.9	14-04-1986	no value	no value
15-04-1986	3.7	4.2	15-04-1986	no value	no value

Table II.7. Average daily temperature and total daily precipitation measured by meteorological stations in Warsaw and Ostroleka in the period 16 April – 31 May 1986 (Institute of Meteorology and Water Management data).

Average daily temperature °C			Total daily precipitation [mm]		
Date	**N# 285 Ostroleka**	**N# 375 Warszawa Okecie**	**DATE**	**N# 285 Ostroleka**	**N# 375 Warsaw Okecie**
16-04-1986	7	7.3	16-04-1986	no value	0
17-04-1986	7.5	8.3	17-04-1986	2.5	1.3
18-04-1986	10.2	9.7	18-04-1986	6.6	6.6
19-04-1986	9.3	8.7	19-04-1986	0.6	0.1
20-04-1986	3.7	4.6	20-04-1986	0.1	0
21-04-1986	6.3	7.5	21-04-1986	0.1	0.4
22-04-1986	12.5	12.6	22-04-1986	no value	no value
23-04-1986	16	15.2	23-04-1986	no value	no value
24-04-1986	15.8	17.2	24-04-1986	no value	no value
25-04-1986	17.7	17.9	25-04-1986	0	no value
26-04-1986	18.1	17.3	26-04-1986	no value	no value
27-04-1986	17.7	17.6	27-04-1986	no value	no value
28-04-1986	**17.8**	**17.1**	**28-04-1986**	**no value**	**no value**
29-04-1986	**17.7**	**17.9**	**29-04-1986**	**no value**	**no value**
30-04-1986	**16.1**	**18.3**	**30-04-1986**	**no value**	**0**
01-05-1986	**12.2**	**13.5**	**01-05-1986**	**no value**	**no value**
02-05-1986	**11.8**	**12.2**	**02-05-1986**	**no value**	**no value**
03-05-1986	**14.5**	**14.7**	**03-05-1986**	**no value**	**no value**
04-05-1986	**13.8**	**13.7**	**04-05-1986**	**no value**	**no value**
05-05-1986	**13.5**	**12.9**	**05-05-1986**	**no value**	**no value**
06-05-1986	**14.9**	**14.6**	**06-05-1986**	**no value**	**no value**
07-05-1986	**14.6**	**14**	**07-05-1986**	**no value**	**no value**
08-05-1986	17.3	16.4	08-05-1986	0.1	3
09-05-1986	12	11.4	09-05-1986	14.1	8.9
10-05-1986	12	11.3	10-05-1986	no value	0.6
11-05-1986	14.5	13.8	11-05-1986	5	9.2
12-05-1986	13.1	12.2	12-05-1986	no value	4.4
13-05-1986	15.1	14.3	13-05-1986	no value	no value
14-05-1986	18.4	18.3	14-05-1986	22.1	10.3
15-05-1986	17	17.6	15-05-1986	0.2	0
16-05-1986	14.9	15.3	16-05-1986	no value	no value
17-05-1986	13.4	15.1	17-05-1986	no value	no value
18-05-1986	14.3	15.4	18-05-1986	no value	0
19-05-1986	15.4	15.8	19-05-1986	6	2.5
20-05-1986	13.8	14.9	20-05-1986	no value	no value
21-05-1986	15.8	16	21-05-1986	no value	no value
22-05-1986	15.2	15.9	22-05-1986	8.2	3.1
23-05-1986	15	15.9	23-05-1986	no value	no value
24-05-1986	19.2	19	24-05-1986	1.3	1.6
25-05-1986	13.2	13.5	25-05-1986	no value	no value
26-05-1986	17.1	16.7	26-05-1986	no value	no value
27-05-1986	20.1	20.6	27-05-1986	no value	no value
28-05-1986	17.7	19.6	28-05-1986	19.9	32.8
29-05-1986	10.8	10.9	29-05-1986	3.1	1.8
30-05-1986	10	10.5	30-05-1986	10	8.9
31-05-1986	10.2	10.2	31-05-1986	0.3	0.1

II.4.2. Transport of air masses during the Chernobyl releases

Figures II.8–II.16 show the map of Poland with the trajectories of airborne radioactive material movement from Chernobyl to Poland at the last days of April 1986. There are presented trajectories at 00:00 and 12:00 GMT. To simplify these figures, there are only trajectories estimated for winds near the ground (red), the 925 mb pressure level, i.e., about 800 m (blue) and the 850 mb pressure level, i.e., 1500 m (green). This data have been elaborated by the Institute of Meteorology and Water Management in the Meteorological and Hydrological Forecasting and Warning Centre. Two circles mark regions of interest Warsowia and Ostroleka areas.

II.4.3. Rainfall data for the first days after the accident

The meteorological data for weather conditions from 26 April to 15 May 1986 were obtained from 33 meteorological stations and meteorological posts. The locations of the weather observation points are shown in Figures II.17 and II.18 together with precipitation records. Table II.9 shows data of precipitation, which were recorded daily. It can be seen that on 29 April and 30 April 1986, during the transit of the radioiodine cloud, there were only sparse and local rains of different intensity in a few locations of the Mazovia province. It resulted in elevated level of ^{131}I and ^{137}Cs deposition in small spots but it did not result in high contamination of pasture grass and milk as these rains did not affect pasture land. The ratio ^{131}I/^{137}Cs in this spots ranged for 8 to 15 (calculated on 27 April 1986). However, intensive rains occurred in the most districts of Mazovia province a week later, on 8 and 9 May 1986, resulted in washout of airborne radioiodine from the next cloud from Chernobyl releases on 5 May 1986, but causing an order of magnitude lower contamination.

The influence of intensive rains from 10 to 15 May 1986 was only of short weathering half-time on the grass.

Table II.8. Estimated daily releases of ^{131}I during the accident [II.5].

Day of release	Percentage	Daily releases (PBq)
26 April	40.4	704
27 April	11.6	204
28 April	8.5	150
29 April	5.8	102
30 April	3.9	69
1 May	3.5	62
2 May	5.8	102
3 May	6.1	107
4 May	7.4	130
5 May	7.4	130
Total	100	1760

Table II.9. Rainfall records during the period 26 April – 15 May 1986 in Mazovia province.

Meteo post name	Long.	Lat.	Date of rainfall																			
			26 04	27 04	28 04	29 04	30 04	01 05	02 05	03 05	04 05	05 05	06 05	07 05	08 05	09 05	10 05	11 05	12 05	13 05	14 05	15 05
Brwinow	20.72	52.13					7.3								5.6	3	0.9	10.2	2.4		21.8	0.1
Dankow	20.70	51.73					0.1								6.9	3.4	1.6	11.3	0.2		4.7	1.9
Grabowiec	21.38	51.10				0.2									3.2	11	12.1	6.5	0.4			0.1
Kaweczyn	20.35	52.17													0.8	1.6	2.8		14.8	4.6	17	
Kozienice	21.53	51.55				1									4	17.4	0.1	10.1	0		1.9	
Laziska - Gorne	20.92	51.33													1.9	11.2	3.2	12.2	0.1		1.6	
Legionowo	20.97	52.40													3.3	8.1	5.8	9	0.5		15.8	
Mlawa	20.35	53.10													1.4	1.4		4.9			20.6	11.2
Myszyniec	21.38	53.38													0.1	8.5		5.8			22.6	3.5
Niegow	21.38	52.50													0.7	15.1		6.2	6.2		18.7	0
Ostroleka	21.53	53.07													0.1	14.1		5			22.1	0.2
Platerow	22.83	52.30														1.5	1.2	7.2			0	0
Plock-Trzepowo	19.72	52.58													1.6	3.6	0	5.4	1.4		15.5	12.7
Poswietne	20.38	52.63													1.1	2.8	0	4	5.3		13.8	13.5
Przasnysz	20.90	53.03													2.5	6.8	0	6			14.8	3.6
Przedwojewo	20.67	52.92													1.1	4.7	0.1	5.7	0.3		30	15
Pultusk	21.10	52.73														16		5.2	2.9		36.5	
Radzikow	20.65	52.22													2		3.6	8	7		14	
Seroczyn	21.92	52.02														16.1	3.4	8.5	1.5		0.1	
Siedlce	22.23	52.17														8.4	1.6	7.9				
Sinoleka	21.92	52.22															21.9	4.1	1.5		0.1	
Swider	21.25	52.12													2.9	8.2	0.4	9.2	0.1		7.5	
Warszawa Obserw.Astr.	21.03	52.22					0.8								2.4	7.7	8.5	11.3	1.3		8.6	0.1
Warszawa-Okecie	20.95	52.15													3	8.9	0.6	9.2	4.4		10.3	
Boglewice	21.00	51.80					1.4								6.9	3.8	2.1	10.5	0.3			
Domanice	22.18	52.03														12	2.2	8.2	0.6			0.5
Drozdy	20.82	51.98													5.8	3	1.2	10.1	1.4		14.8	0.5
Mszczonow	20.53	51.98					6.1								5.4	2.6	1.1	9.8	1.2		15.6	0.6
Strzegowo	20.28	52.90				0.6									1.2	3.2	0.1	5.2			22	13.8
Warszawa-Kaweczyn	21.13	52.27					0.7								2.8	8.2	8.2	10.5	1.6		8.5	0.1
Wolomin	21.23	52.35					10.3								3.1	8.6	7	8.2	0.6		10.2	
Wyszkow	21.45	52.58													0.6	15.2	0	5.8	5.8		20.2	
Zwolen	21.58	51.35													3.1	14.1	6	7.2	0.1		0.5	

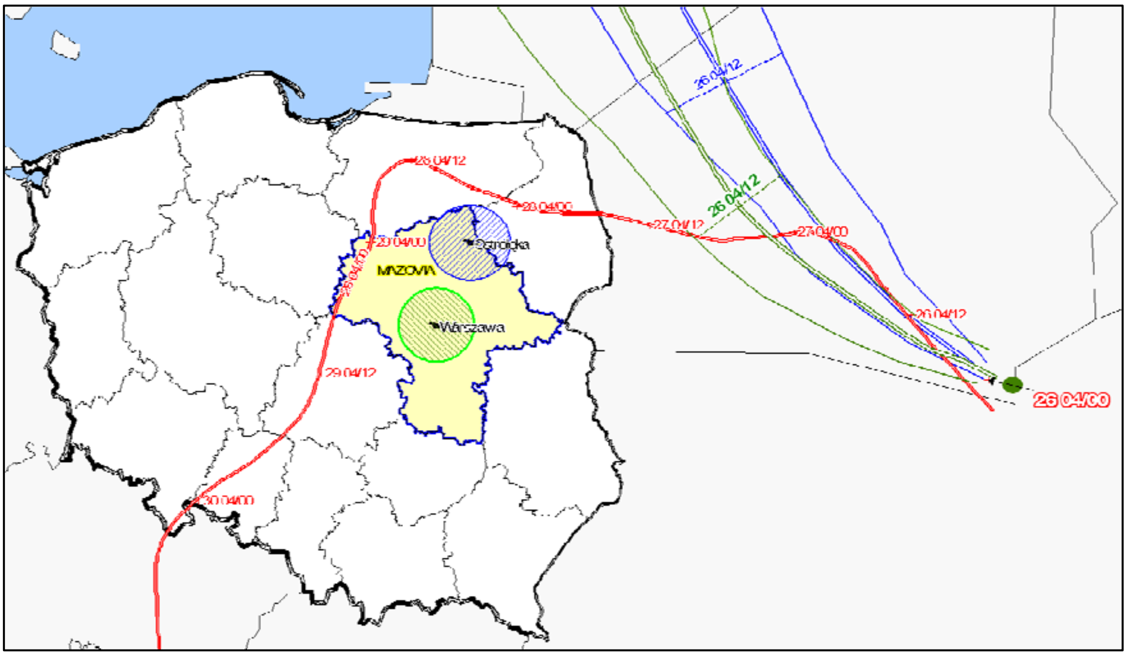

Fig. II.8. Air mass movements originating from Chernobyl on 26 April 00:00 GMT. Plumes red, blue, and green correspond to: surface winds, 925 mb – 800 m altitude, 850 mb – 1500 m altitude respectively.

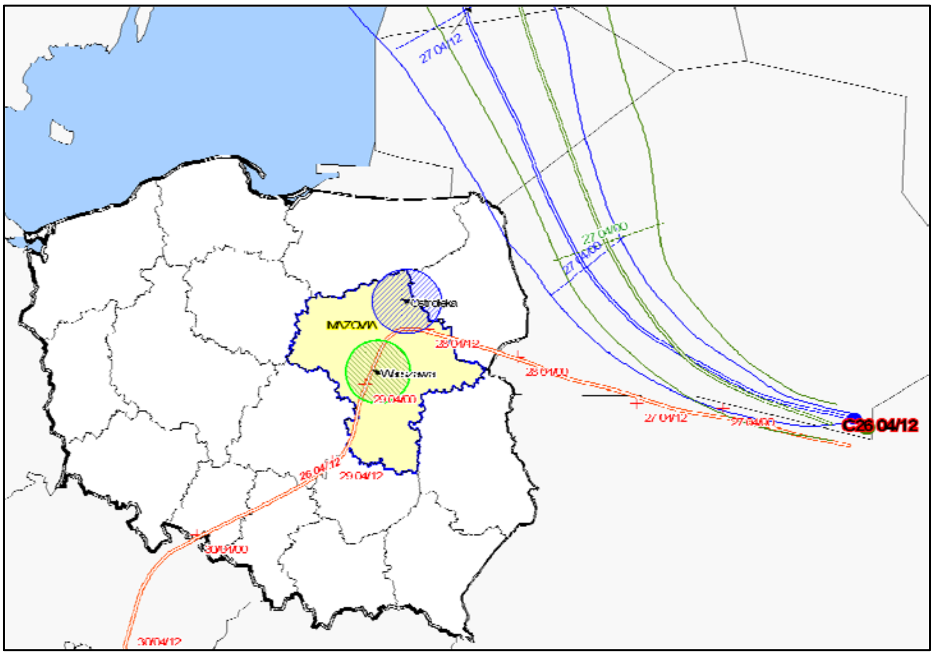

Fig. II.9. Air mass movements originating from Chernobyl on 26 April 12:00 GMT. Plumes red, blue, and green correspond to: surface winds, 925 mb – 800 m altitude, 850 mb – 1500 m altitude respectively.

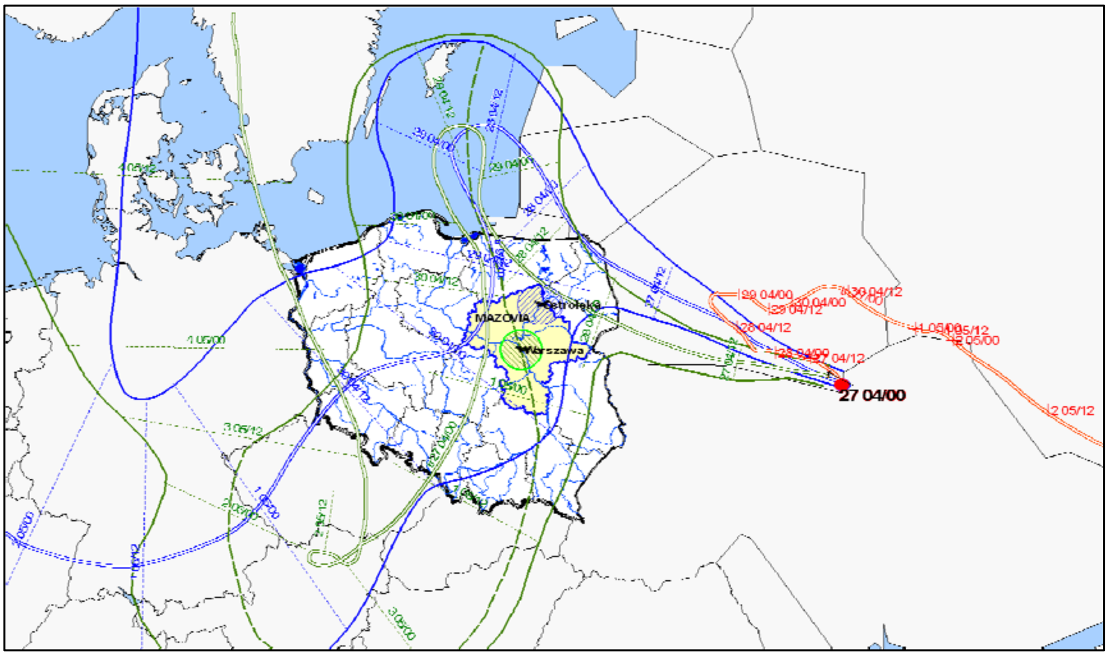

Fig. II.10. Air mass movements originating from Chernobyl on 27 April 00:00 GMT. Plumes red, blue, and green correspond to: surface winds, 925 mb – 800 m altitude, 850 mb – 1500 m altitude respectively.

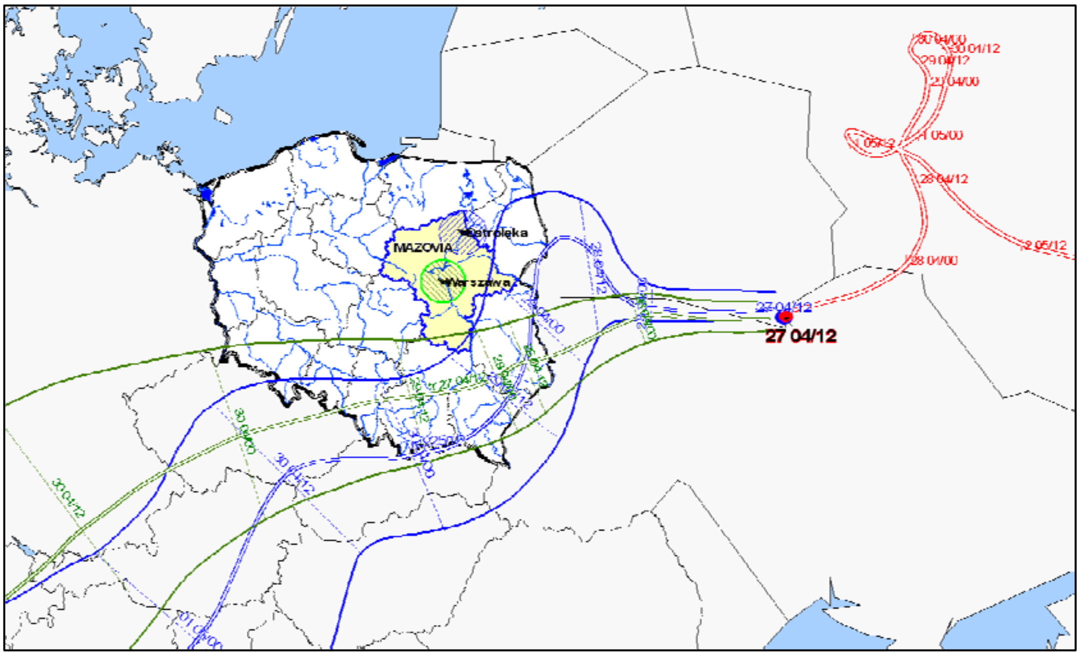

Fig. II.11. Air mass movements originating from Chernobyl on 27 April 12:00 GMT. Plumes red, blue, and green correspond to: surface winds, 925 mb – 800 m altitude, 850 mb – 1500 m altitude respectively.

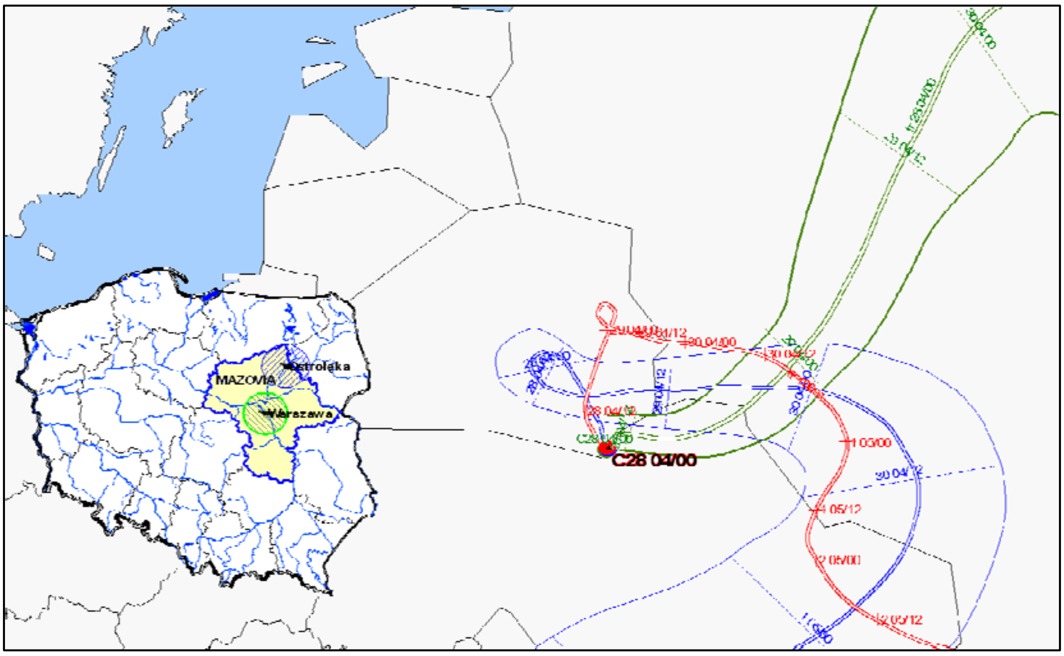

Fig. II.12. Air mass movements originating from Chernobyl on 28 April 00:00 GMT. Plumes red, blue, and green correspond to: surface winds, 925 mb – 800 m altitude, 850 mb – 1500 m altitude respectively.

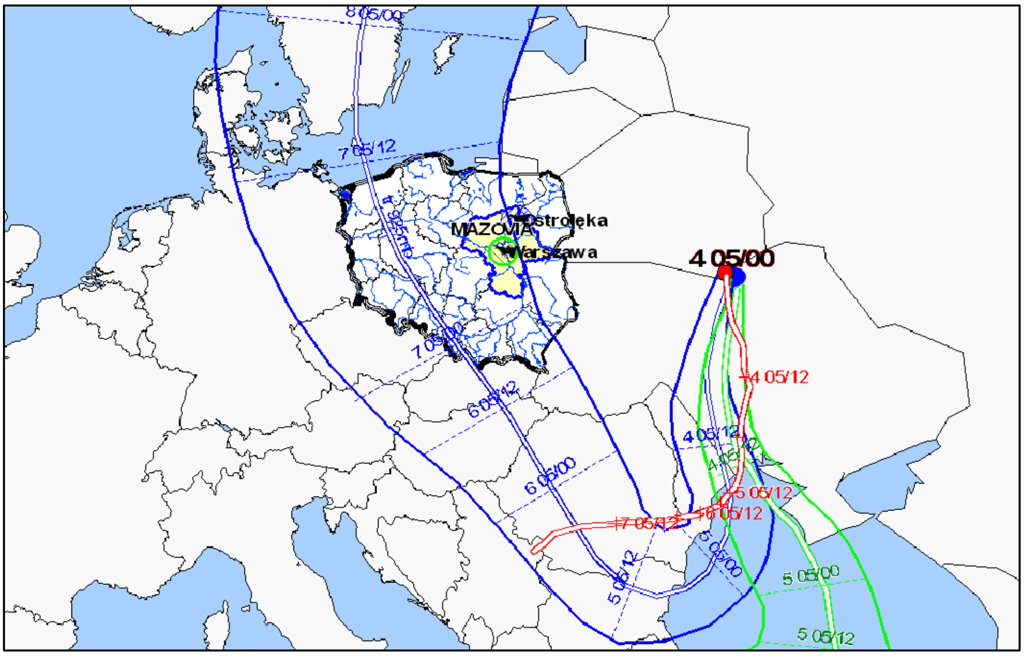

Fig. II.13. Air mass movements originating from Chernobyl on 4 May 00:00 GMT. Plumes red, blue, and green correspond to: surface winds, 925 mb – 800 m altitude, 850 mb – 1500 m altitude respectively.

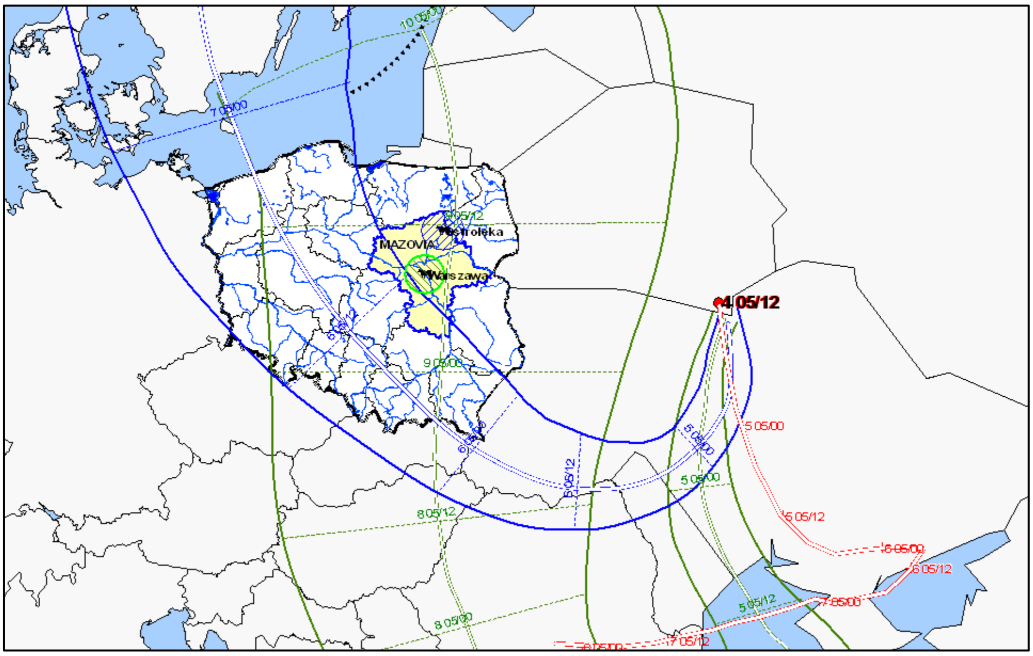

Fig. II.14. Air mass movements originating from Chernobyl on 4 May 12:00 GMT. Plumes red, blue, and green correspond to: surface winds, 925 mb – 800 m altitude, 850 mb – 1500 m altitude respectively.

Fig. II.15. Air mass movements originating from Chernobyl on 5 May 00:00 GMT. Plumes red, blue, and green correspond to: surface winds, 925 mb – 800 m altitude, 850 mb – 1500 m altitude respectively.

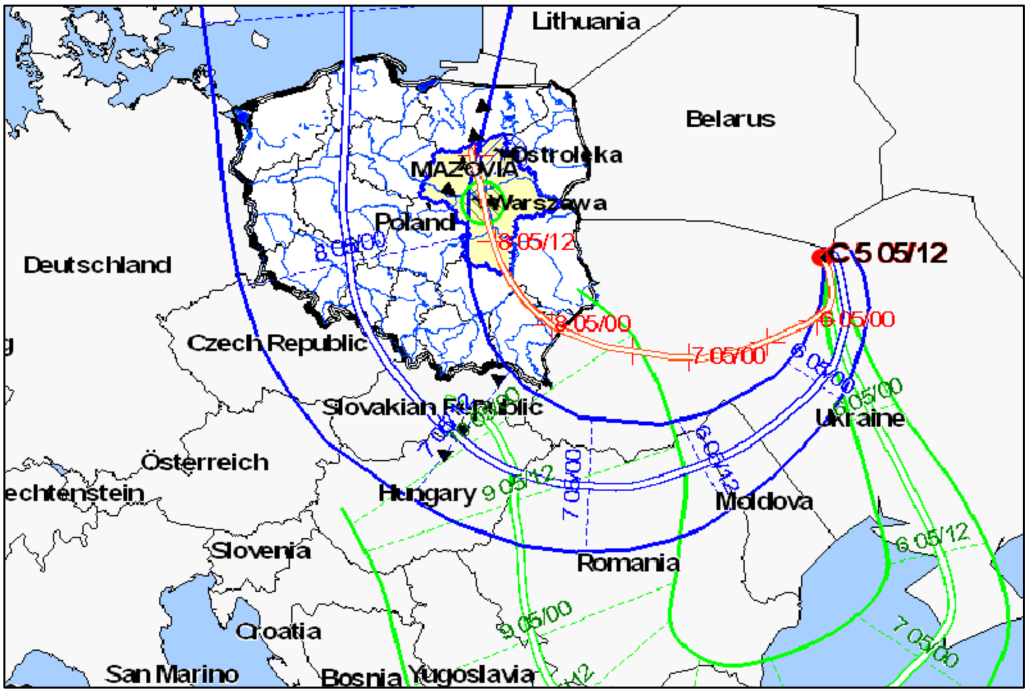

Fig. II.16. Air mass movements originating from Chernobyl on 5 May 12:00 GMT. Plumes red, blue, and green correspond to: surface winds, 925 mb – 800 m altitude, 850 mb – 1500 m altitude respectively.

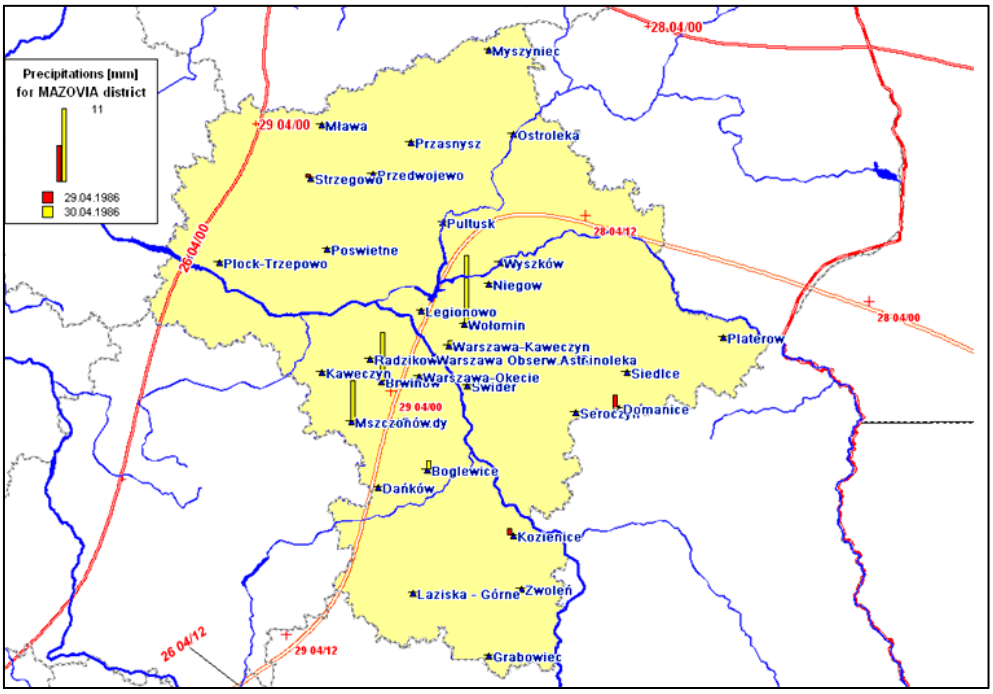

Fig. II.17. Localisation of rain-falls in Mazovia province on 29 and 30 April 1986.

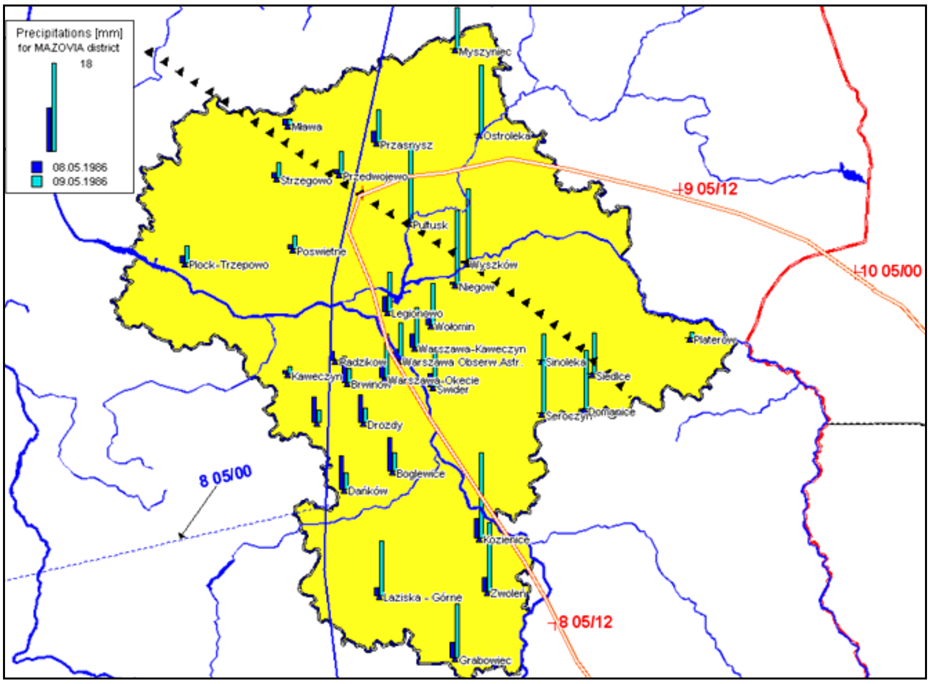

Fig. II.18. Localisation of rain-falls in Mazovia province on 8 May and 9 May 1986.

II.4.4. Isotopic composition of deposition

The measurements of the ^{131}I deposition indicated a considerable variation, even over short distances. The inconstant ratio of ^{131}I aerosol activity collected on fiber filters to the aerosol activity of ^{137}Cs was observed that indicated on a quick transformation of particulate form of radioiodine to reactive or organic phase. The $^{131}I/^{137}Cs$ ratio of aerosols observed in air samples collected on filters in Warsaw ranged from 6 to 20 during 2 hour measurements. A similar $^{131}I/^{137}Cs$ ratio was observed in soil.

One could estimate the $^{131}I/^{137}Cs$ ratio in dry deposition using Monte Carlo simulation assuming that:

(1) Initial ratio of airborne ^{131}I to ^{137}Cs is equal to 15 with triangular distribution: min 8; max 20;
(2) radioiodine speciation: particulate 50 % with lognormal distribution SD= 15%;
(3) reactive (I_2) 40 % with lognormal distribution SD = 4%;
(4) organic (CH_3I) 10 % correlated;
(5) aerosols deposition velocity: 3 cm/s with triangular distribution: min 1.7 cm/s; max 5.3 cm/s;
(6) reactive (I_2) deposition velocity: 30 cm/s with rectangular distribution: min 27; max 33 cm/s.

The results of Monte Carlo simulation are presented in Figure II.19. The mean isotopic ratio is 60 within 10% percentile range of 40–85.

II.4.5. Food consumption rates

Consumption rates for milk, milk products and lettuce were evaluated by Polish Central Statistical Office on the basis of questionnaire investigation in 1990. The representative data for Mazovia province were calculated as averages from particular districts encompassed by the province.

Location of the districts is presented on Figure II.20. One could notices that the consumption rates in particular districts not differ more than 30% in exception of fresh lettuce for Warsaw district of rural population. However, it is difficult to assess real consumption habit in Poland during the first two weeks of May 1986, because due to the government warning, most of the people refrained from eating fresh lettuce or some of them washed lettuce very carefully, moreover most of the parents did not give lettuce to children. The measured ^{131}I thyroid contents did not indicate on apparent correlation between people eating or not eating fresh lettuce. One could use the wider uncertainty ranges or compare the ^{131}I thyroid burden with and without lettuce consumption.

In order to simplify calculations, the consumption rates of milk products, namely: hard and cottage cheese, and milk drinks (yogurts and kefirs) were recalculated to fresh milk and together with fresh milk expressed as total milk Tables II.10–II.12.

II.4.6. Protective measures

The Governmental Commission for Assessment of Nuclear Radiation and Prophylactic Measures decided on 29 April 1986 to distribute the prophylactic doses of stable iodine for infants; children 1–10 years old and teenagers up to 16 years old over eleven voivodships of Poland (see Figure II.21).

This action took place (from 29 April – 4 May 1986), but for Mazovia province mainly on 29 and 30 April 1986. Administrated amount of stable iodine:

- 15 mg for infants younger than 1 year;
- 30 mg for children 1–10 years old; and
- 60 mg for teenagers up to 16 years old.

Stable iodine was administered in a form of “Lugol” liquid.

II.4.6.1. Reduction of thyroid burden by stable iodine

Because evaluation of internal dose to thyroid, when stable iodine is given, requires more sophisticated metabolic model of iodine in human body than simple ICRP model, the reduction of committed dose to thyroid depending on the time gap between acute uptake of radioiodine ^{131}I and intake of stable iodine is presented in Figure II.22 and in Table II.13. Note that in a case of spread in time pattern of intakes evaluation of dose reduction required more complicated calculation. To enable calculations for models without such feature the Excel spreadsheet program is available for downloading from EMRAS I-131 Working Group website: http://www-ns.iaea.org/projects/emras/emras-iodine-131-wg.asp?s=8.

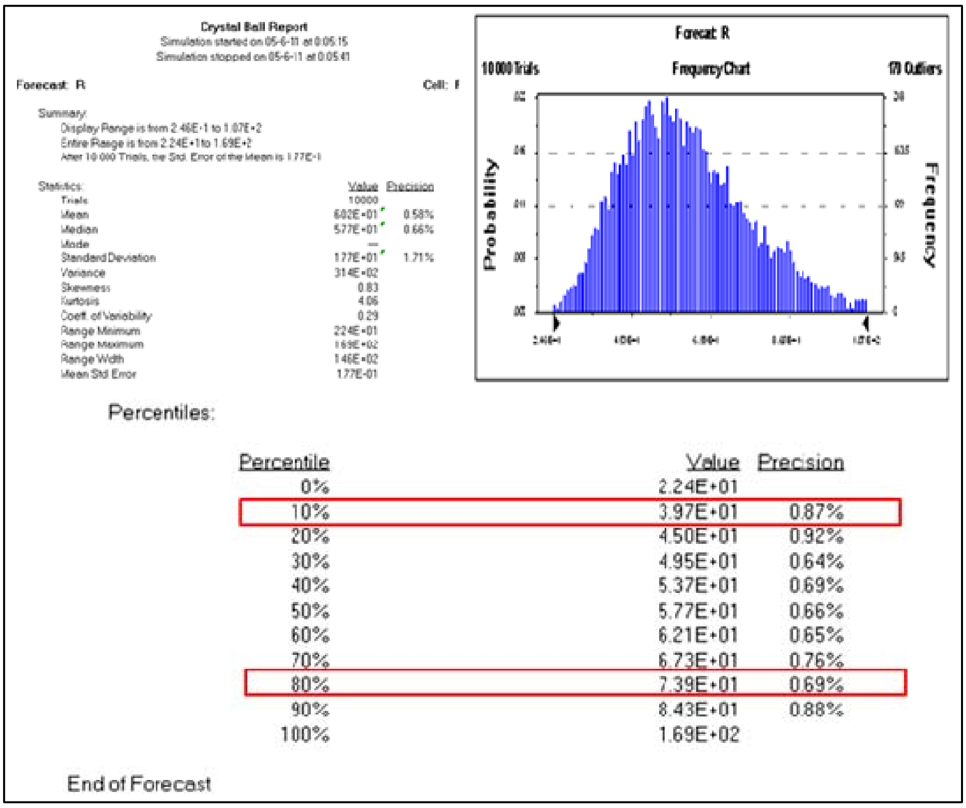

Fig. II.19. Results of Monte Carlo simulation of $^{131}I/^{137}Cs$ isotopic ratio for deposition.

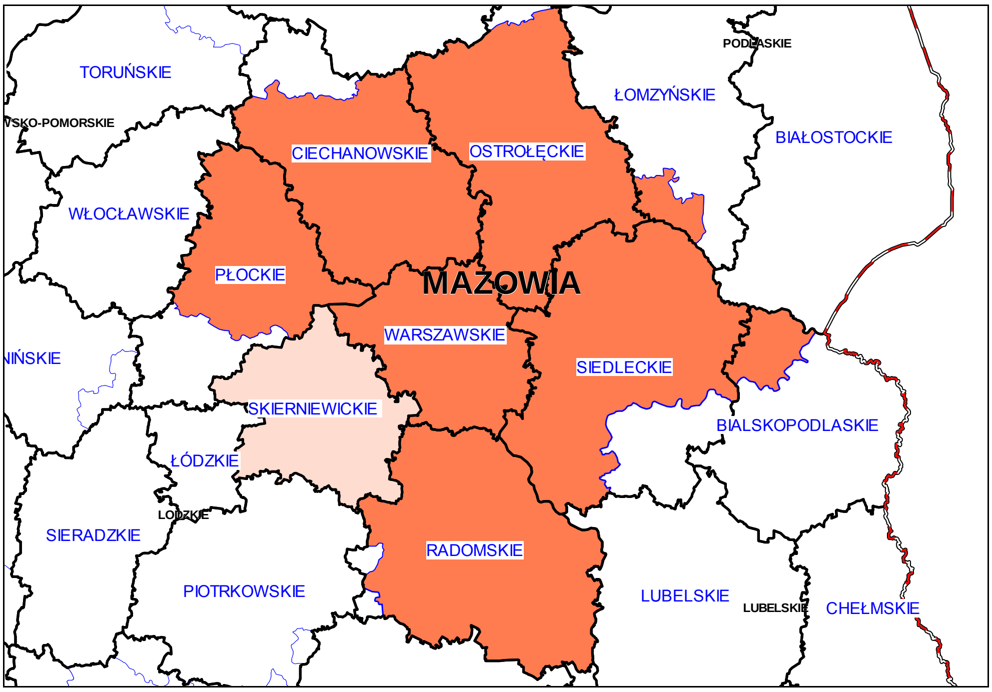

Fig. II.20. Location of neighboring districts in Mazovia Province.

Fig. II.21. Historical photo of prophylactic action.

Table II.10. Food consumption rates for adult urban inhabitants (kg y^{-1}, mean ± St. Dev).

Urban Population				
Diet product	**District**	**Average: Consumption [kg per year]**		
Hard Cheese	Ciechanowskie	9.5		
	Ostroleckie	9.6		
	Radomskie	7.6		
	Siedleckie	8.4		
	Skierniewickie	7.8		
	Warszawskie	13.4		
Cheese – Average ± SD		**9.4**	±	**2.0**
Cottage cheese	Ciechanowskie	5.6		
	Ostroleckie	6.2		
	Radomskie	4.9		
	Siedleckie	5.5		
	Skierniewickie	5.3		
	Warszawskie	8.6		
Cottage cheese – Average ± SD		**6.0**	±	**1.2**
Milk	Ciechanowskie	61.8		
	Ostroleckie	60.5		
	Radomskie	56.3		
	Siedleckie	51.7		
	Skierniewickie	54.2		
	Warszawskie	46.2		
Milk – Average ± SD		**55.1**	±	**5.3**
Milk drinks	Ciechanowskie	4.3		
	Ostroleckie	4.1		
	Radomskie	6.7		
	Siedleckie	6.2		
	Skierniewickie	3.4		
	Warszawskie	9.4		
Milk drinks – Average ± SD		**5.7**	±	**2.0**
Total Milk Average ± SD		**94.3**		**14.3**
Fresh lettuce	Ciechanowskie	9.1		
	Ostroleckie	8.9		
	Radomskie	9.7		
	Siedleckie	8.0		
	Skierniewickie	5.2		
	Warszawskie	5.0		
Fresh lettuce Average ± SD		**7.7**	±	**1.9**

Table II.11. Food consumption rates for adult rural inhabitants (kg y^{-1}, mean ± St. Dev).

RURAL POPULATION				
Diet product	**District**	**Average: Consumption [kg per year]**		**SD**
Hard Cheese	Ciechanowskie	10.1		
	Ostroleckie	6.6		
	Radomskie	7.1		
	Siedleckie	6.0		
	Skierniewickie	8.4		
	Warszawskie	7.6		
Hard Cheese - Average ± SD		**7.6**	±	**1.3**
Cottage cheese	Ciechanowskie	7.4		
	Ostroleckie	4.7		
	Radomskie	5.5		
	Siedleckie	4.7		
	Skierniewickie	6.5		
	Warszawskie	4.8		
Cottage cheese – Average ± SD		**5.6**	±	**1.0**
Milk	Ciechanowskie	110.2		
	Ostroleckie	115.4		
	Radomskie	89.8		
	Siedleckie	146.3		
	Skierniewickie	102.2		
	Warszawskie	63.4		
Milk – Average ± SD		**104.5**	±	**25.2**
Milk drinks	Ciechanowskie	3.4		
	Ostroleckie	0.8		
	Radomskie	1.7		
	Siedleckie	1.6		
	Skierniewickie	2.2		
	Warszawskie	4.2		
Milk drinks – Average ± SD		**2.3**	±	**1.14**
Total Milk - Average ± SD		**135.2**	±	**31.4**
Fresh lettuce	Ciechanowskie	8.3		
	Ostroleckie	7.9		
	Radomskie	7.1		
	Siedleckie	11.2		
	Skierniewickie	7.3		
	Warszawskie	37.7		
Fresh lettuce Average ± SD		**13.2**	±	**11.0**

Table II.12. Food consumption rates for different age groups in Mazovia province.

Age Groups	Hard Cheese [kg per year]	Cottage cheese [kg per year]	Milk [kg per year]	Milk drinks [kg per year]	Total Milk [kg per year]	Total Milk [kg per day]	Fresh Lettuce [kg per year]	Fresh Lettuce [kg per day]
Urban Population								
Adult	9.4 ± 2.0	6.0 ± 1.2	55 ± 5	5.7 ± 2.0	94 ± 14	0.26 ± 0.04	7.7 ± 1.9	0.021 ± 0.005
15 Years Old	8.0 ± 1.7	5.1 ± 1.0	92 ± 9	4.8 ± 1.7	126 ± 16	0.34 ± 0.05	6.5 ± 1.6	0.018 ± 0.004
10 Years Old	6.0 ± 1.3	3.9 ± 0.8	101 ± 10	3.6 ± 1.3	126 ± 15	0.34 ± 0.04	4.9 ± 1.2	0.013 ± 0.003
5 Years Old	3.6 ± 0.8	2.3 ± 0.5	103 ± 10	2.2 ± 0.8	118 ± 13	0.32 ± 0.04	2.9 ± 0.7	0.008 ± 0.002
1 Years Old	1.8 ± 0.4	1.2 ± 0.2	122 ± 12	1.1 ± 0.4	129 ± 13	0.35 ± 0.04	1.5 ± 0.4	0.004 ± 1E-03
Rural Population								
Adult	7.6 ± 1.3	5.6 ± 1.0	105 ± 25	2.3 ± 1.1	135 ± 31	0.37 ± 0.09	13.2 ± 11.0	0.036 ± 0.03
15 Years Old	6.5 ± 1.1	4.8 ± 0.9	175 ± 42	2.0 ± 1.0	201 ± 48	0.55 ± 0.13	11.3 ± 9.4	0.031 ± 0.026
10 Years Old	4.9 ± 0.8	3.6 ± 0.7	191 ± 46	1.5 ± 0.7	211 ± 50	0.58 ± 0.14	8.4 ± 7.0	0.023 ± 0.019
5 Years Old	2.9 ± 0.5	2.1 ± 0.4	195 ± 47	0.9 ± 0.4	207 ± 49	0.57 ± 0.14	5.1 ± 4.2	0.014 ± 0.012
1 Years Old	1.5 ± 0.3	1.1 ± 0.2	231 ± 56	0.4 ± 0.2	237 ± 57	0.65 ± 0.16	2.5 ± 2.1	0.007 ± 0.006

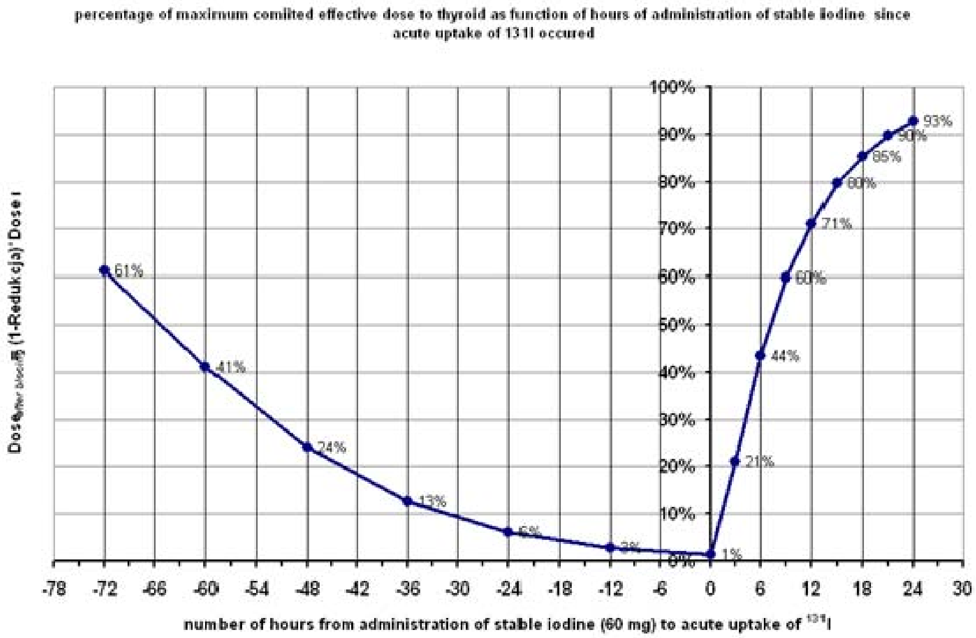

Fig. II.22. Percentage of maximum committed effective dose to thyroid that remains as a function of hours passed after or before intake of stable iodine since acute uptake of ^{131}I occurred.

Table II.13. Fraction of maximum committed effective dose to thyroid that remains as a function of hours passed after or before intake of stable iodine since acute uptake of ^{131}I occurred.

Numer of hours	remained fraction of committed dose to thyroid
-72	0.61
-60	0.41
-48	0.24
-36	0.13
-24	0.06
-12	0.03
0	0.01
3	0.21
6	0.44
9	0.60
12	0.71
15	0.80
18	0.85
21	0.90
24	0.93

II.4.6.2. Restriction of grazing of cows

Unfortunately there is very little information about practical implementation of this recommendation in Mazovia province. One reported in May 1986 that almost 60% of private farms had not resources to keep cows in cowshed fed by uncontaminated fodder. The statistic data on the number of cows and grass as well as hay production in particular counties of Mazovia province enable to make rough estimation of fodder resources in the period of April and May 1986. Assuming that each province has to be self-sufficient, the balance can be described by formula:

$$(M_t + P_t) \cong N_{cows} \times (w_{cow} + s_{cow}) \tag{II.1}$$

where:

M_t is the yearly fodder production in meadows [tons];
P_t is the yearly fodder production in pasturing land [tons];
N_{cows} is the number of cows in each province;
s_{cow} is the fodder consumption during summer period per one cow [kg]; and
w_{cow} is the fodder consumption during winter period per one cow [kg].

An estimation of w_{cow} and s_{cow} is shown TableII.14.

One can estimate the percentage of cows that could have been kept in cowsheds up to 31 May 1986 when ^{131}I grass contamination declined according to formula:

$$F_{eff} = \frac{N^E{}_{cows}}{N_{cows}}\% = \frac{(M_t + P_t) - N_{cows} \times s_{cow}}{N_{cows} \times w^E{}_{cow}}\% \tag{II.2}$$

The results of analysis of fodder resources are presented in Table II.15. The weighted averages based on contribution of particular district to the whole area indicate that for Warsaw area (Warsaw town) about 83% of milk could have come from cows that had not been put on the pasture whereas for Ostroleka area only 59%. Another approach could be to calculate the time T_E until the district fodder recourses allowed to keep cows in cowsheds according to formula:

$$T_E = T_{10.10.1985} + \frac{(M_t + P_t) - N_{cows} \times s_{cow}}{N_{cows} \times p_{eq}} \tag{II.3}$$

where:

p_{eq} is the daily consumption rate of pasture during cows stalling (35 kg).

The T_E calculated for particular districts are shown in the last column of Table II.15.

Excepting some cases of districts where poor state of resources give not acceptable time of pasturing cows (February 1986) that is probably caused by different cows diet, the Ostroleka area districts express much less ability to support cows with less contaminated fodder.

Both approaches provide the quantitative analysis with a high uncertainty, it is worth emphasizing, that information about real implementation of the grazing ban would have never have been revealed.

Table II.14. Fodder consumption during spring and winter period per one cow.

Period	from	to	days	Pasture equivalent [kg f.w. per day]	Fooder consumption per cow [kg f.w.]
s_{cow} - summer period 1985	1-05-1985	10-10-1985	162	45	7290
w_{cow} -winter period 1985/1986	11-10-1985	29-04-1986	200	35	7000
w^{E}_{cow} - prolonged winter period 1985/1986	11-10-1985	31-05-1986	232	35	8050

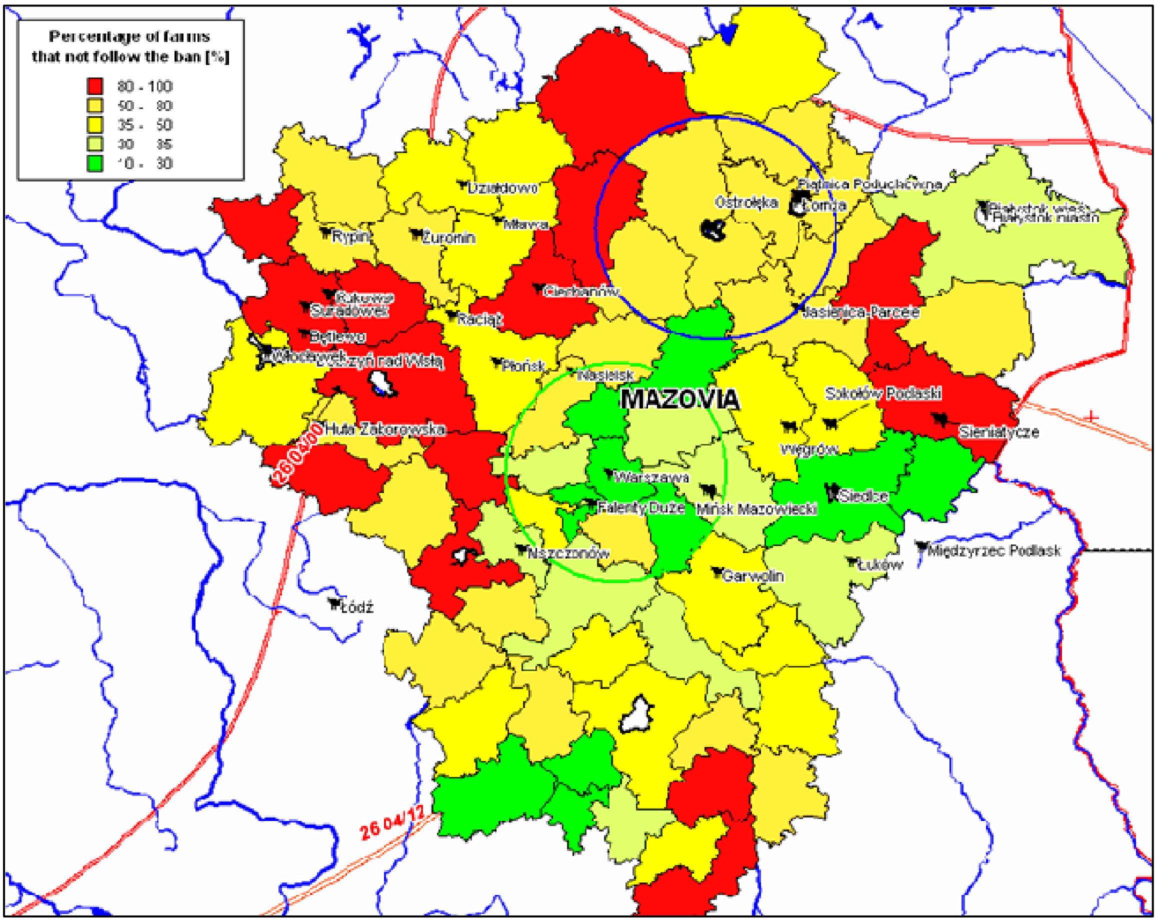

Fig. II.23. Map of the hay and fodder resources in Mazovia province.

Table II.15. An assessment of fodder resources in particular counties of Mazovia province in1986.

POWIAT	Delivery area	Milk [thousants liters]	Contribution to the total milk production	Number of cows	[ha]	Meadows [kg f.w.]	Pasturing land [ha]	Pasturing land [kg f.w.]	F_{eff} percentage of cows that could have been kept in cowsheds up to 31 May 1986	T_e Time until cows could have been kept in cowshed
grodziski mazowiecki	WARSAW AREA	12894	3.9%	3704	4025	1.4E+07	2766	4.0E+07	91%	07 May 1986
grojecki	WARSAW AREA	37648	11.3%	10815	7157	3.2E+07	7004	1.3E+08	99%	26 May 1986
legionowski	WARSAW AREA	7060	2.1%	2028	3107	7.8E+06	1961	2.5E+07	113%	27 June 1986
minski	WARSAW AREA	65508	19.7%	18818	15996	9.6E+07	5639	1.4E+08	66%	10 March 1986
nowodworski mazow.	WARSAW AREA	20549	6.2%	5903	4417	1.3E+07	4418	6.2E+07	67%	14 March 1986
otwocki	WARSAW AREA	20218	6.1%	5808	7263	4.2E+07	2529	5.6E+07	119%	09 July 1986
piaseczynski	WARSAW AREA	10036	3.0%	2883	2372	5.9E+06	2565	3.3E+07	79%	08 April 1986
pruszkowski	WARSAW AREA	3826	1.2%	1099	1639	4.1E+06	1051	1.4E+07	110%	20 June 1986
pultuski	WARSAW AREA	48913	14.7%	14051	8100	4.9E+07	4586	1.1E+08	54%	10 February 1986
warszawski	WARSAW AREA	4672	1.4%	1342	1940	6.8E+06	1204	1.7E+07	128%	01 August 1986
warszawski zachodni	WARSAW AREA	10064	3.0%	2891	3691	1.7E+07	1795	2.7E+07	97%	19 May 1986
wolominski	WARSAW AREA	46626	14.0%	13394	12540	7.3E+07	6187	1.3E+08	97%	22 May 1986
wyszkowski	WARSAW AREA	44193	13.3%	12695	12069	7.2E+07	4396	1.1E+08	84%	20 April 1986
Weighted average based on the contribution to the total milk production									**83%**	
kolnenski	OSTROLEKA AREA	79219	12%	22764	14305	8.0E+07	8982	1.8E+08	51%	04 February 1986
lomzynski	OSTROLEKA AREA	92853	14%	26682	18545	9.3E+07	11857	2.4E+08	63%	03 March 1986
makowski	OSTROLEKA AREA	67426	10%	19369	11511	6.9E+07	6366	1.6E+08	56%	15 February 1986
ostrolecki	OSTROLEKA AREA	178310	27%	51222	40486	1.6E+08	26064	5.0E+08	69%	17 March 1986
piski	OSTROLEKA AREA	35214	5%	10119	10385	2.6E+07	9000	1.2E+08	85%	23 April 1986
przasnyski	OSTROLEKA AREA	88003	13%	25280	15543	6.2E+07	11171	1.8E+08	28%	12 December 1985
szczycienski	OSTROLEKA AREA	52350	8%	15043	15849	4.0E+07	15635	2.0E+08	110%	20 June 1986
zambrowski	OSTROLEKA AREA	58520	9%	16816	8464	5.1E+07	3896	9.7E+07	19%	22 November 1985
Weighted average based on the contribution to the total milk production									**59%**	

II.5. Radioiodine measurements – Data for models comparison

II.5.1. ^{131}I concentration in air

Air concentration of ^{131}I over Warsaw was measured in various hours' intervals by two independent monitoring stations of the Central Laboratory for Radiological Protection. The extended monitoring program started on 28 April 1986 immediately after an appearance of contamination in the ground layer of air in the Warsaw region and lasted up to 15 June 86 when Chernobyl releases had evidently ceased.

II.5.1.1. Measurements of ^{131}I concentration in air by station A(FEP15 Petrianow)

The station A belonged to the monitoring system in the Warsaw region resulting from nuclear tests in Central Asia. The monitoring of air contamination has been conducted by Dosimetry Department of CLOR since 1972. The sampling time ranged from 10 minutes to 3 days depending upon the level of radionuclide concentration in air. Samples of radioactive aerosols were taken from the air with FEP15 Petrianow -1.7 fiber filter of area of an 0.25 m^2 surface at 40 cm $\cdot$s^{-1} flow velocity. Volumes of the air ranged from 50 to 20 000 cubic meters. The filter medium, with aerosols collected, was pressed to the form of discs of 50 mm diameter. The radionuclides present in the samples were determined by gamma spectrometry methods. High purity germanium detectors of 60 and 70 cm^3 active volumes and resolution of 2 keV (for ^{60}Co 1333 keV) with Canberra 85 multichannel analyzer were used for collecting and analysis of the spectra. In the samples before 27 April 1986 only natural radionuclides and small amounts of ^{137}Cs (about 1×10^{-6} Bq$\cdot$m^{-3}) were detected. The recorded concentrations of ^{131}I as well as ^{134}Cs and ^{137}Cs in aerosols samples starting from 16 April 1986 are shown in Tables II.16 and II.17. According to the adopted convention in the first column, the sampling start time and end time is shown, then in the following columns the pairs of the same numbers mean average aerosol concentration during the indicated sampling periods. For example: the first filter was measured from 16 April 1986 12:30 GMT to 28 April 1986 11:09 GMT and average radionuclides attached to aerosols concentrations were 0.04, 0.003, and 0.002 for ^{131}I, ^{137}Cs and ^{134}Cs, respectively.

In addition, in the last two columns average isotopic ratios of ^{131}I/^{137}Cs and ^{137}Cs/^{134}Cs are shown (only aerosol fraction for ^{131}I and without decay correction on time of release). The ^{137}Cs/^{134}Cs isotopic ratio is consistent with reported values by other sources.

II.5.1.2. Measurements of ^{131}I concentration in air by Station B („May-pack" filter)

Station B originally was designed for monitoring of radioiodine air contamination in emergency situation at nuclear medicine facilities and did not work continuously. Therefore, since it had to be activated, the measurements of contaminated air had started later comparing with station A. The station B enabled to determine the air concentration of ^{131}I-together with iodine chemical forms: particulate, molecular (I_2) and organic phases (CH_3I). These were measured using „May-pack" filter of diameter 12 cm set:

- particulate phase – Petrianov FPP15;
- molecular (I_2) – activated charcoal (Schleicher&Schüll 508) paper;
- organic (CH_3I) – activated charcoal (Schleicher&Schüll 508) paper impregnated by 10% of TEDA.

The air draw pump was less effective than at station A, air flow velocity was 8 cm $\cdot s^{-1}$ (3 $m^3 \cdot h^{-1}$), over all iodine filtration efficiency of 99.5%. The activity of each of the filters was measured by three channel spectrometer with well NaI (Tl) detector. The recorded ^{131}I concentrations are presented in Tables II.18 and II.19. The station A was situated on the ground and it collected airborne particles at 1.5 meter above, the station B was situated on the roof of building and collected airborne radioiodine at about 12 m above. The distance between these station was about 50 m. Figure II.24 shows comparisons of ^{131}I attached to aerosols measured with station A and B. In spite of different sampling periods one could see fairly good agreement in dynamic of contaminated air as well as agreement in measured concentrations of ^{131}I particulate fraction.

II.5.1.3. Reconstruction of the total ^{131}I concentration for the first twelve hours of 28 April 1986 over Warsaw region

The combined results of these two stations is presented in Tables II.20 and II.21. Results of air measurements by station A in the period of 27 April – 28 April 17:30 were corrected for molecular I_2 and organic CH_3I fractions. The results of station B were taken into account for the rest of the monitoring period up to June 1986. This approach may lead to slightly overestimation of ^{131}I total concentration in air for the 28 April 1986 when aerosol attach fraction of radioiodine appear to be lower than it was assumed. In order to simplify model calculations, on the basis of data presented in Tables II.20 and II.21, daily averages of ^{131}I concentration in air were calculated (see Table II.22) and these values could be accepted as representative for the Mazovia province.

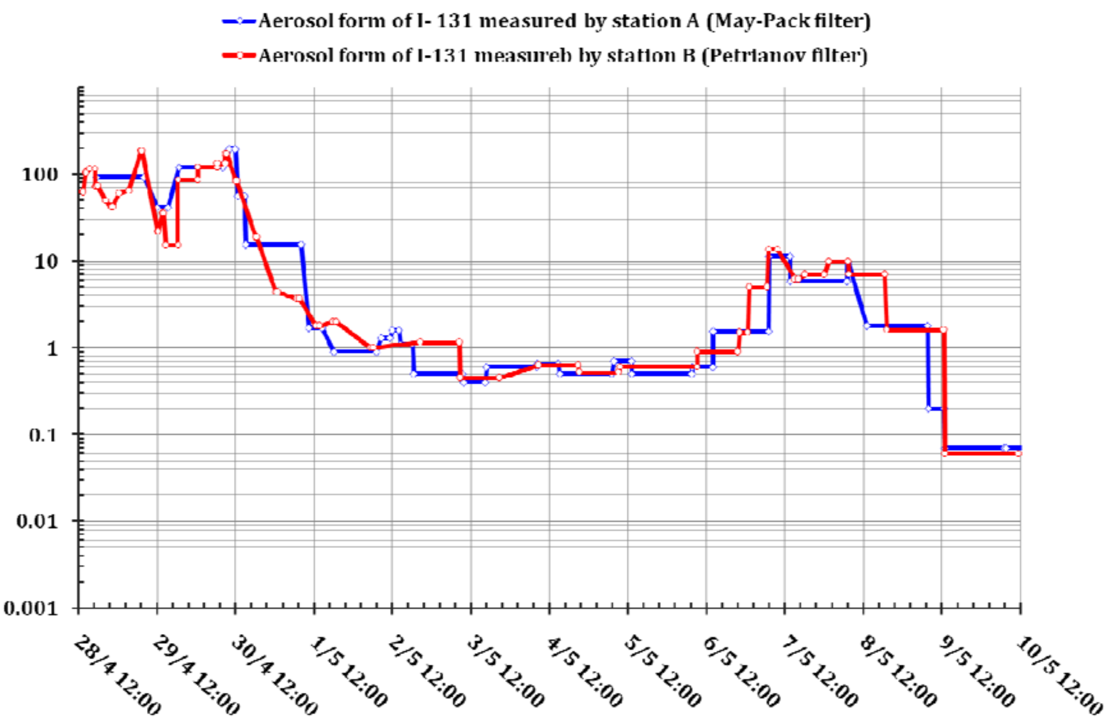

Fig. II.24. Comparison of ^{131}I aerosol fractions concentrations measured by stations A and B.

Table II.16. Aerosol fraction of airborne ^{131}I and ^{134}Cs and ^{137}Cs measured by station A during the period 16 April – 1 May 1986.

Time of measurement	Aerosol ^{131}I [Bq m^{-3}]	Aerosol ^{137}Cs [Bq m^{-3}]	Aerosol ^{134}Cs [Bq m^{-3}]	Isotopic ratio	
				^{131}I/^{137}Cs	^{137}Cs/^{134}Cs
16-04-86 12:30	0.04	0.003	0.002	**13.33**	**1.50**
28-04-86 11:09	0.04	0.003	0.002	**13.33**	**1.50**
28-04-86 11:10	62.4	4	1.9	**15.60**	**2.11**
28-04-86 13:15	62.4	4	1.9	**15.60**	**2.11**
28-04-86 13:55	104	6.5	3.2	**16.00**	**2.03**
28-04-86 14:04	104	6.5	3.2	**16.00**	**2.03**
28-04-86 15:15	116	7.3	3.3	**15.89**	**2.21**
28-04-86 16:55	116	7.3	3.3	**15.89**	**2.21**
28-04-86 17:00	72	3.5	1.7	**20.57**	**2.06**
28-04-86 17:10	72	3.5	1.7	**20.57**	**2.06**
28-04-86 17:30	74	3.5	1.6	**21.14**	**2.19**
28-04-86 17:42	74	3.5	1.6	**21.14**	**2.19**
28-04-86 20:00	50	2.7	1.2	**18.52**	**2.25**
28-04-86 20:11	50	2.7	1.2	**18.52**	**2.25**
28-04-86 22:00	42	2.7	1.2	**15.56**	**2.25**
28-04-86 22:10	42	2.7	1.2	**15.56**	**2.25**
29-04-86 00:05	60.4	5.1	2.3	**11.84**	**2.22**
29-04-86 00:14	60.4	5.1	2.3	**11.84**	**2.22**
29-04-86 03:05	64	5.2	2.4	**12.31**	**2.17**
29-04-86 03:14	64	5.2	2.4	**12.31**	**2.17**
29-04-86 07:00	186	16	7	**11.63**	**2.29**
29-04-86 07:10	186	16	7	**11.63**	**2.29**
29-04-86 12:00	22	2.1	1	**10.48**	**2.10**
29-04-86 12:10	22	2.1	1	**10.48**	**2.10**
29-04-86 13:30	35.6	3.3	1.6	**10.79**	**2.06**
29-04-86 13:50	35.6	3.3	1.6	**10.79**	**2.06**
29-04-86 14:30	15.3	1.4	0.8	**10.93**	**1.75**
29-04-86 18:15	15.3	1.4	0.8	**10.93**	**1.75**
29-04-86 18:15	86.4	10	6	**8.64**	**1.67**
30-04-86 00:15	86.4	10	6	**8.64**	**1.67**
30-04-86 00:16	121.4	14.5	9	**8.37**	**1.61**
30-04-86 06:15	121.4	14.5	9	**8.37**	**1.61**
30-04-86 06:16	134	14.4	8.6	**9.31**	**1.67**
30-04-86 08:46	134	14.4	8.6	**9.31**	**1.67**
30-04-86 08:47	172	18.6	9.6	**9.25**	**1.94**
30-04-86 09:03	172	18.6	9.6	**9.25**	**1.94**
30-04-86 12:00	84	11.4	5.6	**7.37**	**2.04**
30-04-86 12:10	84	11.4	5.6	**7.37**	**2.04**
30-04-86 18:00	19	3.1	1.5	**6.13**	**2.07**
30-04-86 18:20	19	3.1	1.5	**6.13**	**2.07**
01-05-86 00:10	4.4	0.3	0.15	**14.67**	**2.00**
01-05-86 00:40	4.4	0.3	0.15	**14.67**	**2.00**
01-05-86 06:30	3.7	0.6	0.3	**6.17**	**2.00**
01-05-86 07:20	3.7	0.6	0.3	**6.17**	**2.00**
01-05-86 12:30	1.8	0.24	0.12	**7.50**	**2.00**
01-05-86 13:30	1.8	0.24	0.12	**7.50**	**2.00**
01-05-86 17:40	2	0.17	0.08	**11.76**	**2.13**
01-05-86 18:40	2	0.17	0.08	**11.76**	**2.13**

Table II.17. Aerosol fraction only of airborne ^{131}I and ^{134}Cs and ^{137}Cs measured by station A during the period 2 May – 2 June 1986.

Time of measurement	Aerosol ^{131}I [Bq m^{-3}]	Aerosol ^{137}Cs [Bq m^{-3}]	Aerosol ^{134}Cs [Bq m^{-3}]	Isotopic ratio	
				$^{131}I/^{137}Cs$	$^{137}Cs/^{134}Cs$
02-05-86 05:00	1	0.1	0.04	**10.00**	**2.50**
02-05-86 06:00	1	0.1	0.04	**10.00**	**2.50**
02-05-86 20:20	1.16	0.17	0.08	**6.82**	**2.13**
03-05-86 08:15	1.16	0.17	0.08	**6.82**	**2.13**
03-05-86 08:35	0.45	0.035	0.017	**12.86**	**2.06**
03-05-86 20:35	0.45	0.035	0.017	**12.86**	**2.06**
04-05-86 08:30	0.63	0.036	0.016	**17.50**	**2.25**
04-05-86 20:45	0.63	0.036	0.016	**17.50**	**2.25**
04-05-86 21:00	0.52	0.045	0.02	**11.68**	**2.25**
05-05-86 09:00	0.52	0.045	0.02	**11.68**	**2.25**
05-05-86 09:30	0.6	0.05	0.022	**12.00**	**2.27**
06-05-86 09:00	0.6	0.05	0.022	**12.00**	**2.27**
06-05-86 09:05	0.9	0.08	0.038	**11.25**	**2.11**
06-05-86 21:30	0.9	0.08	0.04	**11.25**	**2.00**
06-05-86 22:00	1.5	0.13	0.06	**11.54**	**2.17**
07-05-86 00:30	1.5	0.13	0.06	**11.54**	**2.17**
07-05-86 01:00	5	0.4	0.16	**12.50**	**2.50**
07-05-86 06:30	5	0.4	0.16	**12.50**	**2.50**
07-05-86 07:00	13.6	1.07	0.45	**12.71**	**2.38**
07-05-86 09:40	13.6	1.07	0.45	**12.71**	**2.38**
07-05-86 15:00	6.2	0.41	0.18	**15.12**	**2.28**
07-05-86 16:00	6.2	0.41	0.18	**15.12**	**2.28**
07-05-86 18:00	7	0.5	0.2	**14.00**	**2.50**
07-05-86 23:59	7	0.5	0.2	**14.00**	**2.50**
08-05-86 01:15	9.86	0.76	0.32	**12.97**	**2.38**
08-05-86 07:15	9.86	0.76	0.32	**12.97**	**2.38**
08-05-86 07:30	7.1	0.85	0.4	**8.35**	**2.13**
08-05-86 18:30	7.1	0.85	0.4	**8.35**	**2.13**
08-05-86 19:00	1.6	0.16	0.07	**10.00**	**2.29**
09-05-86 12:30	1.6	0.16	0.07	**10.00**	**2.29**
09-05-86 12:45	0.06	0.005	0.0025	**12.00**	**2.00**
10-05-86 11:17	0.06	0.005	0.0025	**12.00**	**2.00**
10-05-86 13:30	0.06	0.005	0.0025	**12.00**	**2.00**
11-05-86 08:04	0.06	0.005	0.0025	**12.00**	**2.00**
11-05-86 08:10	0.026	0.0013	0.0006	**20.00**	**2.17**
12-05-86 08:19	0.026	0.0013	0.0006	**20.00**	**2.17**
12-05-86 08:20	0.012	0.001	0.0005	**12.00**	**2.00**
13-05-86 01:20	0.012	0.001	0.0005	**12.00**	**2.00**
13-05-86 01:25	0.014	0.001	0.0005	**14.00**	**2.00**
16-05-86 12:05	0.014	0.001	0.0005	**14.00**	**2.00**
16-05-86 12:15	0.04	0.003	0.0013	**13.33**	**2.31**
20-05-86 13:45	0.04	0.003	0.0013	**13.33**	**2.31**
20-05-86 13:46	0.03	0.0022	0.001	**13.64**	**2.20**
24-05-86 19:30	0.03	0.0022	0.001	**13.64**	**2.20**
24-05-86 19:31	0.018	0.001	0.00046	**18.00**	**2.17**
02-06-86 20:30	0.018	0.001	0.00046	**18.00**	**2.17**

Table II.18. Airborne ^{131}I: total, percentage of aerosol fraction, elemental (I_2) and organic (CH_3I) measured by station B during the period of 28 April – 7 May 1986.

Time of measurement	Aerosol ^{131}I* [Bq m^{-3}]	Total ^{131}I [Bq m^{-3}]	Aerosol fraction [%]	Elemental I_2 fraction [%]	Organic CH_3I fraction [%]
28-04-86 17:30	91.999	162.600	57%	41%	2%
29-04-86 08:00	91.999	162.600	57%	41%	2%
29-04-86 12:00	41.197	60.700	68%	30%	2%
29-04-86 15:20	41.197	60.700	68%	30%	2%
29-04-86 18:45	119.905	172.500	70%	25%	5%
30-04-86 08:10	119.905	172.500	70%	25%	5%
30-04-86 10:02	194.200	270.700	72%	23%	5%
30-04-86 11:55	194.200	270.700	72%	23%	5%
30-04-86 12:45	56.302	110.700	51%	39%	10%
30-04-86 14:46	56.302	110.700	51%	39%	10%
30-04-86 15:10	15.501	33.100	47%	50%	4%
01-05-86 08:03	15.501	33.100	47%	50%	4%
01-05-86 10:27	1.700	5.200	33%	52%	15%
01-05-86 14:27	1.700	5.200	33%	52%	15%
01-05-86 18:05	0.900	2.600	35%	50%	15%
02-05-86 07:05	0.900	2.600	35%	50%	15%
02-05-86 08:37	1.300	3.500	37%	40%	23%
02-05-86 11:12	1.300	3.500	37%	40%	23%
02-05-86 11:56	1.600	4.400	36%	34%	30%
02-05-86 13:59	1.600	4.400	36%	34%	30%
02-05-86 14:26	1.103	3.100	36%	42%	23%
02-05-86 18:00	1.103	3.100	36%	42%	23%
02-05-86 18:30	0.500	1.900	26%	68%	5%
03-05-86 09:22	0.500	1.900	26%	68%	5%
03-05-86 09:50	0.400	1.500	27%	60%	13%
03-05-86 16:20	0.400	1.500	27%	60%	13%
03-05-86 16:45	0.600	2.100	29%	62%	10%
04-05-86 08:12	0.600	2.100	29%	62%	10%
04-05-86 08:15	0.650	1.800	36%	53%	11%
04-05-86 14:37	0.650	1.800	36%	53%	11%
04-05-86 15:13	0.500	1.400	36%	61%	4%
05-05-86 07:03	0.500	1.400	36%	61%	4%
05-05-86 07:46	0.700	1.800	39%	28%	33%
05-05-86 13:05	0.700	1.800	39%	28%	33%
05-05-86 13:12	0.500	1.200	42%	50%	8%
06-05-86 07:30	0.500	1.200	42%	50%	8%
06-05-86 07:38	0.600	1.500	40%	47%	13%
06-05-86 13:56	0.600	1.500	40%	47%	13%
06-05-86 14:03	1.550	2.300	67%	26%	7%
07-05-86 07:03	1.550	2.300	67%	26%	7%
07-05-86 07:09	11.301	13.090	86%	12%	2%
07-05-86 13:34	11.301	13.090	86%	12%	2%
07-05-86 13:39	5.839	8.040	73%	26%	1%

* Aerosol fraction is shown explicit for comparison with measurements of station A.

Table II.19. Airborne ^{131}I: total, percentage of aerosol fraction, elemental (I_2) and organic (CH_3I) measured by station B during the period of 8 May – 16 June 1986.

Time of measurement	Aerosol ^{131}I [Bq m^{-3}]	Total ^{131}I [Bq m^{-3}]	Aerosol fraction [%]	Elemental (I_2) fraction [%]	Organic CH_3I fraction [%]
08-05-86 07:00	5.839	8.040	73%	26%	1%
08-05-86 07:05	9.600	14.300	67%	30%	3%
08-05-86 07:13	9.600	14.300	67%	30%	3%
08-05-86 13:06	1.800	4.200	43%	52%	5%
09-05-86 07:36	1.800	4.200	43%	52%	5%
09-05-86 07:56	0.200	0.700	29%	43%	29%
09-05-86 12:43	0.200	0.700	29%	43%	29%
09-05-86 12:58	0.070	0.390	18%	41%	41%
10-05-86 07:04	0.070	0.390	18%	41%	41%
10-05-86 07:39	0.070	0.300	23%	50%	27%
11-05-86 07:20	0.070	0.300	23%	50%	27%
11-05-86 07:30	0.030	0.190	16%	68%	16%
12-05-86 07:20	0.030	0.190	16%	68%	16%
12-05-86 07:32	0.060	0.110	55%	27%	18%
13-05-86 07:03	0.060	0.110	55%	27%	18%
13-05-86 07:11	0.074	0.120	62%	35%	3%
14-05-86 08:59	0.074	0.120	62%	35%	3%
14-05-86 09:00	0.034	0.100	34%	46%	20%
16-05-86 08:29	0.034	0.100	34%	46%	20%
16-05-86 08:38	0.032	0.080	40%	51%	9%
18-05-86 09:28	0.032	0.080	40%	51%	9%
18-05-86 09:38	0.021	0.051	41%	47%	12%
20-05-86 08:25	0.021	0.051	41%	47%	12%
20-05-86 08:34	0.024	0.050	48%	44%	8%
22-05-86 08:21	0.024	0.050	48%	44%	8%
22-05-86 08:30	0.021	0.038	55%	37%	8%
24-05-86 08:40	0.021	0.038	55%	37%	8%
24-05-86 08:45	0.014	0.029	48%	45%	7%
26-05-86 08:22	0.014	0.029	48%	45%	7%
26-05-86 08:50	0.024	0.052	46%	29%	25%
28-05-86 08:15	0.024	0.052	46%	29%	25%
28-05-86 08:25	0.004	0.014	29%	50%	21%
30-05-86 07:37	0.004	0.014	29%	50%	21%
30-05-86 07:49	0.019	0.028	68%	29%	4%
02-06-86 08:35	0.019	0.028	68%	29%	4%
02-06-86 08:43	0.005	0.007	65%	35%	0%
05-06-86 08:15	0.005	0.007	65%	35%	0%
05-06-86 08:22	0.001	0.004	22%	22%	56%
09-06-86 10:55	0.001	0.004	22%	22%	56%
09-06-86 11:03	0.002	0.008	30%	25%	45%
11-06-86 13:58	0.002	0.008	30%	25%	45%
11-06-86 14:12	0.006	0.015	40%	30%	30%
16-06-86 13:25	0.006	0.015	40%	30%	30%
16-06-86 13:34	0.012	0.024	51%	23%	27%

Table II.20. Combined data of ^{131}I air concentration measured by stations A and B for the period of 27 April – 5 May 1986.

Time of measurement	Station	Total ^{131}I [Bq m^{-3}]	Aerosol fraction [%]	Elemental I_2 fraction [%]	Organic CH_3I fraction [%]
27-04-86 00:00	**A**	**0.07**	57%	41%	2%
27-04-86 23:59	**A**	**0.07**	57%	41%	2%
28-04-86 00:01	**A**	**0.07**	57%	41%	2%
28-04-86 11:09	**A**	**0.07**	57%	41%	2%
28-04-86 11:10	**A**	**110.29**	57%	41%	2%
28-04-86 13:15	**A**	**110.29**	57%	41%	2%
28-04-86 13:55	**A**	**183.81**	57%	41%	2%
28-04-86 14:04	**A**	**183.81**	57%	41%	2%
28-04-86 15:15	**A**	**205.02**	57%	41%	2%
28-04-86 16:55	**A**	**205.02**	57%	41%	2%
28-04-86 17:00	**A**	**127.25**	57%	41%	2%
28-04-86 17:10	**A**	**127.25**	57%	41%	2%
28-04-86 17:30	**A**	**130.79**	57%	41%	2%
28-04-86 17:42	**A**	**130.79**	57%	41%	2%
28-04-86 17:45	**B**	162.60	57%	41%	2%
29-04-86 08:00	**B**	162.60	57%	41%	2%
29-04-86 12:00	**B**	60.70	68%	30%	2%
29-04-86 15:20	**B**	60.70	68%	30%	2%
29-04-86 18:45	**B**	172.50	70%	25%	5%
30-04-86 08:10	**B**	172.50	70%	25%	5%
30-04-86 10:02	**B**	270.70	72%	23%	5%
30-04-86 11:55	**B**	270.70	72%	23%	5%
30-04-86 12:45	**B**	110.70	51%	39%	10%
30-04-86 14:46	**B**	110.70	51%	39%	10%
30-04-86 15:10	**B**	33.10	47%	50%	4%
01-05-86 08:03	**B**	33.10	47%	50%	4%
01-05-86 10:27	**B**	5.20	33%	52%	15%
01-05-86 14:27	**B**	5.20	33%	52%	15%
01-05-86 18:05	**B**	2.60	35%	50%	15%
02-05-86 07:05	**B**	2.60	35%	50%	15%
02-05-86 08:37	**B**	3.50	37%	40%	23%
02-05-86 11:12	**B**	3.50	37%	40%	23%
02-05-86 11:56	**B**	4.40	36%	34%	30%
02-05-86 13:59	**B**	4.40	36%	34%	30%
02-05-86 14:26	**B**	3.10	36%	42%	23%
02-05-86 18:00	**B**	3.10	36%	42%	23%
02-05-86 18:30	**B**	1.90	26%	68%	5%
03-05-86 09:22	**B**	1.90	26%	68%	5%
03-05-86 09:50	**B**	1.50	27%	60%	13%
03-05-86 16:20	**B**	1.50	27%	60%	13%
03-05-86 16:45	**B**	2.10	29%	62%	10%
04-05-86 08:12	**B**	2.10	29%	62%	10%
04-05-86 08:15	**B**	1.80	36%	53%	11%
04-05-86 14:37	**B**	1.80	36%	53%	11%
04-05-86 15:13	**B**	1.40	36%	61%	4%
05-05-86 07:03	**B**	1.40	36%	61%	4%
05-05-86 07:46	**B**	1.80	39%	28%	33%
05-05-86 13:05	**B**	1.80	39%	28%	33%
05-05-86 13:12	**B**	1.20	42%	50%	8%

Table II.21. Combined data of ^{131}I air concentration measured by stations A and B for the period of 6 May – 16 June 1986.

Time of measurement	Station	Total ^{131}I [Bq m^{-3}]	Aerosol fraction [%]	Elemental I_2 fraction [%]	Organic CH_3I fraction [%]
06-05-86 7:30	B	1.20	42%	50%	8%
06-05-86 7:38	B	1.50	40%	47%	13%
06-05-86 13:56	B	1.50	40%	47%	13%
06-05-86 14:03	B	2.30	67%	26%	7%
07-05-86 7:03	B	2.30	67%	26%	7%
07-05-86 7:09	B	13.09	86%	12%	2%
07-05-86 13:34	B	13.09	86%	12%	2%
07-05-86 13:39	B	8.04	73%	26%	1%
08-05-86 7:00	B	8.04	73%	26%	1%
08-05-86 7:05	B	14.30	67%	30%	3%
08-05-86 7:13	B	14.30	67%	30%	3%
08-05-86 13:06	B	4.20	43%	52%	5%
09-05-86 7:36	B	4.20	43%	52%	5%
09-05-86 7:56	B	0.70	29%	43%	29%
09-05-86 12:43	B	0.70	29%	43%	29%
09-05-86 12:58	B	0.39	18%	41%	41%
10-05-86 7:04	B	0.39	18%	41%	41%
10-05-86 7:39	B	0.30	23%	50%	27%
11-05-86 7:20	B	0.30	23%	50%	27%
11-05-86 7:30	B	0.19	16%	68%	16%
12-05-86 7:20	B	0.19	16%	68%	16%
12-05-86 7:32	B	0.11	55%	27%	18%
13-05-86 7:03	B	0.11	55%	27%	18%
13-05-86 7:11	B	0.12	62%	35%	3%
14-05-86 8:59	B	0.12	62%	35%	3%
14-05-86 9:00	B	0.10	34%	46%	20%
16-05-86 8:29	B	0.10	34%	46%	20%
16-05-86 8:38	B	0.08	40%	51%	9%
18-05-86 9:28	B	0.08	40%	51%	9%
18-05-86 9:38	B	0.05	41%	47%	12%
20-05-86 8:25	B	0.05	41%	47%	12%
20-05-86 8:34	B	0.05	48%	44%	8%
22-05-86 8:21	B	0.05	48%	44%	8%
22-05-86 8:30	B	0.04	55%	37%	8%
24-05-86 8:40	B	0.04	55%	37%	8%
24-05-86 8:45	B	0.03	48%	45%	7%
26-05-86 8:22	B	0.03	48%	45%	7%
26-05-86 8:50	B	0.05	46%	29%	25%
28-05-86 8:15	B	0.05	46%	29%	25%
28-05-86 8:25	B	0.01	29%	50%	21%
30-05-86 7:37	B	0.01	29%	50%	21%
30-05-86 7:49	B	0.03	68%	29%	4%
02-06-86 8:35	B	0.03	68%	29%	4%
02-06-86 8:43	B	0.01	65%	35%	0%
05-06-86 8:15	B	0.01	65%	35%	0%
05-06-86 8:22	B	0.00	22%	22%	56%
09-06-86 10:55	B	0.00	22%	22%	56%
09-06-86 11:03	B	0.01	30%	25%	45%
11-06-86 13:58	B	0.01	30%	25%	45%
11-06-86 14:12	B	0.02	40%	30%	30%
16-06-86 13:25	B	0.02	40%	30%	30%
16-06-86 13:34	B	0.02	51%	23%	27%
16-06-86 23:59	B	0.02	51%	23%	27%

Table II.22. Daily averages of ^{131}I concentrations in air and radioiodine forms evaluated on the basis of the data presented in Tables II.20 and II.21.

Daily averages	Total ^{131}I [Bq m-3]	Aerosol fraction [%]	Elemental I_2 fraction [%]	Organic CH_3I fraction [%]
1986-04-27	0.071	57%	41%	2%
1986-04-28	85.700	57%	41%	2%
1986-04-29	136.000	64%	34%	3%
1986-04-30	126.000	59%	36%	5%
1986-05-01	15.000	39%	50%	11%
1986-05-02	2.900	33%	50%	17%
1986-05-03	1.850	27%	64%	9%
1986-05-04	1.750	33%	59%	8%
1986-05-05	1.410	39%	48%	13%
1986-05-06	1.740	52%	39%	9%
1986-05-07	7.710	75%	22%	3%
1986-05-08	6.600	55%	42%	3%
1986-05-09	1.700	28%	45%	27%
1986-05-10	0.328	22%	47%	31%
1986-05-11	0.224	18%	63%	19%
1986-05-12	0.135	43%	40%	17%
1986-05-13	0.117	60%	33%	8%
1986-05-14	0.107	44%	42%	14%
1986-05-15	0.100	34%	46%	20%
1986-05-16	0.087	38%	49%	13%
1986-05-17	0.080	40%	51%	9%
1986-05-18	0.063	41%	49%	11%
1986-05-19	0.051	41%	47%	12%
1986-05-20	0.050	46%	45%	9%
1986-05-21	0.050	48%	44%	8%
1986-05-22	0.042	53%	39%	8%
1986-05-23	0.038	55%	37%	8%
1986-05-24	0.032	51%	42%	7%
1986-05-25	0.029	48%	45%	7%
1986-05-26	0.044	47%	35%	19%
1986-05-27	0.052	46%	29%	25%
1986-05-28	0.027	35%	43%	23%
1986-05-29	0.014	29%	50%	21%
1986-05-30	0.024	55%	35%	9%
1986-05-31	0.028	68%	29%	4%
1986-06-01	0.028	68%	29%	4%
1986-06-02	0.015	66%	33%	1%
1986-06-03	0.007	65%	35%	0%
1986-06-04	0.007	65%	35%	0%
1986-06-05	0.005	37%	26%	37%
1986-06-06	0.004	22%	22%	56%
1986-06-07	0.004	22%	22%	56%
1986-06-08	0.004	22%	22%	56%
1986-06-09	0.006	26%	24%	50%
1986-06-10	0.008	30%	25%	45%
1986-06-11	0.011	34%	27%	39%
1986-06-12	0.015	40%	30%	30%
1986-06-13	0.015	40%	30%	30%
1986-06-14	0.015	40%	30%	30%
1986-06-15	0.015	40%	30%	30%

II.5.2. ^{131}I and ^{137}Cs concentration in soil

The spectrometric measurements of ^{131}I concentration in soil were conducted only occasionally unlike the gross beta measurements of deposition. In the following years the extensive investigations of radiocaesium contents in soil had started but the lack of confidence in the ratio ^{131}I/^{137}Cs in a case of almost mixed deposition (dry and wet) over Polish territory makes reconstruction of ^{131}I deposition very problematic.

Nevertheless, this chapter provides some additional information to bring closer modeler to real radiological situation in Mazovia Province with respect to the insights gained from participation.

According to the sampling records the soil samples were taken from the area of 25 cm × 20 cm and 10 cm, than soil has been dried at the room temperature and put in a standard container of 0.5 l Marinelli beaker type. The measurements of radionuclide concentrations in soil samples are made using a gamma spectrometric system with HPGe detectors located in low-background lead shielding chambers.

The soil samples for further laboratory analyses were collected in 1988, 1989, 1990, 1992, 1996, 1998 and 2000 in the network of the fixed sampling sites which are located at the stations of the Institute of Meteorology and Water Management (the meteorological posts' gardens). At the beginning there were 340 points located all over Poland but recently the number of them was reduced to 255. In the same sites, measurements of the gamma radiation dose were performed. The investigations are performed in the frame of the Polish environmental monitoring system and used for the all-country digital radiological database and for a set of radiological maps of Poland.

The soil samples are collected in undistributed, uncovered areas, without vegetation (only grass) or structures. Each sample is taken by a knife-edge pipe of 2 inch diameter from 10 cm thick surface layer at seven places. Six of them are situated at the circumference of the circle of 2 m radius and one in the centre of the circle. At the laboratory, the soil samples are dried at the room temperature first and then in ovens at temperature not exceeding 105^{o}C. The dried material is crushed to obtain homogeneous sample and put in a standard container of 0.5 l Marinelli beaker type.

The measurements of radionuclide concentrations in soil samples are made using gamma spectrometric GENIE 2000 system with HPGe detectors located in low-background lead shielding chambers. The chambers reduce the external gamma radiation background by two orders of magnitude. The time of each measurement is 80 000 s.

Additionally in a frame of other projects determination of ^{137}Cs soil content was determined using 13 cm diameter and 30 cm core samplers.

The averages of ^{137}Cs deposition in counties that contributed to the diaries in Warsaw and Ostroleka area are presented in Table II.26. One needs to remark that for several counties no direct measurements of ^{137}Cs in soil were performed. In these cases the standard (IDW – Inverse Distance Weight) interpolation from neighboring points was applied. Moreover, the counties borders are set for administrative reasons and cover areas of inhomogeneous deposition of ^{137}Cs (see Figure II.25). This heterogeneity resulted mainly from local rains that occurred on 30 April 1986 and more intensive precipitations during 8–10 May 1986. On the other hand there are only two "recorded" spots of elevated ^{137}Cs content in soil in Mazovia region (see Figure II.25) and the overall average is 4.7 ± 1.5 kBq/m^2, where 1.5 kBq/m^2 is a standard deviation of single value and can be considered as quantifier of uncertainty ranges.

The soil sampling and measurements of ^{137}Cs content in soil started in 1988. Soil samples were taken in the meteorological posts' gardens, therefore the "Location" in the first column of Table II.25 of Scenario W (^{137}Cs concentration in soil) is directly related to the meteopost.
The soil sampling and measurements of ^{137}Cs content in soil started in 1988. Soil samples were taken in the meteorological posts' gardens, therefore the "Location" in the first column of Table II.25 of Scenario W (^{137}Cs concentration in soil) is directly related to the meteopost.

II.5.3. ^{131}I concentration in milk samples

Daily ^{131}I concentrations in milk samples were measured approximately in 20 locations of the region specified (about 100 measurements). Measurements were mostly performed by radiochemical methods, but for several locations gamma spectrometric measurements were given and ^{137}Cs and ^{134}Cs concentrations in the same sample were determined.

Measurements were conducted both for cows on the pasture and cows kept in cowsheds.

The average ^{137}Cs concentration measured in Warsaw-Okecie meteopost – 2.5 km from Falenty dairy was about 4 kB/m^2, therefore close to the average of Mazovia area.

Regarding milk measurements in diaries in Warsaw and Ostroleka town 2.5 km as well as in several other locations there is no apparent correlation between ^{137}Cs density and measured ^{131}I in milk.

II.5.4. Direct measurements of ^{131}I content in human thyroids

^{131}I thyroid contents were measured for about 1200 inhabitants of Mazovia province in the period of 29 April – 5 July 1986 (see Figure II.30). The most numerous measurements were performed during the period 29 April – 15 May 1986. Measurements were conducted with stationary unit in Central Laboratory for Radiological Protection equipped with led collimated coupled 3" × 3" NaI detectors with spectrometric channel set (340–380 keV). Information about the age, sex, date of thyroid blocking and diet (milk consumption) as well as physical activity was associated by interview with each of measurement.

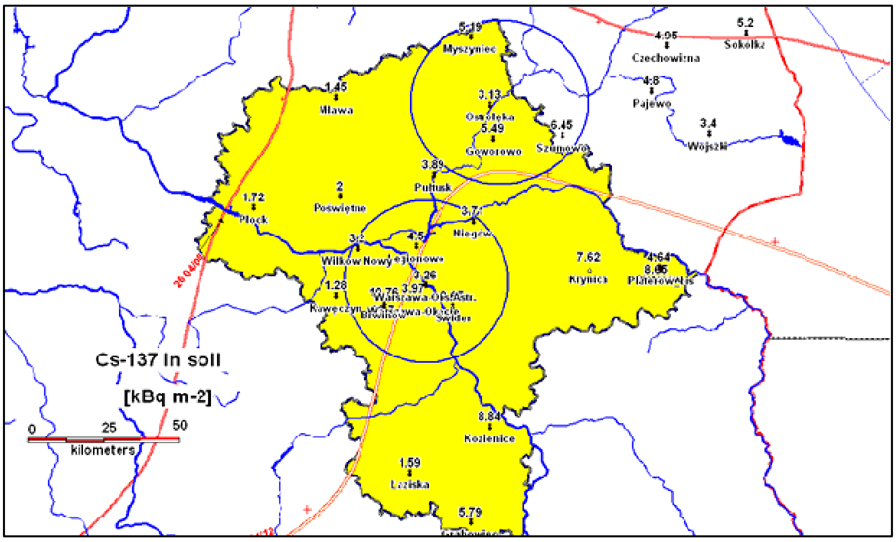

Fig. II.25. Spatial variation of ^{137}Cs content in soil in Mazovia region [kBq ·m^{-2}].

Table II.23. The ^{131}I concentration in soil samples collected in Warsaw from the same place during the period 28 April – 21 May 1986.

Date of sampling	$Bq \cdot kg^{-1}$
30 04 1986	3024
03 05 1986	3300
04 05 1986	3976
05 05 1986	3000
07 05 1986	458
09 05 1986	1150
10 05 1986	1200
11 05 1986	1370
12 05 1986	370
14 05 1986	386
16 05 1986	436
18 05 1986	122
19 05 1986	171
20 05 1986	314
21 05 1986	314

Table II.24. Isotopic ratio in soil samples collected in Warsaw from 30 April – 20 May 1986.

Date of sampling	^{131}I	^{132}Te	^{132}I	^{134}Cs	^{136}Cs	^{137}Cs	^{103}Ru	^{99}Mo	^{95}Zr	^{95}Nb	^{140}Ba	^{140}La	^{141}Ce
30 04 1986	7.37	6.15	5.70	0.54	0.24	1.00	1.02	0.63		0.03	0.70		
04 05 1986	8.31	2.95	2.71	0.59	0.06	1.00	1.16	0.29	0.39	0.03	0.72		
09 05 1986	5.08	1.12	0.96	0.55	0.13	1.00	1.42			0.04	0.57		0.04
20 05 1986	1.81	0.08	0.08	0.55	0.11	1.00	1.00		0.08		0.26		

Table II.25. ^{137}Cs content in soil in Mazovia region.

Location	Longitude	Latitude	^{137}Cs content in soil calculated on 1986 $[kBq \cdot m^{-2}]$
Brwinow bis	20.719	52.118	22.70
Brwinów	20.717	52.133	10.76
Czechowizna	22.889	53.345	4.95
Goworowo	21.562	52.907	5.49
Grabowiec	21.383	51.100	5.79
Kawęczyn	20.350	52.167	1.28
Kozienice	21.533	51.550	8.84
Krynica	22.295	52.301	7.62
Legionowo	20.967	52.400	4.50
Łaziska	20.917	51.333	1.59
Mława	20.350	53.100	1.45
Myszyniec	21.383	53.383	5.19
Niegów	21.400	52.517	3.71
Ostrołęka	21.533	53.067	3.13
Pajewo	22.779	53.130	4.80
Platerow_bis	22.844	52.294	8.65
Platerów	22.833	52.300	4.64
Płock	19.717	52.583	1.72
Poświętne	20.383	52.633	2.00
Pułtusk	21.100	52.733	3.89
Sokółka	23.500	53.405	5.20
Szumowo	22.085	52.921	6.45
Świder	21.250	52.117	8.65
Warszawa-Obs.Astr.	21.033	52.217	3.26
Warszawa-Okęcie	20.950	52.150	3.97
Wilkow Nowy	20.513	52.386	3.20
Wojszki	23.212	52.927	3.40

Table II.26. An assessment of ^{137}Cs deposition in the particular counties of Mazovia region.

Delivery area	Estimated deposition of ^{137}Cs in county kBq/m^2						Measurements of ^{137}Cs kBq/m^2			
	County	**Mean**		**SD**	**Min**	**Max**	**Meteo post location**	**Measured value**	**Location (additonal measurements)**	**Measured value**
WARSAW	grodziski mazowiecki	8.6	±	4.4	2	16	No meteopost		NDM	
WARSAW	grojecki	4.2	±	1.3	3	9	No meteopost		NDM	
WARSAW	legionowski	4.1	±	1.1	3	7	Legionowo	4.5	NDM	
WARSAW	minski	4.5	±	1.0	4	5	No meteopost		NDM	
WARSAW	nowodworski mazowiecki	3.8	±	0.8	2	6	No meteopost		Wilkow Nowy	3.2
WARSAW	otwocki	4.9	±	0.4			Świder	4.0	NDM	
WARSAW	piaseczynski	4.8	±	0.6	4	10	No meteopost		NDM	
WARSAW	pruszkowski	8.4	±	3.7	4	6	Brwinow	10.8	Brwinow bis	22.7
							Warszawa-Okęcie	4.0	NDM	
WARSAW	pultuski	3.6	±	0.5	3	4	Pułtusk	3.9	NDM	
WARSAW	warszawski	4.5	±	0.7	3	6	Warszawa-Obs.Astr.	3.3	NDM	
WARSAW	warszawski zachodni	6.7	±	3.3	1.5	14	No meteopost		NDM	
WARSAW	wolominski	5.7	±	1.8	6	8	No meteopost		Wolomin town	11.2
									Wolomin town bis	6.2
WARSAW	wyszkowski	4.5	±	0.5	4	10	Niegów	3.7	NDM	
Overall average		5.2	±	1.4					NDM	
									NDM	
OSTROLEKA	kolnenski	3.3	±	0.7	2	5	No meteopost		NDM	
OSTROLEKA	lomzynski	3.3	±	0.7	2	5	Marianowo	1.8	NDM	
OSTROLEKA	makowski	3.9	±	0.3	3	4	No meteopost		NDM	
OSTROLEKA	ostrolecki	4.6	±	0.7	3	3.5	Myszyniec	5.2	Goworowo	5.5
OSTROLEKA	OSTROLEKA	4.6	±	0.7	3	3.5	Ostroleka	3.1	NDM	
OSTROLEKA	piski	3.8	±	0.9	2.5	6	Mikołajki	6.8	NDM	
OSTROLEKA	przasnyski	3.6	±	0.5	2.5	4	No meteopost		NDM	
OSTROLEKA	szczycienski	4.3	±	0.9	2.5	5	Szczytno	5.1	NDM	
OSTROLEKA	zambrowski	4.1	±	1.3	2.5	6.5	No meteopost		Szumowo	6.5
Overall average		3.9	±	0.3						

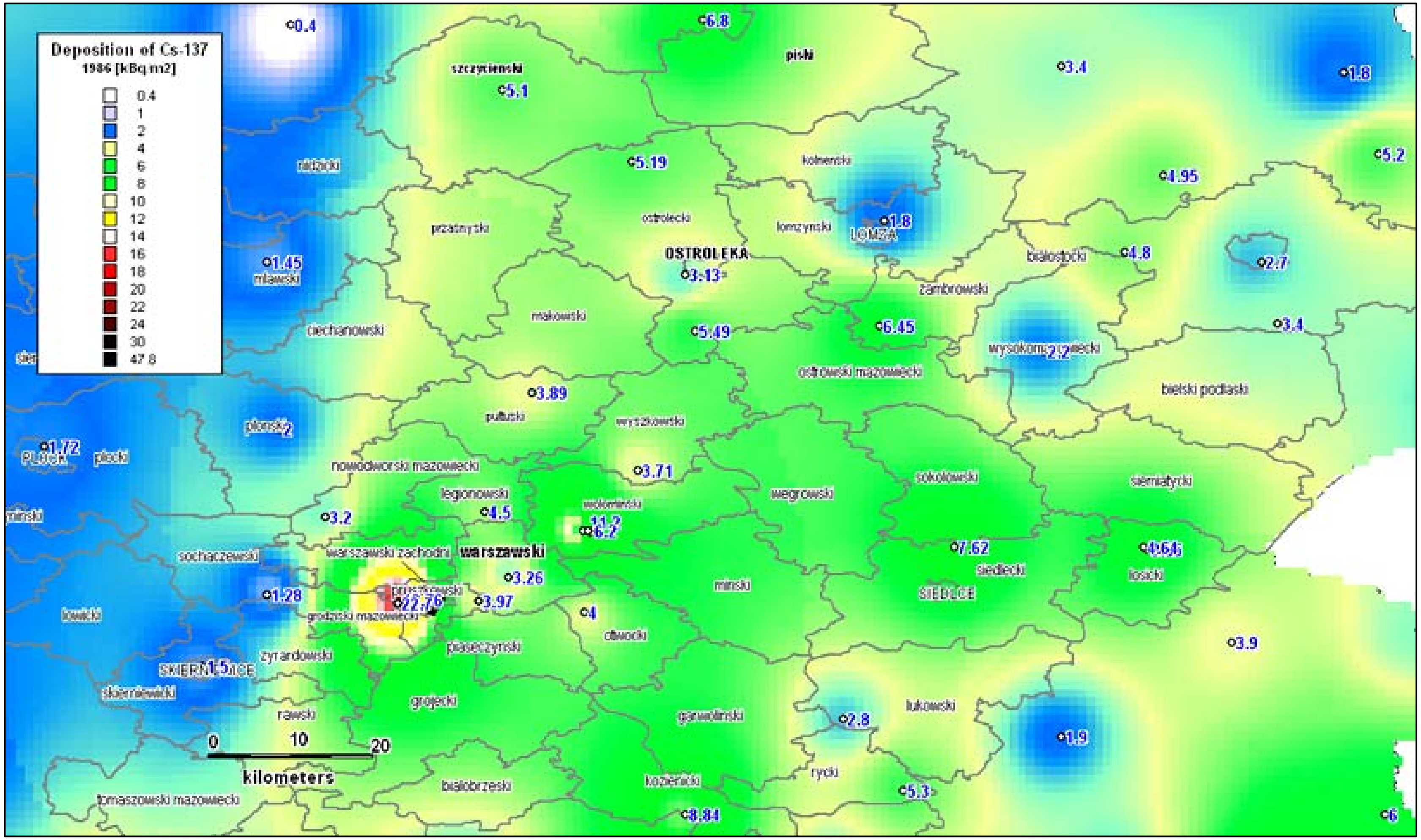

Fig. II.26. An assessment of ^{137}Cs deposition for MAZOVIA region.
(Blue numbers present the sampling points and measured ^{137}Cs soil content (kBq/m^2).

Fig. II.27. Location of milk measurements in Mazovia province.

Table II.27. Measurement data of ^{131}I concentration in milk in the specified locations in WARSAW AREA and the best fit to the measurements values (Bq L^{-1} fresh weight).

DATE	Best fit values	Lower 95% confidence bound	Upper 95% confidence bound	SPECIFIED LOCATIONS IN WARSAW AREA									
				FALENTY DUŻE DAIRY	WARSAW TOWN DAIRY	LEGIONOWSKI DAIRY	PŁONSKI	PŁONSKI NW	NOWODWORSKI - MAZOWIECKI	WONOMIŃSKI	MINSKI	PRUSZKOWSKI	OTWOCKI
27 04 86													
28 04 86	**173**	104	260		145								
29 04 86	**307**	184	460		545								
30 04 86	**349**	209	524		521					683	330		540
01 05 86	**373**	224	559	130	175					360			
02 05 86	**382**	229	572	52		827	423	213	679				
03 05 86	**379**	227	569	35				303					
04 05 86	**368**	221	552	21	158	188	183		115				
05 05 86	**351**	211	527	17		283	260	378	33			430	
06 05 86	**331**	199	496	8		328	290	468	328				
07 05 86	**308**	185	462		117	243	143	413	278	407	389		
08 05 86	**284**	171	426	20						115	138		
09 05 86	**260**	156	390		170	334					93		
10 05 86	**237**	142	355			578							
11 05 86	**214**	128	321	6		448							
12 05 86	**193**	116	289		190	212							
13 05 86	**173**	104	259		100	221							
14 05 86	**154**	92	231		141	273							
15 05 86	**137**	82	206		98								
16 05 86	**122**	73	182		160	250							
17 05 86	**108**	65	161		145	163							
18 05 86	**95**	57	142		107	154							
19 05 86	**84**	50	125		153	106							
20 05 86	**73**	44	110		107	135							
21 05 86	**64**	39	97			113							
22 05 86	**56**	34	85		102	45							
23 05 86	**49**	30	74		89	63							
24 05 86	**43**	26	65			108							
25 05 86	**38**	23	56		36	41							
26 05 86	**33**	20	49		44								
27 05 86	**28**	17	43		31								
28 05 86	**25**	15	37										
29 05 86	**21**	13	32		28	24							
30 05 86	**19**	11	28			12							
31 05 86	**16**	10	24		20	12							
01 06 86	**14**	8	21		19								
02 06 86	**12**	7	18		15								
03 06 86	**10**	6	16		16								

Table II.28. Measurement data of ^{131}I concentration in milk in the specified locations of OSTROLEKA AREA (Bq L^{-1} fresh weight).

DATE	Best fit values	Lower 95% confidence bound	Upper 95% confidence bound	OSTROLEKA AREA					
				MAKOWSKI	PISKI	OSTROLEKA DAIRY	PRZASNYSKI DAIRY	ZAMBROWSKI	SZCZYCIENSKI
27 04 86									
28 04 86	**887**	558	1507						
29 04 86	**1392**	876	2366			175	1381	468	
30 04 86	**1666**	1049	2832	25	13	238	1850		1588
01 05 86	**1779**	1120	3024	60				3180	
02 05 86	**1783**	1123	3031		128				1604
03 05 86	**1717**	1081	2919		457	2450	1555	2535	
04 05 86	**1608**	1013	2734		492		1521	2583	
05 05 86	**1476**	929	2509			1025			607
06 05 86	**1333**	840	2267		217	2000			
07 05 86	**1190**	749	2023			2175	1144		
08 05 86	**1052**	662	1788		309				
09 05 86	**922**	580	1567			600	777		
10 05 86	**802**	505	1364		335	300			
11 05 86	**694**	437	1180			600			
12 05 86	**597**	376	1016		243	400	850		
13 05 86	**512**	322	870			625	845		
14 05 86	**437**	275	743						
15 05 86	**372**	234	632			500	646		
16 05 86	**315**	199	536				546		
17 05 86	**267**	168	453				400		
18 05 86	**225**	142	383				359		
19 05 86	**189**	119	322			103	278		
20 05 86	**159**	100	271			293	244		
21 05 86	**133**	84	227			418			
22 05 86	**112**	70	190						
23 05 86	**93**	59	159			143			
24 05 86	**78**	49	132			75			
25 05 86	**65**	41	110			83			
26 05 86	**54**	34	92						
27 05 86	**45**	28	76						
28 05 86	**37**	23	63						
29 05 86	**31**	19	53						
30 05 86	**26**	16	44			23			
31 05 86	**21**	13	36						
01 06 86	**18**	11	30						
02 06 86	**15**	9	25			18			
03 06 86	**12**	8	20						

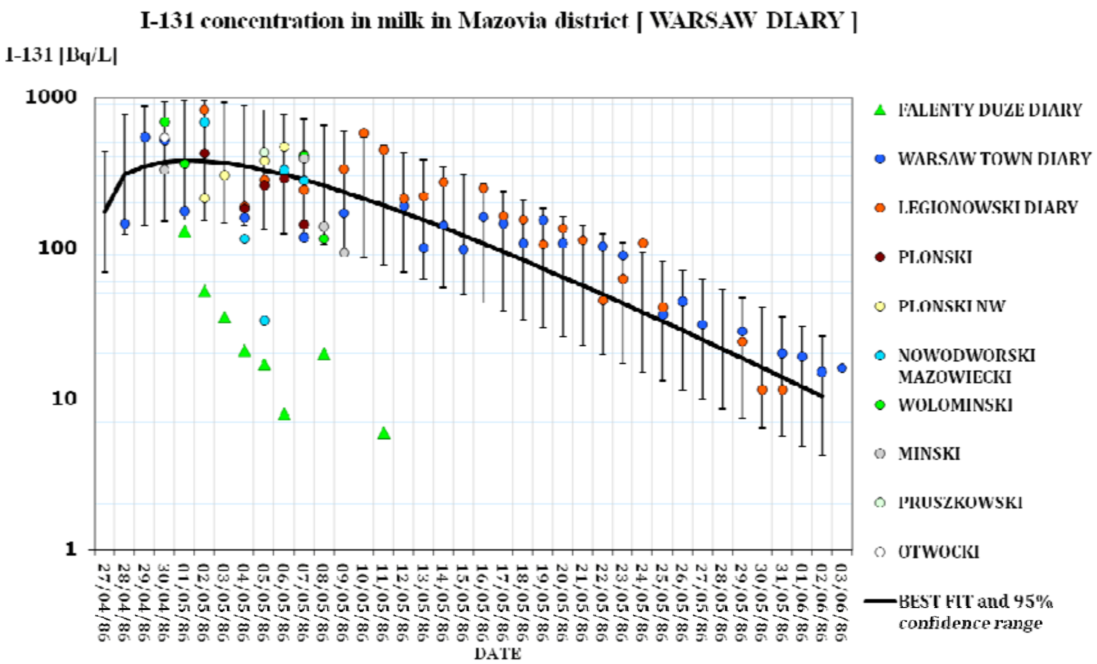

Fig. II.28. Measurements data of ^{131}I concentration in milk in the specified locations in WARSAW AREA and the best fit to the measurements values (Bq L^{-1} fresh weight).

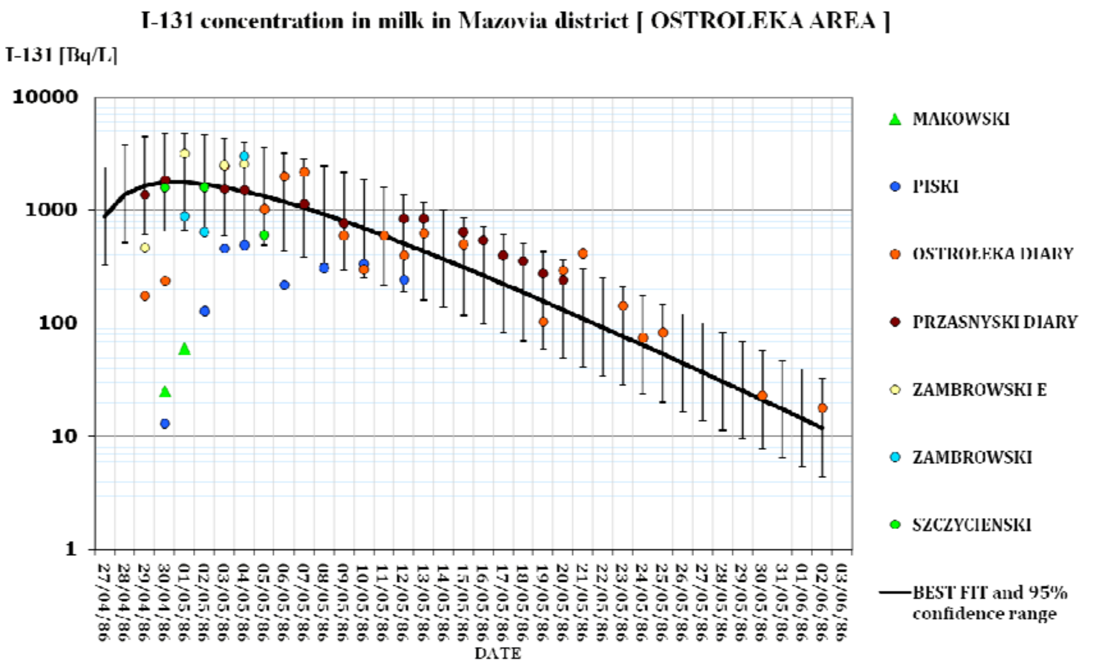

Fig. II.29. Measurements data of ^{131}I concentration in milk in the specified locations in OSTROLEKA AREA and the best fit to the measurements values (Bq L^{-1} fresh weight).

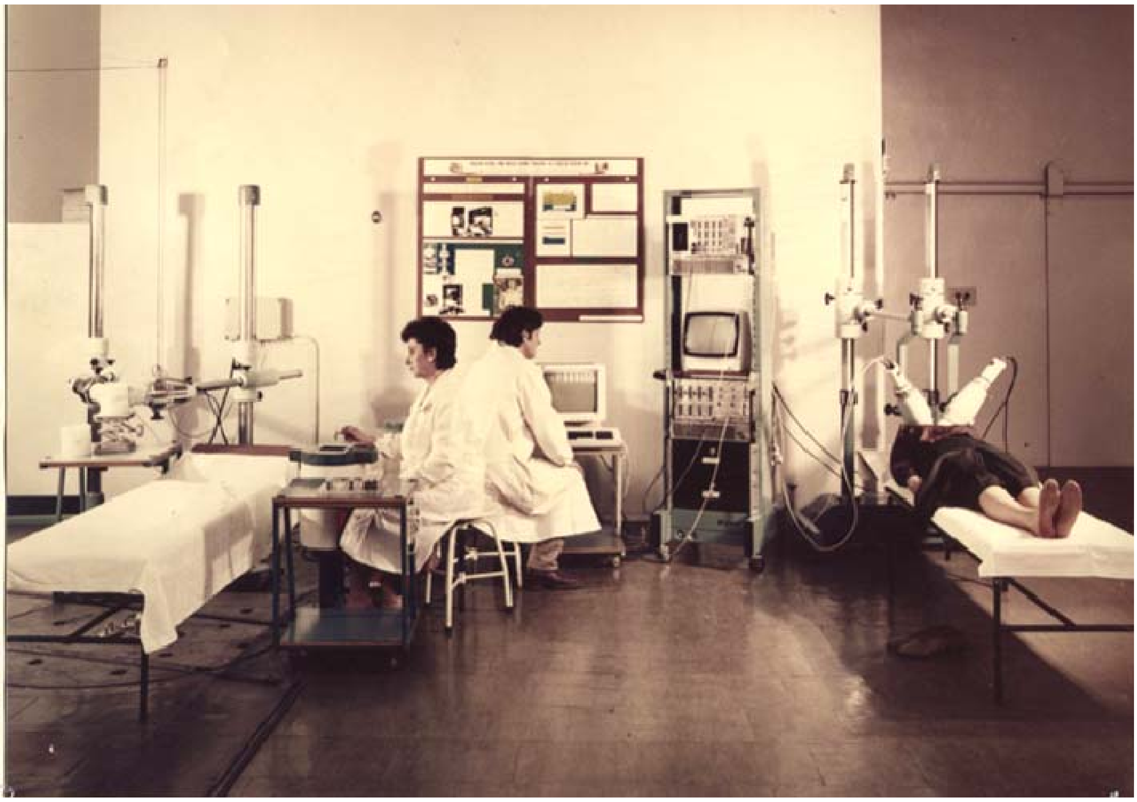

Fig. II.30. Measurements of ^{131}I in thyroid (1986).

Table II.29. Measurements data of ^{131}I thyroid content for adult inhabitants of WARSAW town [Bq].

DATE	WARSAW (ADULTS) age >=20											
	No stb. Iodine				60 mg stable iodine on 29 04 86				60 mg stable iodine on 30 04 86			
	N# of meas. in given day	Arithmetic mean	95% Confidence interval		N# of meas. in given day	Arithmetic mean	95% Confidence interval		N# of meas. in given day	Arithmetic mean	95% Confidence interval	
			Lower Bound	Upper Bound			Lower Bound	Upper Bound			Lower Bound	Upper Bound
29-04-86	76	808	*802*	*814*								
30-04-86	130	1120	*1110*	*1130*								
02-05-86	153	748	*743*	*753*								
03-05-86	12	772	*720*	*827*								
04-05-86	11	774	*715*	*839*	2	360	*180*	*723*				
05-05-86	64	732	*723*	*741*	8	396	*290*	*539*	17	478	456	500
06-05-86	84	778	*769*	*786*	13	354	*333*	*378*	7	696	543	891
07-05-86	41	670	*656*	*684*	12	307	*288*	*327*	7	630	517	767
08-05-86	39	702	*683*	*722*	4	563	*306*	*1036*	4	380	309	467
09-05-86	44	775	*754*	*796*	3	509	*439*	*591*	9	694	614	786
10-05-86	6	587	*377*	*916*	1	284	*189*	*426*	8	567	512	627
12-05-86	18	641	*604*	*679*	8	467	*416*	*525*	9	650	522	809
13-05-86	23	609	*586*	*634*	5	351	*124*	*993*	2	237	24	2365
14-05-86	25	499	*482*	*516*	1	269	*179*	*404*	11	256	232	284
15-05-86	2	330	*160*	*681*	4	365	*281*	*473*	5	317	272	369
16-05-86	5	654	*605*	*708*	1	197	*131*	*296*	2	351	306	402
17-05-86	1	742	*495*	*1113*	3	303	*188*	*487*	3	250	221	282
19-05-86	2	1200	*120*	*12004*	2	195	*146*	*261*	6	657	527	819
20-05-86	20	769	*696*	*849*	2	164	*111*	*243*	5	280	267	295
21-05-86	12	382	*371*	*394*	1	117	*78*	*176*	3	437	382	500
22-05-86	12	404	*376*	*434*								
23-05-86	5	410	*311*	*541*	2	146	*107*	*200*	7	251	237	265
26-05-86	2	255	*60*	*1088*					1	321	214	482
27-05-86	14	220	*210*	*230*	3	246	*72*	*844*	4	425	337	536
28-05-86	12	326	*297*	*358*	2	411	*241*	*702*	3	336	134	842
30-05-86	6	275	*145*	*522*	1	157	*105*	*236*	8	304	243	380
02-06-86	1	439	*293*	*659*	1	58	*39*	*87*	3	463	156	1375
03-06-86	1	123	*82*	*185*					1	280	187	420
04-06-86	5	105	*84*	*130*					1	155	103	233
05-06-86	3	165	*57*	*474*	1	370	*247*	*555*	2	139	101	190
06-06-86	2	235	*205*	*269*					1	88	59	132
09-06-86	1	733	*489*	*1100*								
10-06-86	1	39	*26*	*59*								

Table II.30. Measurements data of ^{131}I thyroid content for teenagers inhabitants of WARSAW town [Bq].

DATE	WARSAW (TEENAGERS) age >= 10–17							
	60 mg stable iodine on 29 04 86				60 mg stable iodine on 30 04 86			
	N# of meas. in given day	Arithmetic mean	95% Confidence interval		N# of meas. in given day	Arithmetic mean	95% Confidence interval	
			Lower Bound	Upper Bound			Lower Bound	Upper Bound
29-04-86								
30-04-86								
02-05-86								
03-05-86								
04-05-86								
05-05-86								
06-05-86	2	494	*219*	*1114*				
07-05-86	2	214	*143*	*321*	2	582	*388*	*873*
08-05-86	2	507	*238*	*1080*	2	608	*405*	*912*
09-05-86					2	371	*247*	*557*
10-05-86	2	324	*216*	*486*	7	718	*660*	*782*
12-05-86					2	578	*455*	*735*
13-05-86	2	755	*503*	*1133*	2	393	*262*	*590*
14-05-86					3	458	*409*	*512*
15-05-86					2	316	*211*	*474*
16-05-86					2	304	*203*	*456*
17-05-86	2	246	*164*	*369*	2	283	*189*	*425*
19-05-86					2	374	249	561
20-05-86					3	387	358	418
21-05-86	2	223	*149*	*335*				
22-05-86								
23-05-86	2	191	*127*	*287*	2	485	*323*	*728*
26-05-86								
27-05-86								
28-05-86					3	804	*535*	*1209*
30-05-86					2	320	*213*	*480*
02-06-86								
03-06-86								
04-06-86								
05-06-86								
06-06-86								
09-06-86								
10-06-86								

Table II.31. Measurements data of ^{131}I thyroid content for children of WARSAW town [Bq].

DATE	WARSAW (CHILDREN) age >= 3–10							
	30 mg stable iodine on 29 04 86				30 mg stable iodine on 30 04 86			
	N# of meas. in given day	Arithmetic mean	95% Confidence interval		N# of meas. in given day	Arithmetic mean	95% Confidence interval	
			Lower Bound	Upper Bound			Lower Bound	Upper Bound
29-04-86								
30-04-86								
02-05-86								
03-05-86								
04-05-86								
05-05-86	2	733	*489*	*1100*	2	*805*	*562*	*1154*
06-05-86	2	289	*176*	*475*	2	*322*	*215*	*483*
07-05-86	2	313	*279*	*350*	15	*714*	*372*	*1371*
08-05-86	5	447	*397*	*505*	15	*655*	*573*	*747*
09-05-86	4	469	*348*	*632*	11	*726*	*683*	*772*
10-05-86	2	284	*189*	*426*	17	*625*	*599*	*652*
12-05-86	2	194	129	291	4	*516*	*425*	*626*
13-05-86	6	332	294	376	11	*806*	*685*	*948*
14-05-86	2	298	264	335	8	*407*	*369*	*448*
15-05-86					8	*304*	*272*	*340*
16-05-86					2	*322*	*215*	*483*
17-05-86	2	202	180	227	8	*371*	*286*	*480*
19-05-86	3	257	235	281	15	*727*	*674*	*785*
20-05-86					4	*315*	*248*	*400*
21-05-86	2	338	225	507	3	*1114*	*163*	*7614*
22-05-86					4	*696*	*435*	*1112*
23-05-86	2	163	131	204	6	*305*	*284*	*328*
24-05-86	2	118	79	177				
26-05-86					10	*419*	*348*	*504*
27-05-86					4	*351*	*307*	*401*
28-05-86	2	500	333	750	2	*338*	*176*	*649*
30-05-86					4	239	*141*	*406*
02-06-86					2	330	*145*	*753*
03-06-86								
04-06-86					3	110	*80*	*151*
05-06-86					2	285	*190*	*428*
06-06-86								
09-06-86					2	268	179	402
10-06-86								

Table II.32. Measurements data of ^{131}I thyroid content for adult inhabitants of OSTROLEKA area [Bq].

WARSAW (ADULTS) age >=20												
	No stb. Iodine				60 mg stable iodine on 29 04 86				60 mg stable iodine on 30 04 86			
DATE	N# of meas. in given day	Arithmetic mean	95% Confidence interval		N# of meas. in given day	Arithmetic mean	95% Confidence interval		N# of meas. in given day	Arithmetic mean	95% Confidence interval	
			Lower Bound	Upper Bound			Lower Bound	Upper Bound			Lower Bound	Upper Bound
29-04-86												
30-04-86												
02-05-86												
03-05-86												
04-05-86												
05-05-86												
06-05-86												
07-05-86												
08-05-86												
09-05-86												
10-05-86												
12-05-86												
13-05-86												
14-05-86									2	732	*488*	*1098*
15-05-86									2	3320	*2213*	*4980*
16-05-86									2	2471	*1647*	*3707*
17-05-86	2	4120	*3869*	*4386*								
19-05-86	3	2303	*1611*	*3290*								
20-05-86												
21-05-86					36	910	*884*	*937*	2	813	*542*	*1220*
22-05-86									2	987	*869*	*1121*
23-05-86	3	5304	*1959*	*14357*	3	1756	*1711*	*1803*	2	14610	*2377*	*89811*
26-05-86	2	3827	*2551*	*5741*					3	2370	*2089*	*2690*
27-05-86	6	1463	*1244*	*1721*	2	1033	*1030*	*1035*	2	372	*216*	*638*
28-05-86									3	1047	*746*	*1470*
30-05-86	7	2681	*2229*	*3225*	2	1384	*1371*	*1397*	4	521	*374*	*726*
02-06-86	4	3433	*1608*	*7329*					2	1419	*1150*	*1752*
03-06-86	3	615	*320*	*1181*	2	1126	*523*	*2424*				
04-06-86	2	1743	*1162*	*2615*								
05-06-86									2	126	*84*	*189*
06-06-86									2	289	*193*	*434*
09-06-86												
10-06-86												
11-06-86	3	355	*246*	*513*					2	296	*197*	*444*
13-06-86	2	277	*185*	*416*								
17-06-86	2	414	*276*	*621*					2	3612	*2408*	*5418*

Table II.33. Measurements data of ^{131}I thyroid content for teenagers inhabitants of OSTROLEKA area [Bq].

DATE	OSTROLEKA area (TEENAGERS) age >= 10–17							
	60 mg stable iodine on 29 04 86				60 mg stable iodine on 30 04 86			
	N# of meas. in given day	Arithmetic mean	95% Confidence interval		N# of meas. in given day	Arithmetic mean	95% Confidence interval	
			Lower Bound	Upper Bound			Lower Bound	Upper Bound
29-04-86								
30-04-86								
02-05-86								
03-05-86								
04-05-86								
05-05-86								
06-05-86								
07-05-86								
08-05-86								
09-05-86								
10-05-86								
12-05-86								
13-05-86								
14-05-86								
15-05-86								
16-05-86								
17-05-86					2	7020	*4680*	*10530*
19-05-86								
20-05-86								
21-05-86	71	1592	*1573*	*1610*	2	1656	*1104*	*2484*
22-05-86	1	1411	*941*	*2117*				
23-05-86	1	2407	*1605*	*3611*	2	6945	*4630*	*10418*
26-05-86								
27-05-86	2	897	*719*	*1117*	2	2560	*1707*	*3840*
28-05-86	1	1605	*1070*	*2408*				
30-05-86	1	1778	*1185*	*2667*	2	1119	*746*	*1679*
02-06-86					2	2793	*1621*	*4814*
03-06-86								
04-06-86	1	836	*557*	*1254*				
05-06-86								
06-06-86								
09-06-86								
10-06-86								

Table II.34. Measurements data of ^{131}I thyroid content for children of OSTROLEKA area [Bq].

DATE	OSTROLEKA AREA (CHILDREN) age >= 3–10							
	30 mg stable iodine on 29 04 86				30 mg stable iodine on 30 04 86			
	N# of meas. in given day	Arithmetic mean	95% Confidence interval		N# of meas. in given day	Arithmetic mean	95% Confidence interval	
			Lower Bound	Upper Bound			Lower Bound	Upper Bound
29-04-86								
30-04-86								
02-05-86								
03-05-86								
04-05-86								
05-05-86								
06-05-86								
07-05-86								
08-05-86								
09-05-86								
10-05-86								
12-05-86								
13-05-86								
14-05-86								
15-05-86					1	14300	*9533*	*21450*
16-05-86					1	1473	*982*	*2210*
17-05-86					1	4480	*2987*	*6720*
19-05-86					1	1725	*1150*	*2588*
20-05-86								
21-05-86	71	1265	*1250*	*1281*	1	1409	*939*	*2114*
22-05-86					1	556	*371*	*834*
23-05-86					6	6649	*2987*	*14800*
24-05-86	1	681	*454*	*1022*	4	2762	*2240*	*3405*
26-05-86								
27-05-86					3	615	*537*	*704*
28-05-86	5	1032	*904*	*1179*	1	1111	*741*	*1667*
30-05-86	1	2570	*1713*	*3855*	4	1834	*1206*	*2790*
02-06-86					2	3617	*2105*	*6215*
03-06-86					2	242	*232*	*253*
04-06-86	1	759	*506*	*1139*				
05-06-86								
06-06-86								
09-06-86								
10-06-86								
20-06-86					1	699	*466*	*1049*

II.6. Doses assessment in the Mazovia area from radioactive iodine

II.6.1. An assessment of the effectiveness of the preventive dose of stable iodine KI

Reconstruction of ^{131}I doses for the population of Poland required an assessment of the influence of the preventive dose of stable iodine on the reduction of ^{131}I dose H_{50} in thyroid gland. The simple ICRP model seemed to be less useful, but the model of the metabolism of iodine in the thyroid gland developed by Johanson [II.5] and Johnson [II.6] enabled the quantitative accurate assessment of changes depending on the blocking dose of stable iodine. Although the reduction of radiation dose to thyroid depends on the time span between acute uptake of radioiodine ^{131}I and the intake of stable iodine (see Figure II.31) in a case of a prolonged intake, evaluation of reduction of H_{50} dose required more complicated calculation and it was a fundamental problem in the assessment of the ^{131}I hazard for populations of Poland. This assessment was carried out with the help of computer simulation on the basis of available measurement data of ^{131}I concentration in air and contaminated foodstuffs, especially in milk and milk products. Figure II.32 shows different dynamic of the ^{131}I activity in the thyroid gland for adults who inhaled contaminated air measured in Warsaw (28 April – 30 May 1986) at different dates of thyroid blockade. The effect of thyroid blockade for adults drinking contaminated milk (without inhalation of contaminated air) is shown in Figure II.33. The results of computer simulation of H_{50} reduction for different air and milk contamination variants that might be typical for Poland are presented in Table II.35. Assuming short (24 hours) ^{131}I cloud passage, the thyroid dose H_{50} as a result of inhalation could be reduced by about 75% (closely three times) when thyroid blockade was undertaken on 28 April 1986 12:00 and by 62% when blockade is taken on 29 April 1986 12:00. For prolonged ^{131}I air contamination the blockade is less efficient. When one considers the ingestion pathway, the blockade on 1 May 1986 12:00 could be most effective (30%) as it correlates then with maximum of ^{131}I concentration in milk (occurring on 1–2 May 1986 in most contaminated areas in Poland, see Figures II.35 and II.36). When inhalation and ingestion pathways are considered together, then both terms on 28, 29, 30 April and 1 May are comparable, giving H_{50} reduction from 10 to 30%. Assuming that "Lugol" solution of KI was given to the majority of children on 30 April 1986, the reduction in the dose was lower for areas in which the contamination appeared later.

II.6.2. An assessment of effectiveness of cows' pasturage ban

Theoretical model calculations show that even 10 days delay in the beginning of cows pasturage gives 50 times (98%) reduction of integrated ^{131}I concentration in milk (see Figure II.34). Delay of cow pasturage to 30 May gives reduction of integrated ^{131}I concentration in milk by 99.8%. However in practice this countermeasure was effective for limited numbers of farms because of spring's hay shortage. Measurements of ^{131}I concentration in milk and afterward analysis indicated that only about 20% of farms were able to obey the ban. The quantitative evaluation of this countermeasure is difficult because of lack sufficient measurements data.

II.6.3. *An assessment of countermeasures effectiveness and thyroid dose H_{50} from direct measurements of ^{131}I in the thyroid gland*

Credible view on the level of radiation hazard from ^{131}I for the population of Poland could be obtained from direct measurements of ^{131}I activities in the thyroid gland. Such measurements were being carried on by CLRP and by the Institute of Atomic Energy in the period from 4 May 1986 to 27 June 1986 [II.7, II.8]. Totally 2020 measurements of the thyroid gland were performed. The largest number of measurements was made for Warsaw province (1405 measurements) including: 1143 measurements of adults, 42 measurements of children 15 years old, 126 measurements of children 10 years old, 91 measurements of children 5 years old. About 760 measurements of adults were made in the Institute of the Atomic Energy. The information about the date of applying the stable iodine blockade was gotten from the interviews. However, only for the Warsaw province-1405 measurements (see Figures II.37 and II.38), Ostroleka -133 measurements (see Figures II.39 and II.40) and Bialystok- 195 measurements, the number and of representativeness of measurements enable to extended assessments of H_{50} doses for entire area.

Measured ^{131}I contents in thyroid gland both for adults, teenagers and children indicate a significant contribution of the ingestion pathway (consumption of contaminated ^{131}I milk) to the ^{131}I thyroid burden. Measured values show big scattering, as result of very changeable ^{131}I levels in milk, local air contamination as well as various behavior of population. Although theoretically very effective (see Section II.6.2), the ban of cows' pasturage in open areas appeared not very efficient in practice due to spring's shortage of uncontaminated hay in many private farms [II.9]. Figure II.41 illustrates the methodology of the doses assessment. The curve predicted by the model was fitted to the measured ^{131}I activity in the thyroid gland in the given day of the measurement, then the computer program calculated the integral of the ^{131}I activity in thyroid and the H_{50} dose, using dose conversion factors characteristic for the given age group. Values of H_{50} doses for inhabitants of some high, average and low contaminated areas in Poland are presented in Table II.36. The averages of thyroid dose H_{50} for critical age groups, i.e., children 1–5 and 5–10 years of inhabitants of majority contaminated areas of Poland are close to the dose limit for population (20 mSv)[11], however in some areas H_{50} doses exceed this limit 3 times; for the Ostroleka province: 80–56 mSv in the group of children 1–5 years old (maximum dose 279 mSv); 75–56 mSv in the group of children 5–10 years old (maximum dose 256 mSv). There is no reason, however, to exclude the possibility of occurrence of similar values in the other high contaminated areas (i.e., in southern Poland).

Administration of preventive stable iodine liquid ("Lugol") might reduce H_{50} doses of about 40% but this factor can considerably change in individual cases due to it's significantly dependence both from the individual parameters as well from local differences in the dynamic of radioiodine contaminations.

[11] Dose equivalent of 20 mSv in thyroid ≅ 1mSv effective dose (dose limit for population in normal operation of nuclear installation).

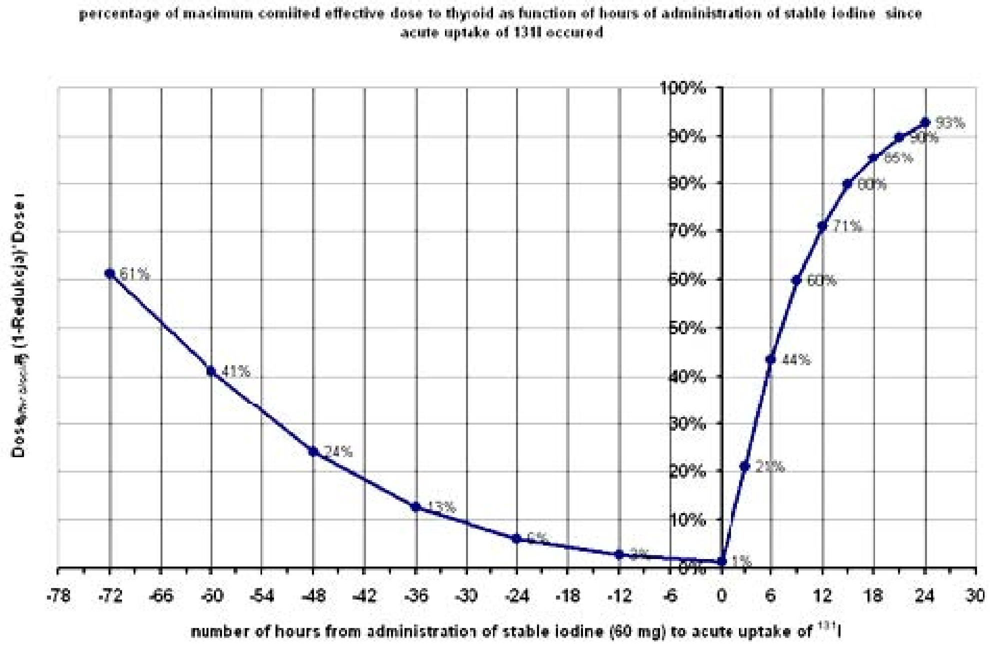

Fig. II.31. Percentage of maximum committed effective dose to thyroid that remains as a function of hours passed after or before intake of stable iodine since acute uptake of ^{131}I occurred.

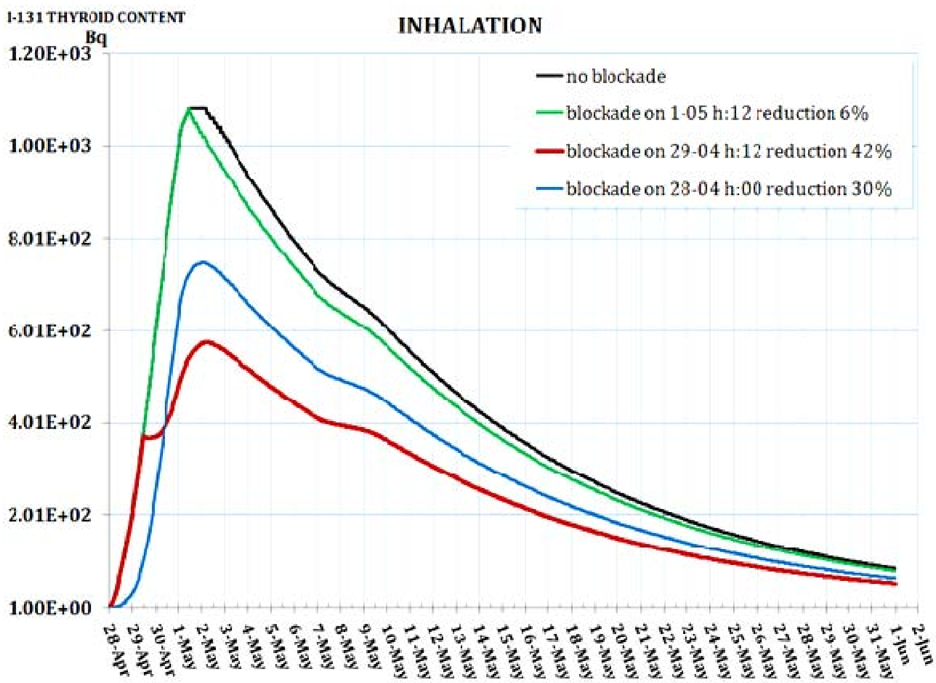

Fig. II.32. Changes of the ^{131}I activity in the thyroid gland of the adult for intakes of radioiodine by inhalation of contaminated air measured in Warsaw (28 April – 30 May 1986) at different dates of thyroid blockade with stable iodine.

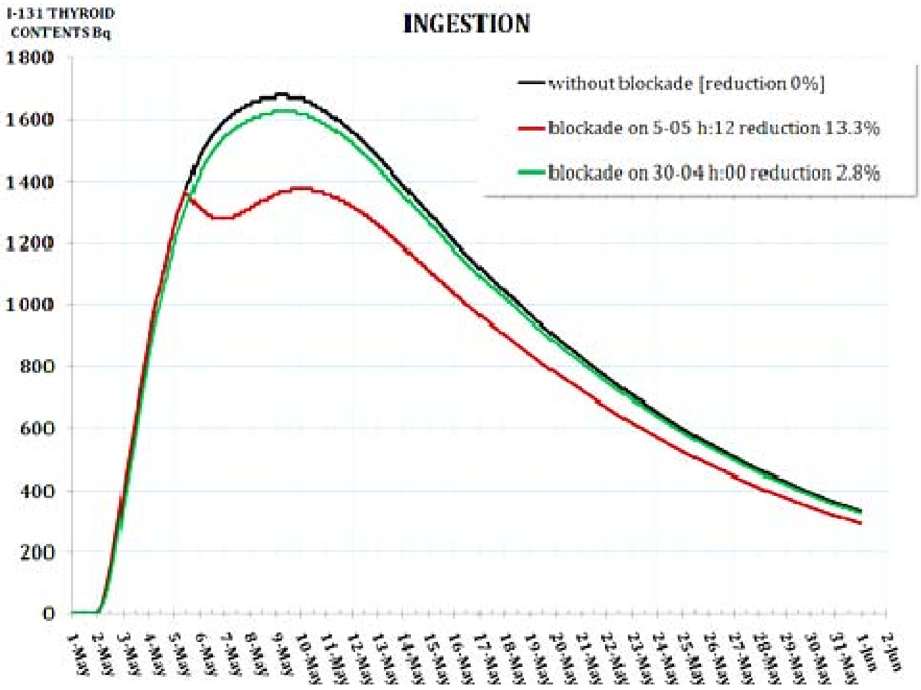

Fig. II.33. Changes of the ^{131}I activity in the thyroid gland of the adult for intakes of radioiodine by ingestion of contaminated milk measured in Warsaw area (28 April – 15 June 1986) at different dates of thyroid blockade with stable iodine.

Table II.35. Reduction in the H_{50} dose depending on the time of the administration of iodine. Recommended amount of stable iodine: 60 mg for teenagers from 10 to 16 years old, 30 mg for children from 1 to 10 years old, 15 mg for children below 1 year old.

Date and time of the administration of stable iodine	**Inhalation pathway**	**Ingestion pathway**	**Inhalation and ingestion pathway**	**Contribution to the total dose [%]**	
	Reduction [%] Max - Min	**Reduction [%] Max - Min**	**Reduction [%] Max - Min**	**Inhalation pathway**	**Ingestion pathway**
28 April 1986 00:00	***72 - 30***	***11- 1***	***31- 10***	*13 - 25*	*87 - 75*
28 April 1986 12:00	***76- 38***	***14 -1***	***35-13***	*12 - 23*	*88 - 77*
29 April 1986 12:00	***62 - 43***	***22 -2***	***35 - 14***	*20 - 22*	*80 - 78*
30 April 1986 12:00	***28 - 26***	***28 - 5***	***28 - 12***	*33 - 27*	*67 - 73*
1 May 1986 12:00	***6 -5***	***29 - 15***	***21 - 12***	*40- 34*	*60 - 66*
2 May 1986 12:00	***3 - 2***	***27 - 14***	***18 - 10***	*40 -33*	*60 - 67*
5 May 1986 12:00	***5 - 1***	***18 - 13***	***14 - 9***	*37 - 35*	*63 - 65*
No administration	***0***	***0***	***0***	*33*	*67*

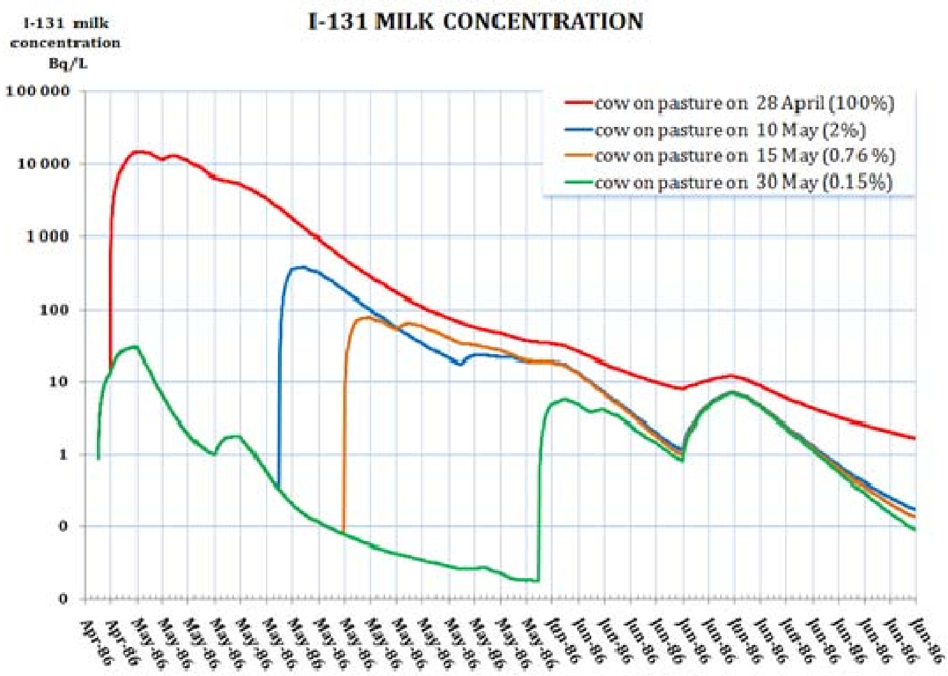

Fig. II.34. Dynamic of ^{131}I concentration in milk versus time for various variants of start cows grazing in open areas. Percentages in parentheses show ratio of integrated ^{131}I concentration in milk for particular term of cows grazing to item on 28 April 1986.

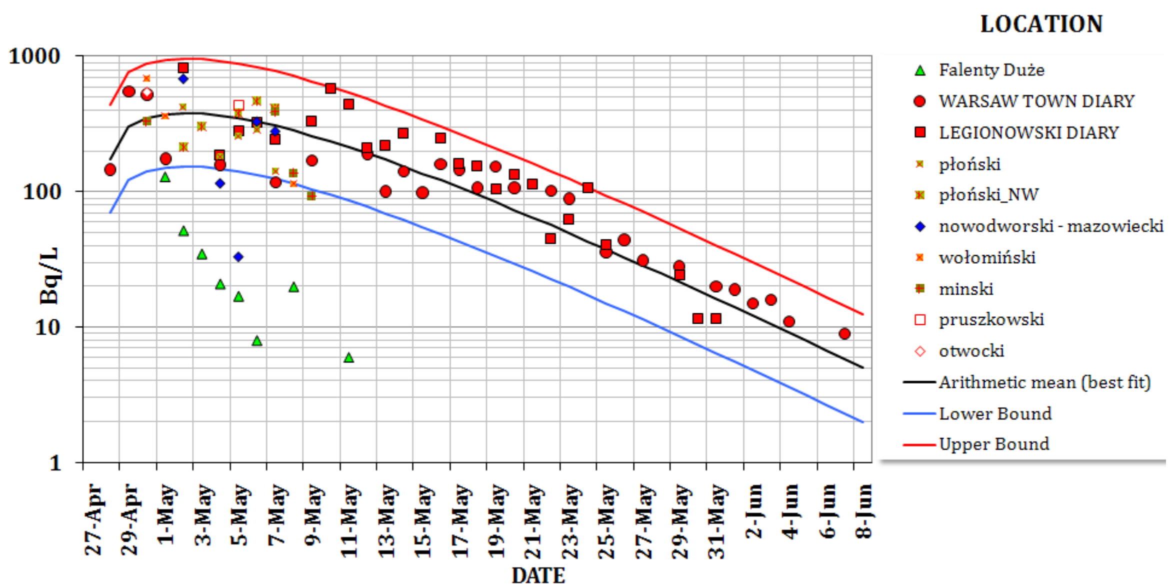

Fig. II.35. Measured ^{131}I milk concentration in Warsaw province in the period (28 April – 8 June 1986). Continuous curves describe: black curve- best fit to measured average ^{131}I concentrations in the milk, red curve: upper bound of average values (x2.5), the blue curve: lower bound of average values (1/2.5). Integrated ^{131}I concentration in the milk= 5954 [$Bq \cdot L^{-1} \cdot d$]. Green triangles – measured ^{131}I concentration in milk for cows kept in cowsheds.

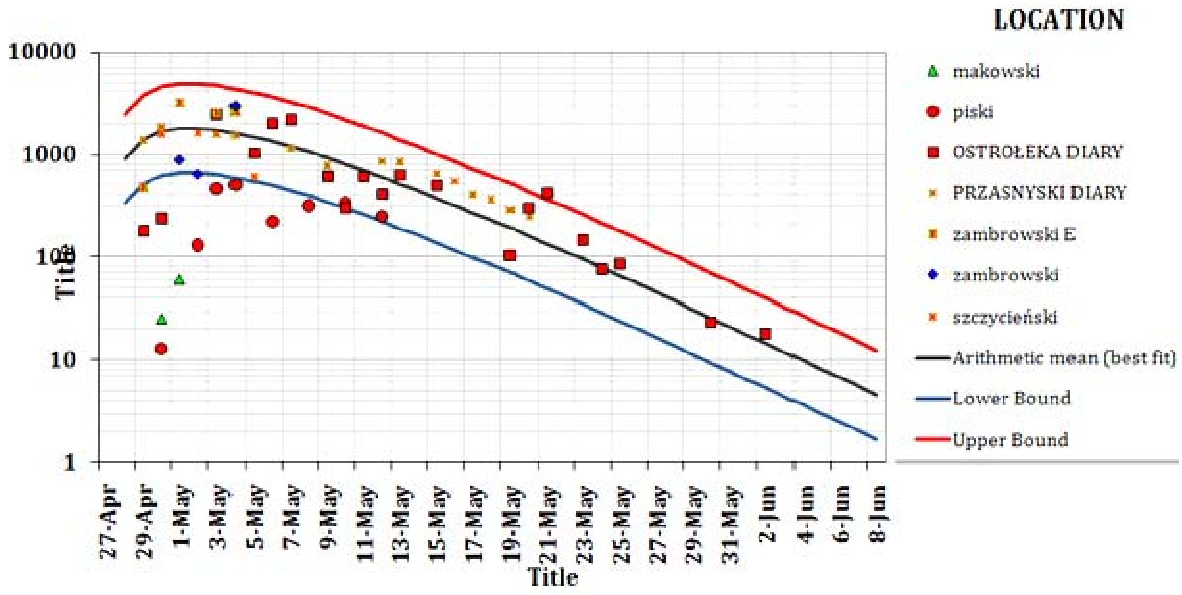

Fig. II.36. Measured ^{131}I milk concentration Ostroleka, Ciechanow and Bialystok provinces in the period (28-04 - 8.06 1986 r). Continuous curves describe: black curve- best fit to measured average ^{131}I concentrations in the milk, red curve: upper bound of average values (x2.5), the blue curve: lower bound of average values (1/2.5). Integrated ^{131}I concentration in the milk= 22282 [$Bq \cdot L^{-1} \cdot d$]. Green triangles and red dots – measured ^{131}I concentration in milk for cows kept in cowsheds.

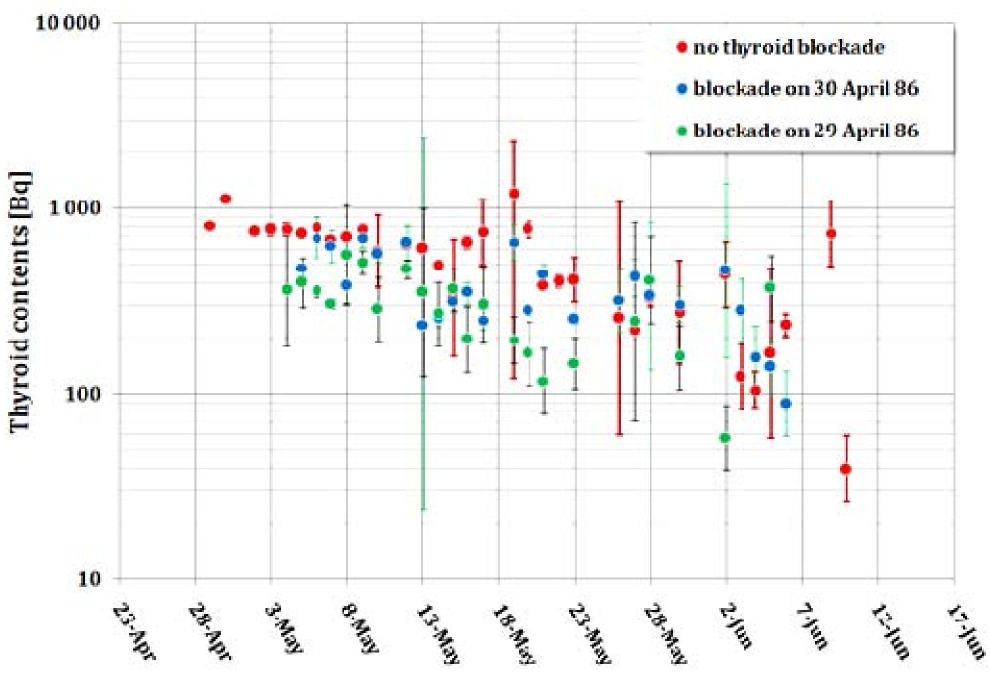

Fig. II.37. Daily averages of measured ^{131}I thyroid contents for Warsaw inhabitants (Adults).

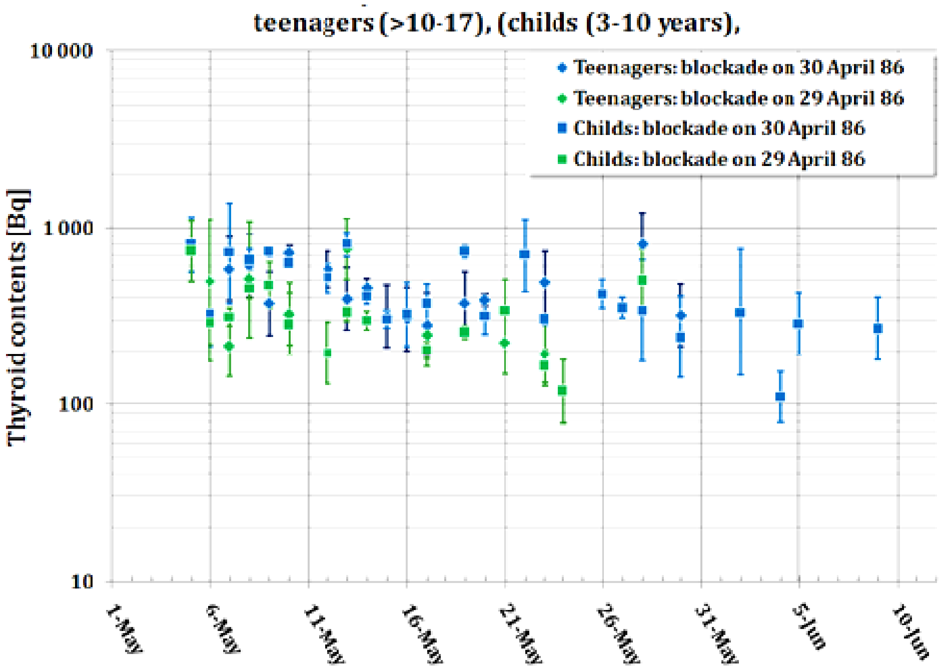

Fig. II.38. Daily averages of measured ^{131}I contents for Warsaw inhabitants (teenagers, children).

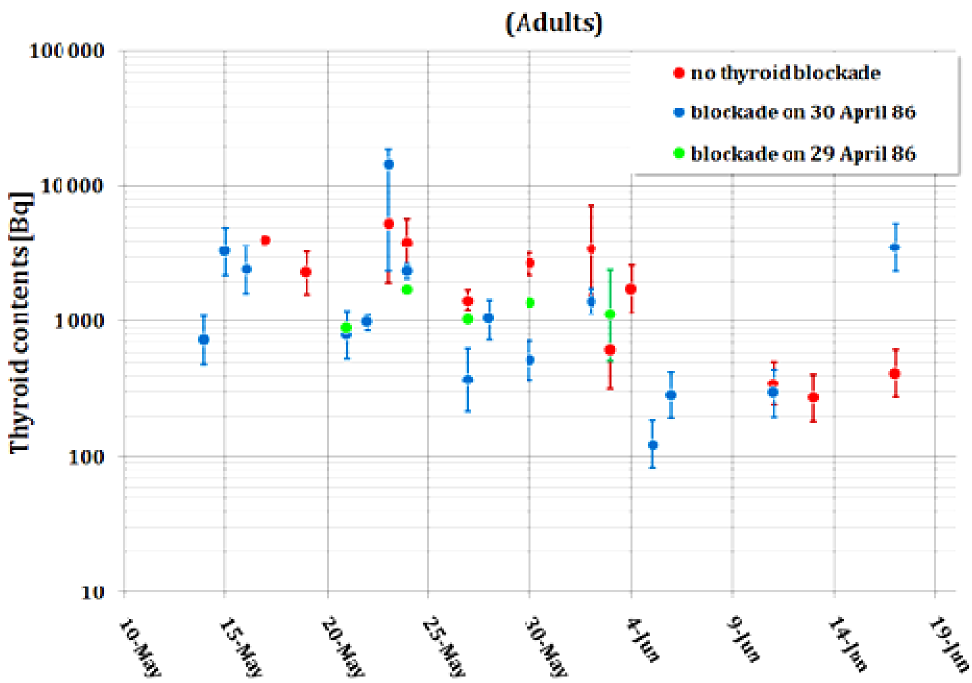

Fig. II.39. Daily averages of measured ^{131}I thyroid contents for Ostroleka inhabitants (Adults).

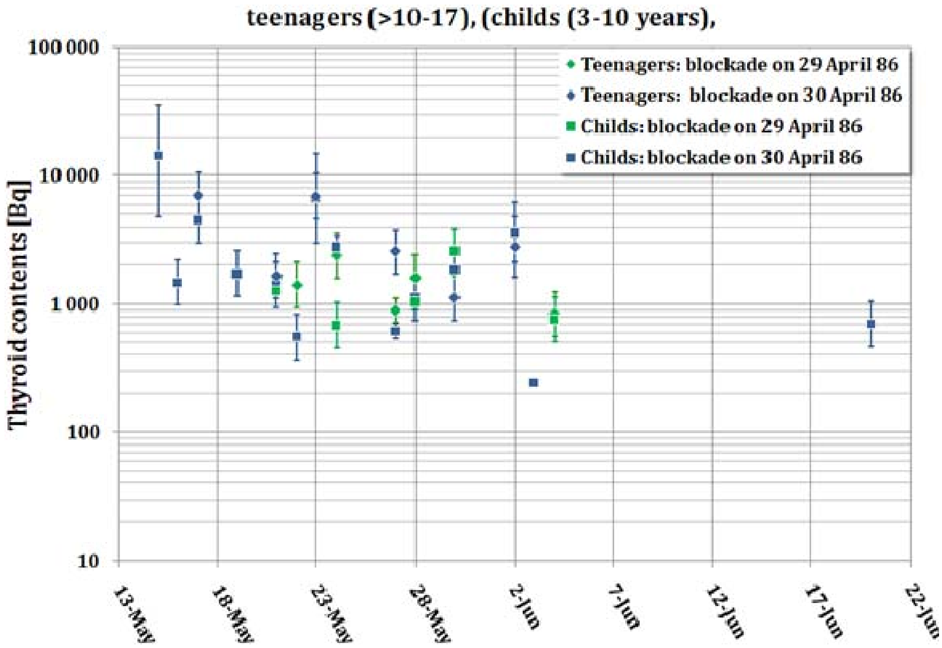

Fig. II.40. Daily averages of measured ^{131}I contents for Ostroleka inhabitants (teenagers, children).

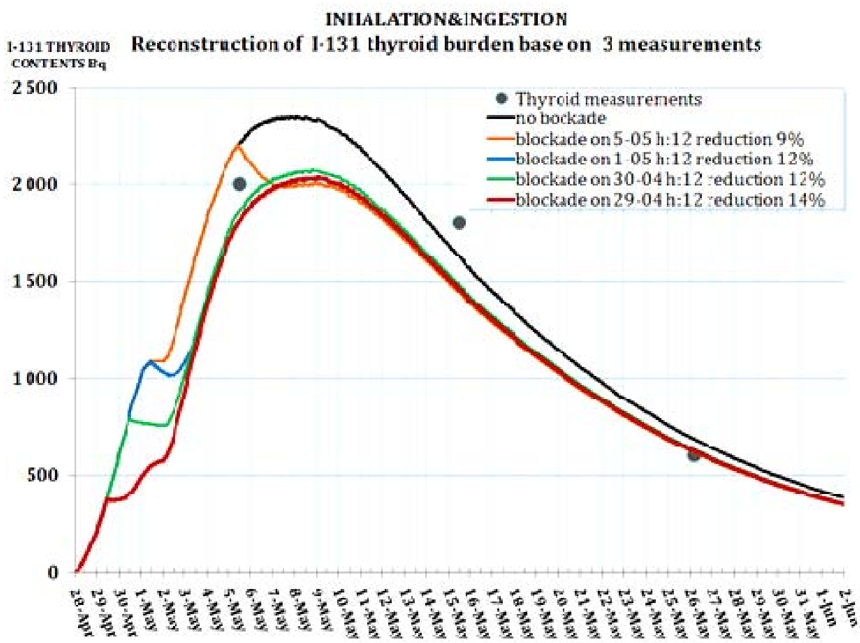

Fig. II.41. Example of methodology used for evaluation of H_{50} on the basis of direct measurement of ^{131}I content in thyroid. Dots represent three measurements of ^{131}I content in thyroid for the one person. Curves present predicted ^{131}I thyroid content versus time for different variants of thyroid blockade.

Table II.36. Thyroid dose equivalent H_{50} of inhabitants high, medium and low contaminated regions in Poland. An assessment on the basis of direct measurements of ^{131}I in thyroids.

PROVINCE	DATE OF BLOCKADE	DOSE EQUIVALENT TO THYROID H_{50} [mSv] FOR STANDARDIZED AGES GROUPS				
		ADULT	**TENAGER 15Y**	**CHILD 10 Y**	**CHILD 5 Y**	**CHILD 1 Y**
		AVERAGE*(N#[a])* **$L_{95\%} \div U_{95\%}$[b]** **Min - Max[c]**	**AVERAGE*(N#)*** **$L_{95\%} \div U_{95\%}$** **Min - Max**	**AVERAGE*(N#)*** **$L_{95\%} \div U_{95\%}$** **Min - Max**	**AVERAGE*(N#)*** **$L_{95\%} \div U_{95\%}$** **Min - Max**	**AVERAGE*(N#)*** **$L_{95\%} \div U_{95\%}$** **Min - Max**
Ostroleka	No blockade	**25.8***(33)* 20.0÷33.3 **3.1 – 139.9**			**245.6***(1)*	
	After 1 May	**13.3***(2)* **10.3 – 15.6**				
	29 or 30 April	**18.9***(33)* 13.3÷26.7 **2.1 – 216.8**	**41.2***(10)* 28.5÷59.5 **12.2 – 96.7**	**75.3***(22)* 54.8÷103.5 **15.1 – 251.9**	**55.8***(30)* 43.4÷71.6 **15.5 – 279.3**	**79.9***(2)* **52.8 – 99.1**
Bialystok	After 1-May	**6.8***(1)*				
	29 or 30 April	**6.0***(42)* 5.1÷7.0 **0.6 -14.4**	**16.9***(70)* 15.3÷18.6 **5.9 – 57.4**	**20.3***(60)* 18.4÷22.4 **6.0 – 56.5**	**28.7***(19)* 18.2÷45.3 **4.2 – 86.9**	**7.4***(3)* 5.0÷11.0 **5.4 - 10.8**
Warsaw	No blockade	**4.1***(864)* 3.9÷4.3 **0.1 – 37.0**		**9.0***(2)* **7.9 – 9.9**	**2.7***(1)*	
	After 1-May	**2.6***(33)* 2.0÷3.4 **0.5 – 11.9**	**4.8***(4)* 3.3÷7.0 **2.3 – 5.9**	**6.9***(4)* 4.6÷10.5 **4.1 – 10.6**	**5.2***(1)*	
	29 or 30 April	**2.1***(256)* 1.9÷2.3 **0.1 – 38.0**	**5.0***(36)* 4.1÷6.1 **1.3 – 22.4**	**6.6***(119)* 6.0÷7.6 **1.5 – 29.8**	**11.8***(88)* 9.5÷14.8 **0.6 – 110.5**	**4.0***(4)* 2.1÷7.5 **1.4 – 6.9**
	28-04 April	**0.9***(4)* 0.7÷1.2 **0.6 – 1.3**			**8.5***(1)*	

[a] Number of measurement in parentheses.
[b] Lower and upper bund of 95% confidence interval log-normal average.
[c] Minimal and maximal value in series of measurements.

ANNEX II. FORMULARIES

II-1. Calculation for model testing

Table II-1. Average ^{131}I concentration in milk for specified locations (Bq l^{-1} fresh weight).

Daily averages	FALENTY			WARSAW DAIRY			OSTROLEKA AREA		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86									
28 04 86									
29 04 86									
30 04 86									
1 05 86									
2 05 86									
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28 05 86									
29 05 86									
30 05 86									
31 05 86									
Milk Integrals *									

∗ For the period 27 04 – 31 05 86.

Table II-2. Predictions of ^{131}I thyroid burden for inhabitants of WARSAW - children [Bq].

WARSAW (children)						
Daily averages	30 mg stable iodine on 29 April 86			30 mg stable iodine on 30 April 86		
	age 3 –10 in 1986			age 3 –10 in 1986		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86						
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Table II-3. Predictions of ^{131}I thyroid burden for inhabitants of WARSAW - teenagers [Bq].

WARSAW TOWN (TENAGERS)						
Daily averages	60 mg stable iodine on 29 April 86			60 mg stable iodine on 30 April 86		
	age >10 – 17 in 1986			age >10 – 17 in 1986		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86						
28 04 86						
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1 05 86						
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Table II-4. Predictions of ^{131}I thyroid burden for inhabitants of WARSAW - adults [Bq].

WARSAW ADULTS									
Daily averages	No stable iodine			60 mg stable iodine on 29 April 86			60 mg stable iodine on 30 April 86		
	Adult >20 in 1986			Adult >20 in 1986			Adult >20 in 1986		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86									
28 04 86									
29 04 86									
30 04 86									
1 05 86									
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15 06 86									

Table II-5. Predictions of ^{131}I thyroid burden for inhabitants of OSTROLEKA AREA - children [Bq].

OSTROLEKA AREA (CHILDREN)						
Daily averages	**30 mg stable iodine on 29 April 86**			**30 mg stable iodine on 30 April 86**		
	age 3 –10 in 1986			**age 3 –10 in 1986**		
	Arithmetic mean	**95% Confidence interval**		**Arithmetic mean**	**95% Confidence interval**	
		Lower Bound	**Upper Bound**		**Lower Bound**	**Upper Bound**
27 04 86						
28 04 86						
29 04 86						
30 04 86						
1 05 86						
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Table II-6. Predictions of ^{131}I thyroid burden for inhabitants of OSTROLEKA AREA - teenagers [Bq].

OSTROLEKA AREA (TEENAGERS)						
Daily averages	60 mg stable iodine on 29 April 86			60 mg stable iodine on 30 April 86		
	age >10 – 17 in 1986			age >10 – 17 in 1986		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86						
28 04 86						
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1 05 86						
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Table II-7. Predictions of ^{131}I thyroid burden for inhabitants of OSTROLEKA AREA – adults [Bq].

OSTROLEKA AREA (ADULTS)									
Daily averages	No stable iodine			60 mg stable iodine on 29 April 86			60 mg stable iodine on 30 April 86		
	Adult >20 in 1986			Adult >20 in 1986			Adult >20 in 1986		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86									
28 04 86									
29 04 86									
30 04 86									
1 05 86									
2 05 86									
3 05 86									
4 05 86									
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II-2. Calculation for model comparison

Table II-8. The total integrated ^{131}I air concentration in ground level air and contribution of the radioiodine phases, i.e., particulate, reactive gaseous and organic over Mazovia area [Bq.m3.d].

INTEGRATED ^{131}I AIR CONCENTRATION [Bq m^3 d]			RADIOIODINE PHASES [%]		
Arithmetic mean	95% Confidence interval		particulate	reactive gaseous I_2	organic CH_3I
	Lower Bound	Upper Bound			

Table II-9. Average ^{131}I concentration in grass for specified locations.

Daily averages	WARSAW			OSTROLEKA AREA		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
27 04 86						
28 04 86						
29 04 86						
30 04 86						
1 05 86						
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7 05 86						
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9 05 86						
10 05 86						
11 05 86						
12 05 86						
13 05 86						
14 05 86						
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25 05 86						
26 05 86						
27 05 86						
28 05 86						
29 05 86						
30 05 86						
31 05 86						

Table II-10. Mean doses to thyroid from inhalation for inhabitants of WARSAW (mSv).

Countermeasures	new born			age 1 in 1986			Age 5 in 1986			age 10 in 1986			adult (age 20 in 1986)		
	Arithmetic mean	95% confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
No stable iodine 28 04 12 pm 29 04 12 pm 30 04 12 pm 1 05 12 pm															

Table II-11. Mean doses to thyroid from inhalation for inhabitants of OSTROLEKA AREA (mSv).

Countermeasures	new born			age 1 in 1986			Age 5 in 1986			age 10 in 1986			adult (age 20 in 1986)		
	Arithmetic mean	95% confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
No stable iodine 28 04 12 pm 29 04 12 pm 30 04 12 pm 1 05 12 pm															

Table II-12. Mean doses to thyroid from ingestion for inhabitants of WARSAW (mSv).

Location	Countermeasures	new born			age 1 in 1986			Age 5 in 1986			age 10 in 1986			adult (age 20 in 1986)		
			95% confidence interval			95% Confidence interval			95% Confidence interval			95% Confidence interval			95% Confidence interval	
		Arithmetic mean	**Lower Bound**	**Upper Bound**	**Arithmetic mean**	**Lower Bound**	**Upper Bound**	**Arithmetic mean**	**Lower Bound**	**Upper Bound**	**Arithmetic mean**	**Lower Bound**	**Upper Bound**	**Arithmetic mean**	**Lower Bound**	**Upper Bound**
COWS ON PASTURE FROM 28 04 86	No stable iodine															
	28 04 12 pm															
	29 04 12 pm															
	30 04 12 pm															
	1 05 12 pm															
COWS ON PASTURE FROM 1 05 86	No stable iodine															
	28 04 12 pm															
	29 04 12 pm															
	30 04 12 pm															
	1 05 12 pm															
COWS ON PASTURE FROM 15 05 86	No stable iodine															
	28 04 12 pm															
	29 04 12 pm															
	30 04 12 pm															
	1 05 12 pm															
COWS ON PASTURE FROM 1 06 86	No stable iodine															
	28 04 12 pm															
	29 04 12 pm															
	30 04 12 pm															
	1 05 12 pm															

Table II-13. Mean doses to thyroid from ingestion for inhabitants of OSTROLEKA AREA (mSv).

Location	Countermeasures	new born			age 1 in 1986			Age 5 in 1986			age 10 in 1986			adult (age 20 in 1986)		
			95% confidence interval			95% Confidence interval			95% Confidence interval			95% Confidence interval			95% Confidence interval	
		Arithmetic mean	Lower Bound	Upper Bound	Arithmetic mean	Lower Bound	Upper Bound	Arithmetic mean	Lower Bound	Upper Bound	Arithmetic mean	Lower Bound	Upper Bound	Arithmetic mean	Lower Bound	Upper Bound
COWS ON PASTURE FROM 28 04 86	No stable iodine															
	28 04 12 pm															
	29 04 12 pm															
	30 04 12 pm															
	1 05 12 pm															
COWS ON PASTURE FROM 1 05 86	No stable iodine															
	28 04 12 pm															
	29 04 12 pm															
	30 04 12 pm															
	1 05 12 pm															
COWS ON PASTURE FROM 15 05 86	No stable iodine															
	28 04 12 pm															
	29 04 12 pm															
	30 04 12 pm															
	1 05 12 pm															
COWS ON PASTURE FROM 1 06 86	No stable iodine															
	28 04 12 pm															
	29 04 12 pm															
	30 04 12 pm															
	1 05 12 pm															

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APPENDIX III. PRAGUE SCENARIO DESCRIPTION VALIDATION OF ENVIRONMENTAL MODELS USING DATA FROM CHERNOBYL I-131 AIR POLLUTION IN CENTRAL BOHEMIA AREA

III.1. Background

The reliable reconstruction of an average and personal thyroid dose in areas affected by release of radioiodine is important for the following applications: special medical aid to the population and measures of social protection, information of the public and the authorities and support of epidemiological studies. The accident at the Chernobyl Power Plant on April 26, 1986, caused the release into the atmosphere of a large amount of radioiodine (particularly, ^{131}I), which resulted the exposures of thyroid gland in populations of Belarus, the Russian Federation, Ukraine, as well as in other countries. Numerous reports have confirmed an increasing rate of thyroid cancer, particularly in the most heavily contaminated regions of Ukraine and Belarus, but also in Russia. Also, in other countries epidemiological studies have been carried out and adequate measurements data sets of most important environment components are available. As previously concluded, the certain assessments should be performed by more than one assessor or modelling group. Multiple independent assessments are important for the identification of discrepancies in expert judgment and interpretation of input data. Appropriate resources should be allocated for resolving identified issues before drawing final conclusions.

The assessment of the effectiveness of applied countermeasures in some areas of Europe, Ukraine and Belarus is important for the elaboration of a consistent and effective emergency plan and for the assessments of uncertainties in dose estimates and probability of induced thyroid cancers.

The Iodine Working Group (IWG) has been established within the framework of the IAEA EMRAS program and aimed at increasing the confidence in methods and models for the assessment of thyroid doses related to the environmental releases of ^{131}I.

The IWG activities is supervised and partly sponsored by the U.S. National Cancer Institute (NCI), through its the Radiation Epidemiology Branch, Division of Cancer Epidemiology.

The IWG activities are focused on several main tasks:

(1) collection of measurement data sets, quality assurance of input and measurement data and evaluation of appropriate scenario for model validation purposes;
(2) model runs and comparison of outputs with the independent data sets; blind test models calculations (without disclosing observed data); and
(3) evaluation of discrepancies between results and identification of the most important sources of bias and uncertainty.

Several statistical tools have been used to evaluate the models performance i.e. ratios of predictions to observed values as well as reliability indexes. The main objectives of the exercises that have been carried out by the IWG are:

(1) to evaluate the performance of the participating models in dose reconstruction exercises in cases when ^{137}Cs tracer is used to estimate the deposition of ^{131}I; and
(2) to assess the applicability of the models for the assessment of countermeasure.

The particular emphasis was placed on the improvement of models applicability for realistic assessments of doses and associated uncertainties and on the justification of different variants of protective actions. Such protective actions consist of sheltering, rapid distribution of stable iodine or supply to animals the clean fodder. The optimum response will often involve the combined use of these countermeasures.

Since the start of the IWG activity, three scenarios have been completed. The first Scenario Plavsk has focused on the uncertainty of dose assessment when ^{137}Cs tracer is used to estimate the ^{131}I impact - that was a very common approach in the cases of numerous contaminated areas in Belarus, Ukraine and Russia. The second Scenario Warsaw was initiated on June 2005 and aims at versatile assessment of the effectiveness of short-term protective measures that were applied in this province during 29–30 April to reduce the radioiodine thyroid burden of inhabitants. These countermeasures included: administration of stable iodine in form of solution (so called "Lugol liquid") to children and teenagers up to the age of 16, putting grazing animals on stored feed, followed by the banning of potentially contaminated milk, milk products and leafy vegetables.

The next IWG foreseen task will focus on several aspects of precautionary approaches for areas with higher risk of radioiodine contamination (in vicinity of NPP). The third scenario (The Central Bohemia Area) was issued at the beginning of June 2006. The major area of emphasis was an assessment of the reduction of potential radiation exposure to the thyroid gland in context of special agricultural practices and specific fodder and foodstuffs preparation methods.

The dose assessment professionals had an opportunity to examine their skills, methods and conceptual approaches to the specified level of the assessment, when countermeasures should be evaluated with the consideration of their effectiveness. The data provided by this exercise enables the risk manager to identify the most important sources of uncertainty with respect to the radiological assessments involving I-131 in the risk reduction measures context. This may help to improve the current emergency response system.

III.2. Introduction

III.2.1. General descriptions of the Central Bohemia region

III.2.1.1. Geographical information

Prague (in Czech Praha), the capitol of the Czech Republic (ČR, Cechia), was selected as the third scenario area.

The Czech Republic is situated in Central Europe, bordering Germany in the west, Poland in the north, the Slovak Republic in the east and Austria in the south. At the time of the Chernobyl accident, the Czech Republic was a part of Czechoslovakia (ČSSR). Secession of the Czech Republic and Slovakia took place on the 1st January 1993. The location of the Czech Republic in Europe is shown in Figure III.1. Czech is historically divided into two parts: the western part called Bohemia and the eastern part called Moravia, as can be seen in Figure III.3. The Czech capital (and the biggest city) is Prague, located approximately in the middle of Bohemia, in the so called Central Bohemia region. On Figure III.2 the approximate location of the Central Bohemia area is shown as a red circle. A more detailed map of the Central Bohemia region is given on Figure III.3, and Figure III.4 presents the Prague cadastral division.

Prague covers an area of 496 km^2, which is equal to 0.6% of the Czech territory. As on December 2004, Prague had 1 170 571 citizens, meaning 11.5% of the Czech population. The density of the population was 2 360 pers./km^2 (130% of the country-averaged value), all of them town population (share in the ČR: 70.2%). For comparison: in the year 1986 it was 1 193 513 people with a population density of 2 406 per/km^2.

The average age of Prague's population in 2004 was: 41.7 years (average for ČR value is 39.8 years), 39.9 years for males and 43.3 years for females. Age structure of the population [%] in CB region in 1986 is given in Table III.1. Also given for comparison with later data is the age distribution of Prague citizens at the 31 December 1993 (see Table III.2).

The average registered number of employees in Prague in 2004 was 909 098 persons (share in the ČR: 28.4%), with most of them working in industry: 104 380 person (9.1%), then in construction: 36 948 people (22.8%) and in agriculture, forestry and fishing: 3 316 person (2.6%). The total number of workers and employees in Central Bohemia in 1986 was 1 533 616 persons. Their professional distribution in [%] is shown in Table III.3.

Table III.1. Age structure of the population [%] in CB region in 1986.

Age group [year]	Prague region		Central Bohemia	
	Men	Women	Men	Women
<1	1.19	0.98	1.24	1.14
1–4	4.88	4.08	5.11	4.63
5–9	6.80	5.75	7.27	6.58
10–14	8.68	7.31	9.14	8.31
15–19	6.74	5.73	7.75	6.99
20–29	11.96	11.08	13.16	11.77
30–39	15.81	14.98	16.02	14.54
40–49	15.95	14.95	14.49	13.23
50–59	10.53	10.74	10.48	10.69
60–69	10.66	12.48	9.41	11.35
70–79	5.02	7.98	4.39	6.99
> 80	1.78	3.94	1.54	3.78

Table III.2. Age distribution of Prague citizens at 31 December 1993 for comparison with later data.

Population, total	People	1 217 023
	from which females	643 908
Population: by age		
0–14	persons	204 683
	from which females	99 707
15–64	persons	820 762
	from which females	423 925
65+	persons	191 578
	from which females	120 276
Average age, total	years	39.3

Table III.3. Total number and professional distribution of workers and employees in Central Bohemia in 1986.

Occupation	Distribution [%]
Workers in industry	54.3
Building workers	6.4
Employees in office	37.8
Farmers	1.5

Fig. III.1. Location of the Czech Republic in Europe.

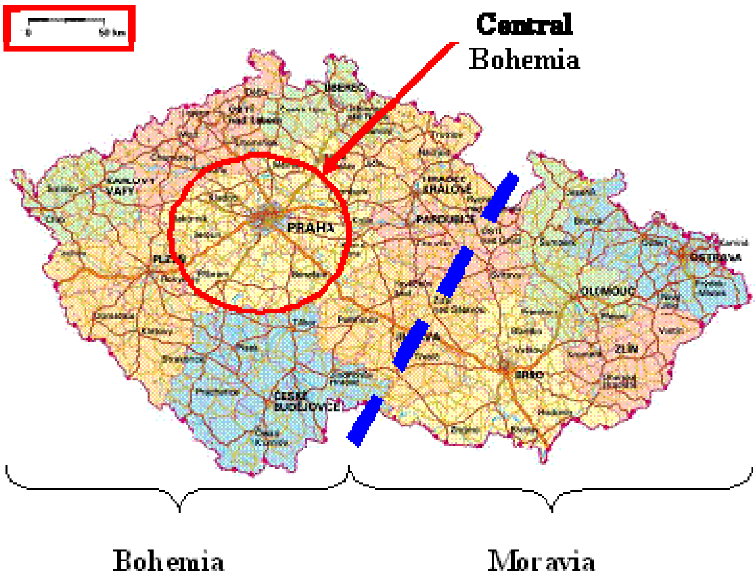


Fig. III.2. Map of the Czech Republic.

Fig. III.3. Map of the central Bohemia Region.

Fig. III.4. Cadastral division of Prague.

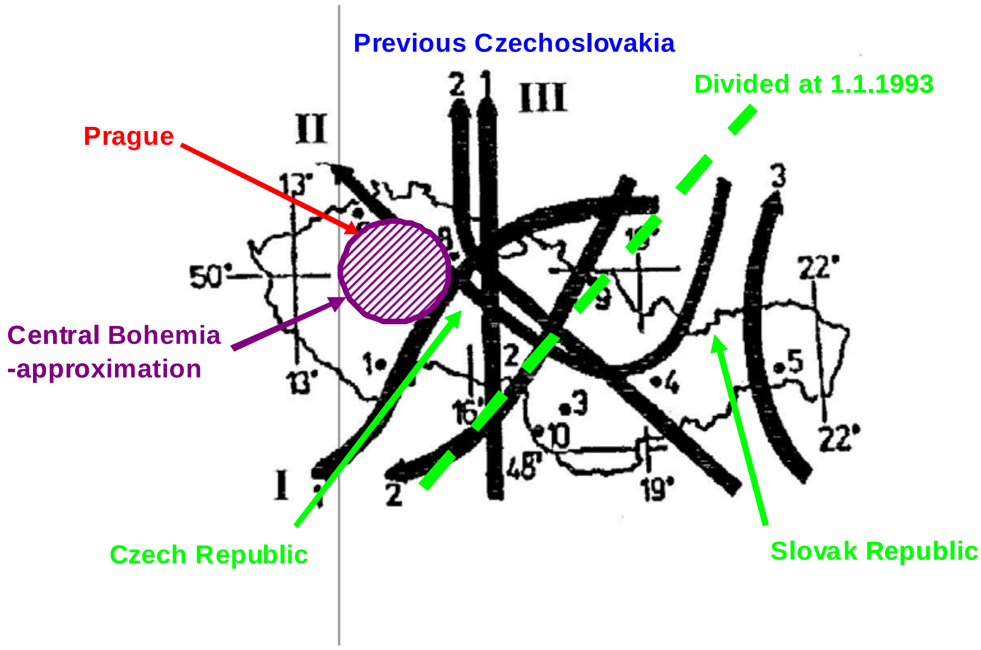
III.2.2. Chernobyl plume over the Central Bohemia region

The first indications of the contaminated plume on the Czechoslovakian territory were detected during the night of the 29–30 April 1986. In the morning of 30 April 1986 the measurements started in several places of the just established monitoring network. They detected there 3 passages of contaminated air through the territory. The first one went during the night between 29–30 April 1986, the second one between 3–4 May and the third one on 7 May 1986. The first and the third passages were registered by all measuring stations on the ČSSR territory, whereas the second one on the Slovakian territory only. Trajectories of contaminated air passages over the former ČSSR, calculated by the Slovak Hydrometeorologic Institute, are given in Figure III.5.

The most important contaminants were identified as ^{131}I, ^{132}Te with ^{132}I, ^{137}Cs and ^{134}Cs. The ambient dose rate equivalent was measured at 9 places in the ČSSR, from which 6 places were located in the present ČR. Locations of all 9 stations are given in Figure III.6, time development of ambient dose rate equivalent, measured in 6 places in the ČR can be seen in Figure III.7.

Trajectories of the middle of contaminated air masses from the Chernobyl NPP during the period 26 April – 5 May 1986, calculated by the Slovak Hydrometeorologic Institute on the bases of wind velocity and direction at the level of 850 hPa, are given in Figures III8–III.10 – time of releases are given in Central European time (CET).

Air aerosols were collected by high volume air samplers; also iodine composition was measured in some places. Fallout samples were taken and in several places in the ČSSR, some measurements with a cascade impactor were performed and in Prague and Bratislava (now Slovak Republic), and grass samples were collected also. The collection and measurement of milk samples began on the 30 May, 1986. Activities of radionuclides in the samples were measured by using a semiconductor gamma spectrometry with the HPGe detector, placed in a steel or lead shielding. Detectors with the relative detection efficiency of about 7% to 25% were used.



Release from the Chernobyl NPP: Passage of contaminated air over the former ČSSR:					
I	1:	27-04-86 02:00	I	1:	30-04-86 07:00
	2:	27-04-86 14:00		2:	30-04-86 14:00
II		26-04-86 02:00	II		from 04-05-86 02:00 to 05-05-86 14:00

Fig. III.5. Passage of contaminated air over the former ČSSR after the Chernobyl accident.

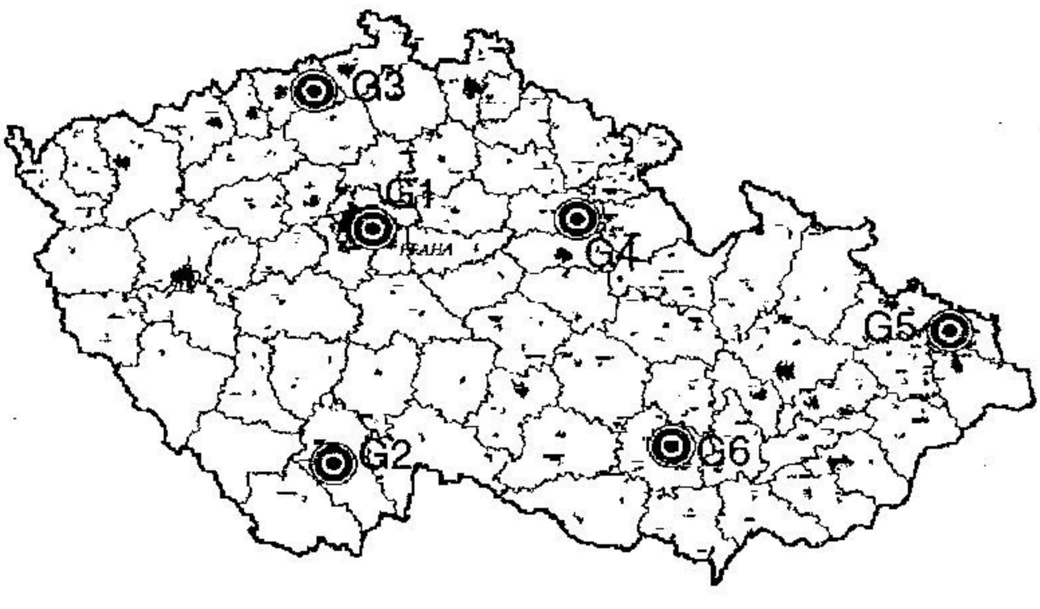


Fig. III.6. Locations of stations measuring external dose rate equivalent in the former ČSSR.

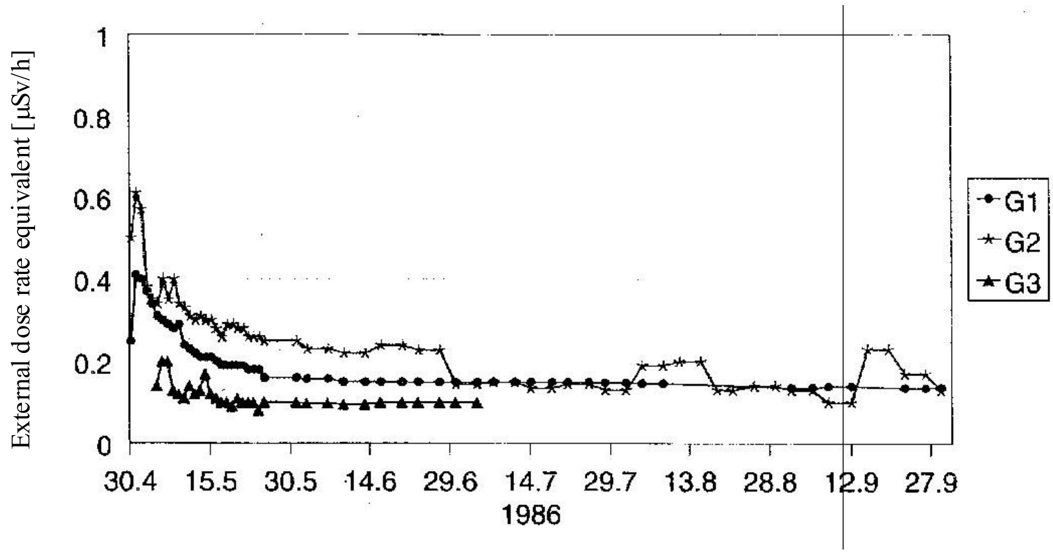


Fig. III.7. Time development of ambient dose rate equivalent in Stations G1, G2 and G3.

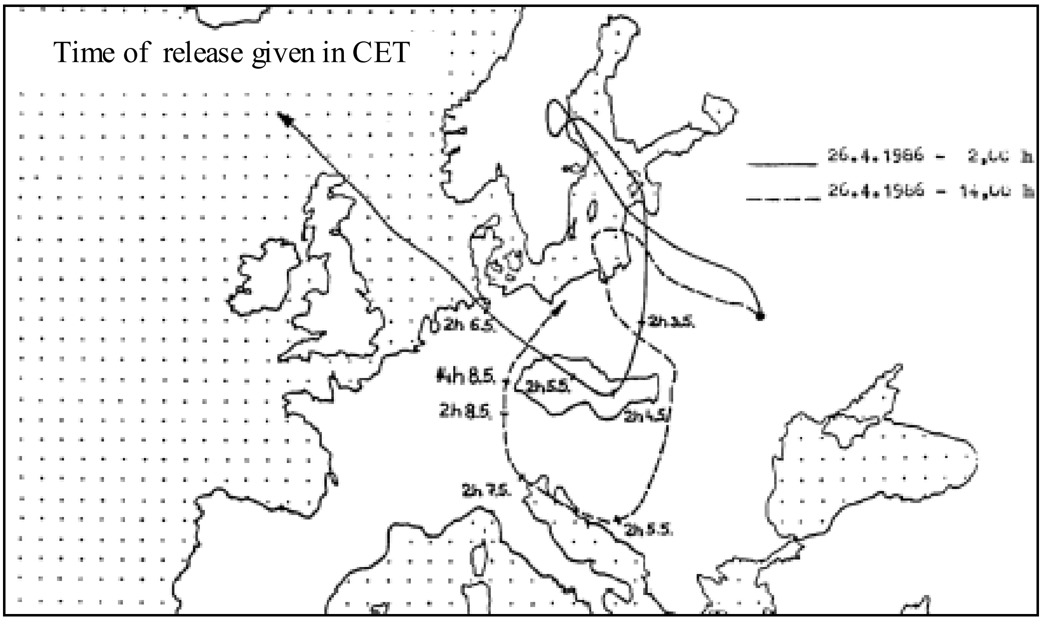


Fig. III.8. Trajectories of the middle of the contaminated air released from the Chernobyl NPP on 26 April 1986.

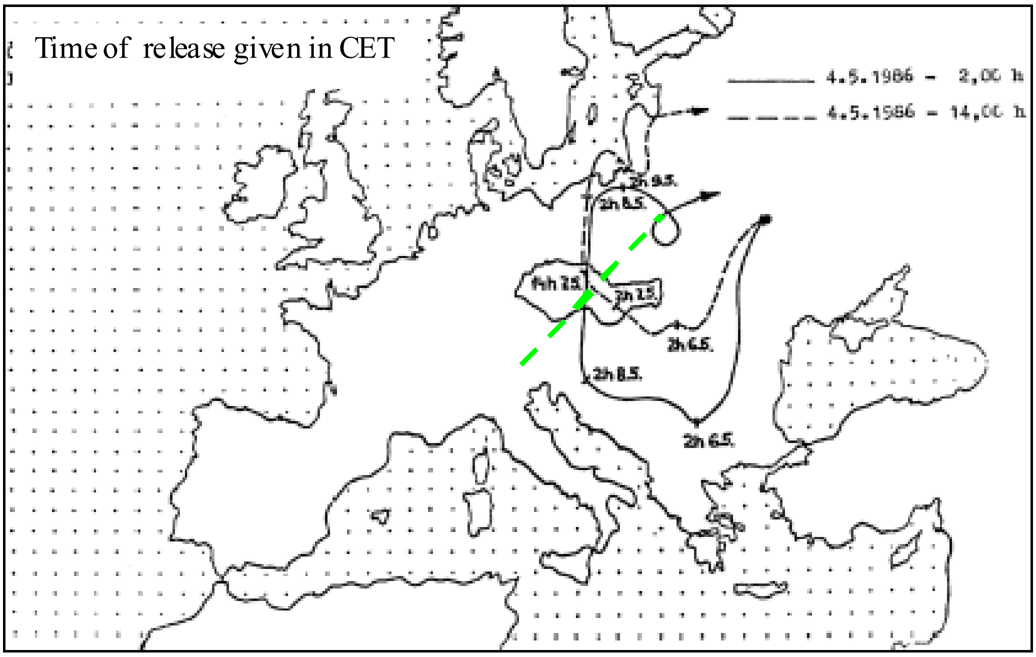


Fig. III.9. Trajectories of the middle of the contaminated air released from the Chernobyl NPP on 4 May 1986.

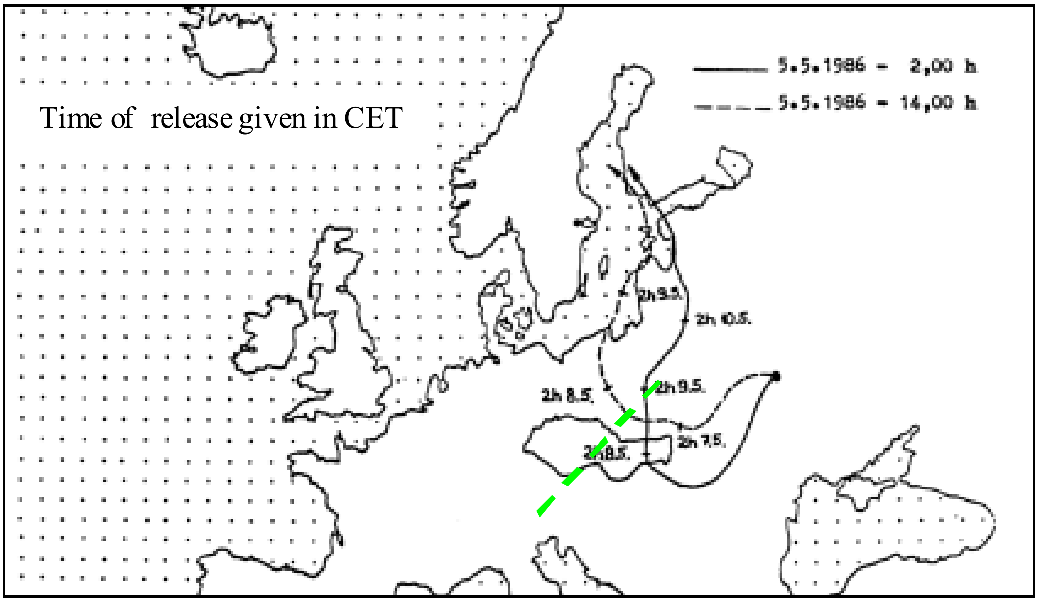


Fig. III.10. Trajectories of the middle of the contaminated air released from the Chernobyl NPP on 5 May 1986.

III.3. Assessment tasks

III.3.1. General

The main task of the scenario is to evaluate the performance of participants' models in assessments of internal doses from ^{131}I in the case when a special cow feeding regime is applied. This regime consists of keeping cows in cowsheds and feeding cows a silage mixture. The scenario can be seen as being divided into 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 estimates of the integrated air concentration, mean inhalation and ingestion doses to the thyroid are compared and analysed for different age groups.

The test region is the Prague urban area where mainly people from Prague were measured. People from the surroundings of Prague were measured too, but they all worked in Prague. Measurements of thyroid were performed in Dukovany NPP (as part of routine monitoring of professionals) located in about 130 km from Prague.

The suggested starting point of the calculation is the evaluation of ^{131}I deposition over the CENTRAL BOHEMIAN REGION on the basis of provided ^{131}I airborne concentrations. The models that would not be able to use the air data could be reconstructed with the use the ^{131}I deposition, applying a ^{137}Cs content in soil (see Table III.42) although with awareness of a higher uncertainty.

The following subsections contain descriptions of the results required in this test scenario. The first group of output results consists of quantities for which measurements exist and can be tested against model predictions, the second group consists of quantities (e.g. radiation doses) which can only be predicted but not compared with measurements. For each quantity, a 95% confidence interval (2.5% and 97.5% lower and upper bound estimates, respectively) should be given to quantify the uncertainty of the results. It is expected that these values will be based on the experts' judgements.

For the quantities listed in Section III.3.2, modellers are requested to estimate the arithmetic mean for the time period specified and for the specified location. Annex III includes the template tables for predictions. Additionally, the template Excel tables are provided. Participants are kindly asked to fill up Excel file templates tables rather than Word format template tables, but both forms are acceptable.

III.3.2. Calculations for model testing

III.3.2.1. ^{131}I concentration in milk

Average ^{131}I concentration in milk from big dairies

Estimate the arithmetic mean of daily values of ^{131}I concentration in milk (Bq L^{-1}) for the period 27 April –16 June 1986 of composite milk samples taken daily from the PRAHA - KYJE dairy.

Estimate the arithmetic mean of daily values of ^{131}I concentration in milk (Bq L^{-1}) for the period 27 April – 16 June 1986 of composite milk samples taken daily from the PRAHA - TROJA dairy.

Estimate the arithmetic mean of daily values of ^{131}I concentration in milk (Bq L^{-1}) for the period 27 April –16 June 1986 of composite milk samples taken daily from the BENEŠOV dairy.

See the templates given in Annex III.

Estimate the integrated ^{131}I concentration in milk (Bq d^{-1} L^{-1}) for the period 27 April –16 June 1986 in the locations specified above.

In twelve dairies in Central Bohemia samples were taken during April and May 1986 (see Table III.4). The chosen dairies are written in capital letters and highlighted in grey. The activity concentrations of radionuclides were measured by using gamma-spectrometry with a HPGe detector.

The position of all dairies are indicated on the map of Central Bohemia shown in Figure III.11, the position of dairies chosen for calculation are shown in Figure III.12 and the gathering regions of the selected dairies are indicated in Figure III.13.

Table III.4. Records of ^{131}I activities in milk in CB region.

Dairy	Measurements period
BENEŠOV	**05-05 – 11-06- 86**
Čáslav	06-05 – 16-06-86
Hostivice	07-05 – 11-06-86
Kačice	08-05 – 31-05-86
Kolín	07-05 – 11-06-86
Mladá Boleslav	08-05 – 31-05-86
Poděbrady	07-05 – 11-06-86
PRAHA – KYJE	**30-04 – 15-06-86**
Praha – Radlice	15-05-86
PRAHA – TROJA	**05-05 – 16-06-86**
Příbram	08-05 – 11-06-86
Slaný	08-05 – 26-05-86

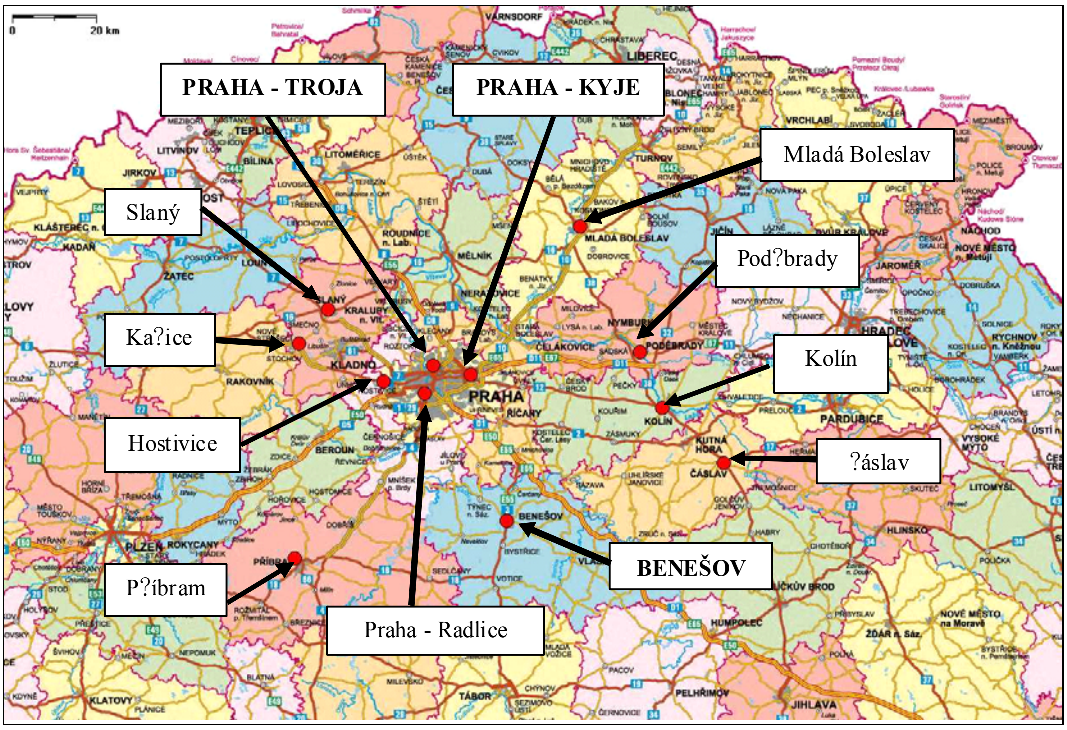


Fig. III.11. Location of dairies in central Bohemia.

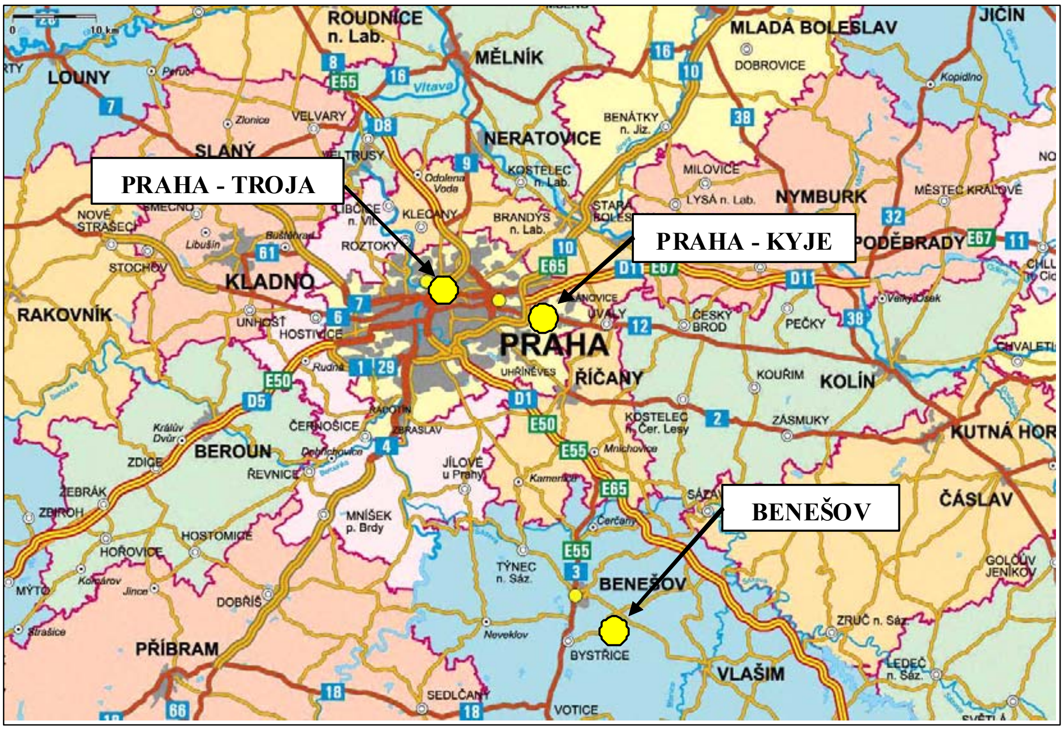


Fig. III.12. Location of dairies chosen for calculation.

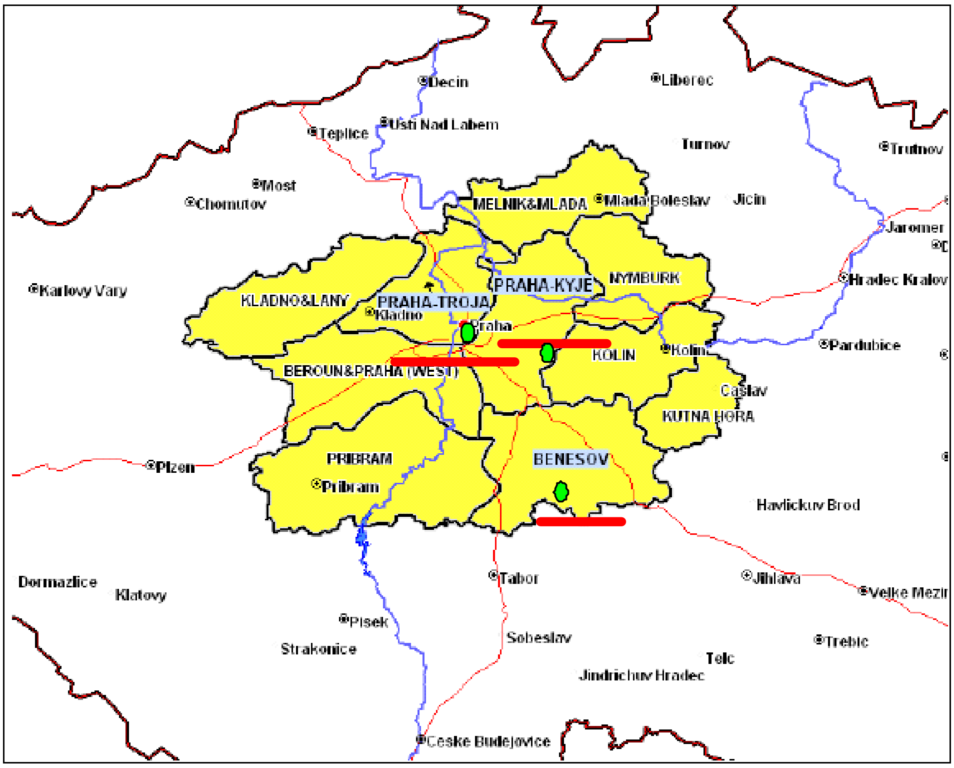


Fig. III.13. Location of dairies in central Bohemia and their gathering regions.

III.3.2.2. ^{131}I thyroid burden

Estimate the arithmetic mean of ^{131}I thyroid content (Bq) for the test adult group of urban population (Prague) and during the period 27 April –20 June 1986. The proposed age's group "adults" (men and women) should provide good statistics for model validation purposes. See the Formularies shown in Annex III.

III.3.3. Calculations for model comparison

III.3.3.1. Integrated air concentration of ^{131}I

The Scenario's original measurements from several locations in Prague are given in Tables III.36–III.41. Recorded data from three aerosol sampling stations (PRAHA– LIBEŇ, PRAHA - LIBUŠ, PRAHA – VINOHRADY) are presented in Tables III.37–III.39 and the average daily air concentrations of the aerosol and gaseous I_2 (station PRAHA – LIBEŇ), are given in Table III.38. The aerosol particle size distribution (station PRAHA – VINOHRADY) was measured by using a cascade impactor. The size distribution for ^{131}I and ^{137}Cs can be seen in Tables III.40 and III.41, respectively. The cascade impactor data for ^{137}Cs in two other places in Czech, in MORAVSKÝ KRUMLOV and OSTRAVA are given in Annex IV to this Appendix, Tables IV-7 and IV-8, respectively.

To compare the starting point of predictions, the participants, when a different approach could be developed, are asked to provide the total integrated ^{131}I air concentration and contributions of the radioiodine phases (expressed as ratio of appropriate integrals).

III.3.3.2. ^{131}I concentration in pasture grass

Estimate the arithmetic mean of ^{131}I in grass for the test location (Prague) in the subsequent days of ^{131}I deposition, i.e. 27 April – 25 of May 1986.

III.3.3.3. ^{131}I concentration in milk for cows pastured on open grassland

This output gives an opportunity for the dose assessment professionals to examine their skills, methods and conceptual approaches for the specified level of the assessment, when countermeasures have to be evaluated with respect to their practicability.

Estimate of the arithmetic mean of ^{131}I concentration in milk for a hypothetical situation when cows had been pastured on open grassland near Prague. This calculation is useful to compare ingestion doses and evaluate dose reduction factor.

III.3.3.4. Inhalation dose

Estimate a mean dose to the thyroid from inhalation (committed equivalent dose to thyroid in mSv) for the specified age groups and time spent in the building. One could consider different dynamics of contaminated plume for a pre-selected location.

The use of the factors for the dose predictions of six different age groups, as shown in Table III.5, is recommended.

III.3.3.5. Ingestion dose

Estimate the mean dose to the thyroid from ingestion (committed equivalent dose to thyroid in mSv) for the specified age groups at various variants of cows feeding regime applied in the CB region. In the first case one can assume the standard agricultural practice typical for the CB region, in the second case, that cows have been grazed in open grassland since the 27 April, 1986. For the sake of model comparison transparency, participants would be asked, to make this assumption, that whole milk is consumed by representatives of particular age groups.

The use of the factors for the dose predictions of six different age groups, as shown in Table III.6, is recommended.

Table III.5. Committed equivalent dose to thyroid from inhalation.

Pathway	Child 1 y	Child 5 y	Child 10 y	Child 15 y	Man
Inhalation [III.1] [Sv/Bq]	2.5×10^{-6}	1.5×10^{-6}	7.4×10^{-7}	4.8×10^{-7}	3.1×10^{-7}

Table III.6. Committed equivalent dose to thyroid from ingestion.

Pathway	Child 1 y	Child 5 y	Child 10 y	Child 15 y	Man
Ingestion [III.2] [Sv/Bq]	3.6×10^{-6}	2.1×10^{-6}	1.0×10^{-6}	6.8×10^{-7}	4.3×10^{-7}

III.4. Input information

III.4.1. Environmental data

III.4.1.1. Agriculture information

Food and fodder production

The area under cultivation in the city of Prague on 31 May, 2004 was 8 915 hectares (0.3% whole agricultural soils in ČR). The harvest for cereals in 2004 was 33 966 tons (0.4% whole ČR). On 1 April 2005 in the city of Prague, 154 934 head of cattle (rate of all ČR: 11.1%) and 415 646 head of pigs (rate of all ČR: 14.4%) were farmed.

The area of agriculturally used soil in the former ČSSR and Prague on 1 January 1986 can be seen in Table III.7. Data about seeding area in the former ČSSR (1985) is given in Table III.8. Before 1989, in Czech most dairy cows were kept in stables throughout the whole year. The number of farming animals in all the former ČSSR and in Prague in the year 1986 is given in Table III.9, production of animal products and animal feed in Prague - city and near surroundings (Prague – west (PZ), Prague – east (PH)) are then given in Table III.10. Data about leafy vegetable production in Prague and near surroundings is given in Table III.11. The area of soil, which was used for seeding, production of vegetables and fodder in the former ČSSR can be seen in Tables III.12 and III.13 respectively.

Distribution of milk production

Data about the number of dairy cows and the milk yield from these cows in Prague in the years 1989, 2000–2003 are given in Table III.14. For the year 1985, the production of some animal products, is described by the yield and absolute value of production (Tables and III.15 and III.16).

Yield of the fodder **at the time of accident**

Dairy cows' feeding rations at the time of the accident were in accordance with information gathered by the Mendel University of Agriculture and Forestry, Brno, Czech Republic, predominantly from ensilage (with ½ gathered the year earlier, with storage mostly covered with tilt) and from hay (ingathered cca 8 months before the accident, storage inside). The green fodder was added only in the highlands from the end of May. In lowlands it was not added except for cows with a combined efficiency (milk + meat). The feeding roughage ratio during the period the 15 April – 15 October 1986 consisted of 1/3 – ½ green pasture, meaning 3–5 kg dry mass of grass. The rest consists of silage (5–7 kg/day) and grain (5–10 kg/day). The dry mass for feedstuff is given in Table III.17. In spite of the fact that the ensilage and hay were covered, their contamination by ^{131}I was possible. Another source of agricultural information [III.3] followed that in 1986, with approximately 50% of farms using green fodder as a part of feeding ratio during the period 1 May – 30 October 1986, where grass was cut and scattered by cattle-bin. On 5 May 1986, in an altitude of 200 m grass is approximately 10 cm high. Another 50% of farms did not use green fodder. The second information seems more relevant. The yield of the grass, alfalfa and clover in dry mass is given in Table III.18 according to data by the Mendel University of Agriculture and Forestry in Brno.

Cows consumption rate

It was recommended to keep dairy cows on winter fodder – if available. The average feeding ration per cow in the former ČSSR in the years 1981 – 1985 is given in Table III.19.

Table III.7. Area of agriculturally used soils (1.1.1986).

Region	Farmland	Arable land [thousands ha]	Meadows
All ČSSR	6794	4786	829
Prague	18	12	1
Central Bohemia	680	570	49

Table III.8. Seeding area in ČSSR (1985).

Products	Area [thousands ha]	Rate [%]
All	4853	100.0
Grain crops	2659	54.8
Potatoes	188	3.9
Fodder crops and root-crops	1497	30.8
Technical plants	412	8.5
Vegetables	65	1.3

Table III.9. Number of animals in thousands of head (1.1.1986).

Region	Number of animals [thousands]	
	cattle	from that DAIRY cows
ČSSR	5065	1860
Prague	10	4

Table III.10. Animal production in Central Bohemia in 1986.

Parameter	Prague - city	Prague - east	Prague - west
	Production [flesh in tons of living weight, milk in thousands of litres, eggs in thous. of pieces]		
Milk	12794	44651	43592
Egg	–	13481	29225
	Production of feed/stuffs [tons]		
Ensilage	44252	216938	142164
Hay	3587	19736	11948
Ensilaged hay	2579	15695	27855
Green fodder	1.00E+05	196324	189486

Table III.11. Some leafy vegetable production [TONs] in Prague and surroundings in 1986.

Vegetables	Prague - city	Prague - east	Prague – west
Cabbage	216	2140	1690
Cauliflower	197	339	110
Kale	35	459	283
Kohlrabi	74	302	74
Lettuce	607	168	16
Spinach	–	2711	139

Table III.12. Seeding area for vegetable and fodder plants [thousands hectare] in ČSSR in 1985.

Product	Seeding area [thousands ha]
Spring legume-crops mixture	164.4
Clover (two-stage cutting)	242.1
alfalfa	290.5
Clover-grass and alfalfa-grass mixtures	103.0

Table III.13. Production of fodder plants [thousand tons – dry mass] and land revenue [t/ha] in 1985.

Product	Production [thousands t – dry mass]		Land revenue [t/ha]	
	ČSSR	Prague	ČSSR	Prague
Clover (two-stage cutting)	2494	4	9.95	8.65
alfalfa	2611	11	9.40	9.06

Table III.14. Dairy cows.

Parameter	Unit	Year				
		1989	2000	2001	2002	2003
Average number of dairy cows	Thousands	1228.5	515.4	483.4	477.0	459.6
Average milk yield per year	L/cow/year	3982.0	5255.0	5589.0	5718	5756.2
Average milk yield per day	L/cow/day	10.91	14.36	15.31	15.67	15.77

Table III.15. Production of animal products in 1985.

Region	Milk [millions of litres]	Eggs [millions of pieces]
ČSSR	6676	5499
Prague	14	25

Table III.16. Yield of production of milk and eggs in 1985.

Region	Average milk yield / cow [L]	Average egg yield per 1 hen [pieces]
ČSSR	3642.7	246.5
Prague	3246.5	256.3

Table III.17. Dry mass for feedstuff.

Feedstuff	fresh mass [kg]	dry mass [kg]
Grass	10	2
Ensilage	10	3
Grain	10	9
hay	10	8.5

Table III.18. Production of pasture from 1 ha in dry mass.

Area 1 ha	Production [ton of dry mass]
Alfalfa	11
Clover	9
Grass (meadow)	6
Pastureland	4.5

Table III.19. Average day feeding ration per cattle in 1981–1985.

Feed	Average daily feeding ration [kg]			
	Dairy cow		Beef cow	
	Summer	Winter	Summer	Winter
Cereals	4.1	4.7	2.4	2.9
Hay	0.6	3.8	0.4	1.5
Green fodder (alfalfa + clover)	50.0	0.0	18.0	0.0
Root crops	0.0	0.2	0.0	0.3
Ensilaged crops	5.0	25.0	7.0	15.4
Ensilage hay	2.0	8.0	1.4	3.5
Straw	3.6	3.6	2.6	2.6

III.4.1.2. Climatic conditions

The climate of the Czech Republic is affected by the interaction of oceanic and continental effects. Western winds prevail and intensive cyclone type activities frequently change air masses and bring rather heavy precipitation. The maritime effect is mainly felt in Bohemia, and continental climate effects have a bigger impact on Moravia and Silesia. Altitude and relief influence the climate to a large extent. 52 817 km^2 of the country's whole territory (66.97%) can be found at an altitude below 500 m, 25 222 km^2 (31.68%) between 500 to 1 000 m, and only 827 km^2 above 1 000 m. The average altitude of the Czech Republic is 430 m.

Meteorological data in ČR is collected from a network of many meteorological stations of the Czech Hydrometeorological Institute Prague, Czech Republic, which afforded all of the next meteorological data. The locations of meteorological stations working in the year 2006 are given in Figure III.14.

The geographical coordinates of meteorological stations located in Central Bohemia are given in Table III.20. Highlighted stations are located in gathering regions from chosen dairies. A list of meteorological stations located in gathering regions for the three chosen dairies are given in Table III.23 and in Figure III.15.

The average daily temperatures from meteorological stations in PRAGUE-CITY during the period 1 January – 31 July 1986 can be seen in Table III.21. The average daily temperatures in meteorological stations outside of Prague, namely ČECHTICE, ONDŘEJOV, BRANDÝS NAD LABEM and TUHAŇ for the period 1 January – 31 July 1986, are given in Table III.22.

III.4.2. Transport of air masses during the chernobyl releases

A record of data about wind velocity and direction from the meteorological station PRAHA – RUZYNĚ, observed during the period 29 April – 11 May 1986 at 07:00 CET is collected in Table III.24. Data about wind velocity and directions in the the period the 1 January – 31 July 1986 for the meteorological station PRAHA – LIBUŠ is given in Table III.25, for the station BRANDÝS NAD LABEM in Table III.26, for the station ČECHTICE in Table III.27, for the station TUHAŇ in Table III.28 and for the station ONDŘEJOV in Table III.29. Trajectories of the first, second and third contaminated air passage through the former ČSSR area (and CB region – red circle) are given in Figures III.16, III.17 and III.18, respectively.

Table III.20. Geographical coordinates of meteorological station in Central Bohemia and Prague.

Code	Name	N lat.	E long.	Sea level [m]
474	Lány [RA]	50° 07'	13° 57’	447
513	Kladno [KL]	50° 10’	14° 07’	293
521	Beroun [BE]	49° 57’	14° 02’	260
522	Neumětely [BE]	49° 51’	14° 02’	322
527	Solenice [PB]	49° 37’	14° 11’	357
561	Semčice [MB]	50° 22’	15° 00’	234
563	**Brandýs nad Labem [PH]**	**50° 11' 07.18”**	**14° 39' 17.31”**	**179**
572	**Ondřejov**	**49° 54' 16.62”**	**14° 47' 03.14”**	**320**
624	Chotusice	49° 59’	15° 12’	315
627	**Čechtice**	**49° 37' 26.50”**	**15° 02' 53.67”**	**490**
519	**Praha-Karlov**	**50° 04' 15.24”**	**14° 25' 42.74”**	**232**
	Praha - Kbely	**50° 07' 54.19”**	**14° 33' 06.05”**	
514	**Praha-Klementinum**	**50° 05' 13.29”**	**14° 24' 59.39”**	**191**
520	**Praha-Libuš**	**50° 00' 24.15”**	**14° 27' 40.19”**	**305**
518	**Praha-Ruzyně**	**50° 05' 32.11”**	**14° 18' 01.58”**	**376**
	Praha – Uhříněves	**50° 02' 03.82”**	**14° 35' 25.87”**	
	Tuhaň	**50° 17' 43.37”**	**14° 31' 02.19”**	**160**

Table III.21. Average daily temperature measured by meteorological stations in Prague-city during the period 1 January – 31 July 1986.

Date	Daily average temperature [oC]					
	Praha - Karlov	Praha - Kbely	Praha - Klementinum	Praha - Libuš	Praha - Ruzyně	Praha - Uhříněves
01-01-86	-5.5	-7.1	-4.2	-5.4	-6.5	-5.8
02-01-86	-2.2	-3.6	-1.3	-2.2	-3.4	-2.6
03-01-86	3.4	2.5	3.1	2.8	1.7	2.4
04-01-86	-1.0	-1.7	-0.3	-1.7	-2.3	-1.2
05-01-86	-1.1	-2.3	-0.2	-2.2	-3.1	-1.5
06-01-86	-0.4	-1.1	0.4	-0.9	-1.9	-0.6
07-01-86	-0.7	-1.1	-0.1	-1.4	-4.1	-2.7
08-01-86	-1.7	-2.8	-1.0	-2.4	-3.6	-3.0
09-01-86	-5.8	-6.8	-5.0	-6.5	-8.9	-6.4
10-01-86	-7.5	-9.6	-6.0	-7.6	-7.9	-8.1
11-01-86	3.0	1.9	2.8	3.0	2.0	2.4
12-01-86	3.0	2.7	3.5	2.6	1.5	2.4
13-01-86	3.3	3.5	3.8	2.7	1.7	2.5
14-01-86	4.5	4.6	5.0	3.7	2.8	3.5
15-01-86	2.3	2.5	3.0	2.0	1.0	2.1
16-01-86	-0.4	-0.7	0.7	-0.8	-1.8	-0.5
17-01-86	-2.1	-3.0	-1.4	-2.9	-3.7	-2.6
18-01-86	-0.8	-1.2	0.0	-0.9	-1.6	-1.6
19-01-86	7.2	7.3	7.5	6.7	5.6	6.5
20-01-86	4.4	4.4	5.0	3.7	2.8	3.6
21-01-86	4.1	3.8	4.4	3.4	2.5	3.0
22-01-86	3.9	3.3	4.4	3.5	2.4	3.6
23-01-86	5.8	6.2	6.6	5.4	5.0	5.6
24-01-86	3.1	3.0	4.0	2.3	1.1	3.0
25-01-86	0.7	0.1	1.1	-0.5	-0.6	0.0
26-01-86	-1.3	-1.8	-0.3	-1.9	-2.9	-1.7
27-01-86	-2.6	-3.0	-1.7	-3.1	-4.1	-3.1
28-01-86	-2.5	-4.4	-1.5	-4.1	-4.2	-3.7
29-01-86	-0.1	-1.3	0.6	-0.8	-2.4	-0.6
30-01-86	2.7	2.4	3.2	2.1	1.3	2.5

Table III.21. (Continued).

Date	Daily average temperature [oC] Praha – Karlov	Praha – Kbely	Praha – Klementinum	Praha – Libuš	Praha – Ruzyně	Praha – Uhříněves
31-01-86	3.7	3.1	4.1	3.2	2.3	3.0
01-02-86	5.5	5.1	6.3	4.8	4.1	5.2
02-02-86	1.9	1.2	2.7	1.4	0.6	2.1
03-02-86	-1.2	-2.3	-0.3	-1.2	-2.6	-1.4
04-02-86	-2.4	-3.7	-1.4	-2.8	-4.0	-3.1
05-02-86	-4.9	-6.4	-3.9	-5.5	-6.1	-5.8
06-02-86	-5.6	-6.7	-4.8	-6.6	-8.2	-7.2
07-02-86	-9.4	-10.6	-8.8	-9.9	-11.9	-9.9
08-02-86	-11.0	-12.4	-9.9	-11.9	-14.0	-11.3
09-02-86	-12.4	-13.3	-11.7	-13.4	-14.2	-13.9
10-02-86	-7.0	-8.1	-5.9	-8.0	-8.6	-9.6
11-02-86	-6.0	-6.9	-5.5	-7.3	-9.8	-10.1
12-02-86	-6.5	-7.7	-5.8	-7.0	-9.1	-8.3
13-02-86	-4.8	-6.8	-4.3	-6.1	-8.5	-8.0
14-02-86	-3.0	-4.7	-2.2	-3.4	-4.2	-4.5
15-02-86	-2.2	-3.4	-1.5	-3.1	-4.0	-2.8
16-02-86	-1.5	-2.6	-0.9	-2.0	-3.1	-2.4
17-02-86	-4.8	-5.8	-3.9	-5.3	-6.3	-5.2
18-02-86	-2.7	-3.7	-2.1	-3.2	-4.7	-3.1
19-02-86	-2.5	-3.0	-1.6	-2.3	-3.6	-2.5
20-02-86	-7.7	-9.1	-6.8	-8.4	-12.1	-9.6
21-02-86	-7.8	-9.5	-6.7	-8.7	-8.8	-10.8
22-02-86	-7.8	-9.1	-6.4	-8.7	-8.8	-8.8
23-02-86	-8.3	-9.5	-7.6	-9.4	-11.8	-9.9
24-02-86	-10.4	-11.4	-9.1	-12.0	-12.7	-13.8
25-02-86	-9.4	-11.4	-8.3	-10.4	-11.3	-11.3
26-02-86	-9.3	-11.2	-8.6	-10.3	-11.8	-11.9
27-02-86	-9.2	-11.1	-8.1	-10.5	-11.7	-10.2
28-02-86	-7.3	-9.7	-6.4	-8.9	-10.8	-10.1
01-03-86	-5.5	-6.6	-4.7	-5.8	-7.0	-5.7
02-03-86	-3.0	-4.0	-2.3	-3.3	-4.0	-3.3
03-03-86	-2.0	-3.2	-1.1	-2.8	-3.2	-3.2
04-03-86	0.5	-0.5	1.1	0.2	-0.9	-0.6
05-03-86	4.3	3.2	4.5	3.6	3.0	3.8
06-03-86	5.9	4.3	6.4	5.2	4.3	4.5
07-03-86	3.4	2.4	3.9	2.4	1.7	2.4
08-03-86	3.3	2.4	4.0	2.8	1.8	2.3
09-03-86	3.9	3.1	4.5	3.2	1.7	2.6
10-03-86	5.5	4.2	5.8	4.3	2.8	3.8
11-03-86	4.1	2.6	4.7	3.5	2.3	3.1
12-03-86	4.4	3.4	5.3	3.9	3.0	3.5
13-03-86	5.7	4.8	6.5	5.3	4.3	5.0
14-03-86	5.8	4.8	6.6	4.9	4.0	4.7
15-03-86	5.6	4.7	6.3	4.8	3.8	4.7
16-03-86	5.5	4.7	6.5	5.6	4.4	5.7
17-03-86	4.1	3.1	4.9	3.2	1.9	2.6
18-03-86	5.8	3.9	6.1	4.4	3.8	4.3
19-03-86	4.8	3.1	5.6	4.5	2.5	4.3
20-03-86	5.2	4.4	5.6	4.2	4.4	4.4
21-03-86	3.6	2.5	4.3	2.9	1.8	3.0
22-03-86	3.2	2.7	4.3	2.7	1.6	3.3
23-03-86	3.6	2.9	4.2	2.9	2.5	3.1
24-03-86	5.9	5.2	6.0	5.3	5.1	5.2
25-03-86	6.0	5.7	6.7	5.6	4.0	5.6
26-03-86	5.9	5.3	6.9	5.5	3.3	5.3

Table III.21. (Continued).

Date	Daily average temperature [oC]					
	Praha - Karlov	**Praha - Kbely**	**Praha - Klementinum**	**Praha - Libuš**	**Praha - Ruzyně**	**Praha - Uhříněves**
27-03-86	8.4	7.8	8.6	8.1	6.5	7.7
28-03-86	12.4	12.4	12.9	11.9	10.7	12.1
29-03-86	7.9	6.5	8.6	7.0	5.9	7.2
30-03-86	5.5	4.6	6.5	4.6	3.9	5.4
31-03-86	9.7	9.1	10.3	9.7	8.4	8.6
01-04-86	8.0	7.2	8.6	7.7	5.3	5.9
02-04-86	9.0	7.1	9.7	8.0	6.7	6.7
03-04-86	10.4	9.2	10.5	9.6	8.6	9.9
04-04-86	5.7	4.9	6.7	4.9	4.3	5.1
05-04-86	5.2	5.1	6.3	4.7	3.5	4.8
06-04-86	5.9	5.2	6.6	5.5	4.1	4.8
07-04-86	14.7	13.1	12.7	13.0	12.1	13.0
08-04-86	14.4	13.8	14.3	14.3	12.4	14.8
09-04-86	16.4	16.0	15.4	15.0	12.8	16.1
10-04-86	3.5	4.6	4.3	3.6	2.2	7.2
11-04-86	-0.9	-1.5	-0.3	-1.5	-3.0	-1.8
12-04-86	-1.2	-1.7	-0.5	-1.3	-2.9	-1.0
13-04-86	0.8	-0.5	1.2	-0.6	-1.3	0.4
14-04-86	4.3	2.7	5.5	3.7	2.7	3.2
15-04-86	9.9	8.5	10.5	9.1	8.9	9.7
16-04-86	10.4	9.2	11.1	9.8	9.9	9.3
17-04-86	10.6	9.5	11.0	10.2	8.5	9.9
18-04-86	7.2	7.2	8.3	6.6	6.2	7.0
19-04-86	5.8	5.6	6.4	5.4	5.1	5.7
20-04-86	6.1	5.7	7.4	5.4	4.5	5.5
21-04-86	11.7	10.2	12.2	10.9	10.1	10.2
22-04-86	13.9	12.7	13.8	14.0	12.2	13.4
23-04-86	14.5	13.1	14.3	13.1	11.2	14.0
24-04-86	18.5	16.1	17.5	16.9	16.9	16.4
25-04-86	14.2	13.2	14.2	13.2	12.2	13.8
26-04-86	16.8	15.6	16.9	15.8	14.2	16.0
27-04-86	14.8	13.9	15.4	14.5	13.4	14.8
28-04-86	17.0	15.8	17.2	16.4	15.1	15.8
29-04-86	17.9	16.8	18.0	17.1	15.0	17.0
30-04-86	17.5	16.5	17.7	16.4	15.7	16.3
01-05-86	15.3	13.5	15.8	14.7	12.6	14.2
02-05-86	16.6	15.3	17.4	16.1	14.6	15.4
03-05-86	19.9	18.0	20.1	18.8	17.4	19.0
04-05-86	20.2	18.7	21.1	19.7	18.3	19.8
05-05-86	20.7	18.5	21.2	20.0	18.2	19.4
06-05-86	20.0	18.8	20.7	19.7	18.0	20.1
07-05-86	19.1	17.5	19.7	18.9	16.1	17.7
08-05-86	12.0	10.4	13.1	11.3	10.3	10.9
09-05-86	10.4	8.8	11.3	10.2	9.8	10.9
10-05-86	13.5	13.3	14.4	13.1	12.1	14.4
11-05-86	15.7	15.2	16.4	15.3	14.5	15.0
12-05-86	16.4	14.9	17.2	15.6	14.4	15.4
13-05-86	19.5	18.1	19.3	18.6	18.2	18.5
14-05-86	18.2	16.4	18.9	17.8	16.1	17.1
15-05-86	17.8	17.2	18.7	16.7	15.9	16.6
16-05-86	15.3	13.1	16.0	14.6	12.9	14.4
17-05-86	18.0	16.0	18.0	16.3	15.8	16.7
18-05-86	20.5	19.0	21.1	19.6	18.9	19.2
19-05-86	19.8	18.5	20.0	18.7	17.3	18.5
20-05-86	17.4	15.7	18.3	16.9	15.5	16.6

Table III.21. (Continued).

Date	Daily average temperature [oC] Praha – Karlov	Praha – Kbely	Praha – Klementinum	Praha – Libuš	Praha – Ruzyně	Praha – Uhříněves
21-05-86	20.3	18.4	20.7	19.6	18.0	18.8
22-05-86	18.4	17.7	19.5	17.6	15.6	18.4
23-05-86	20.1	18.7	20.5	19.2	18.1	18.6
24-05-86	16.2	15.3	17.1	15.5	15.1	15.9
25-05-86	16.5	14.4	17.0	15.0	13.9	15.2
26-05-86	20.5	18.6	21.1	19.8	18.0	19.4
27-05-86	22.9	22.2	22.6	22.2	19.7	21.5
28-05-86	14.6	14.1	15.1	14.4	13.6	13.7
29-05-86	11.6	11.3	12.0	11.3	10.4	11.4
30-05-86	8.0	7.6	8.1	7.6	6.6	7.7
31-05-86	8.4	8.2	9.1	7.2	7.2	7.8
01-06-86	11.3	10.2	12.2	11.2	9.6	10.4
02-06-86	11.6	11.5	12.4	11.1	10.5	10.7
03-06-86	12.9	12.2	13.7	12.3	10.7	12.6
04-06-86	11.5	10.9	12.5	10.8	8.9	10.6
05-06-86	9.9	9.5	10.9	9.1	8.1	9.3
06-06-86	10.6	10.2	11.6	10.0	9.0	9.6
07-06-86	10.5	10.4	11.4	10.2	8.9	10.2
08-06-86	13.9	13.3	14.4	13.0	11.9	13.8
09-06-86	17.3	15.7	17.3	16.3	15.6	15.2
10-06-86	18.4	16.6	19.3	17.5	16.7	17.5
11-06-86	17.2	17.0	17.6	17.0	16.4	17.6
12-06-86	11.2	10.9	11.7	10.7	10.1	10.7
13-06-86	13.3	13.0	13.6	12.7	12.0	12.9
14-06-86	20.4	18.8	20.8	19.3	18.0	18.9
15-06-86	22.7	20.9	22.9	21.7	20.3	21.4
16-06-86	24.4	22.4	25.1	23.8	22.7	23.3
17-06-86	25.3	23.2	25.8	23.8	23.1	22.5
18-06-86	24.4	23.1	24.5	22.7	22.2	22.6
19-06-86	21.5	20.9	21.9	21.2	19.3	20.9
20-06-86	23.5	21.9	24.0	22.8	20.6	21.4
21-06-86	19.5	18.9	19.9	19.2	17.0	18.4
22-06-86	19.5	18.2	20.1	18.4	17.0	18.6
23-06-86	18.4	16.8	19.3	17.3	16.7	17.1
24-06-86	17.9	16.8	19.7	17.7	16.7	18.6
25-06-86	20.4	18.5	20.7	18.7	18.1	17.1
26-06-86	21.4	20.2	21.6	20.5	17.8	19.3
27-06-86	23.1	22.3	23.2	22.2	20.2	20.5
28-06-86	22.6	21.5	23.1	22.4	20.5	21.5
29-06-86	20.2	19.1	20.5	20.0	17.8	18.9
30-06-86	19.5	18.4	20.1	18.6	16.6	18.8
01-07-86	22.5	21.7	22.7	21.6	21.0	20.3
02-07-86	24.6	22.5	24.3	23.1	20.7	22.0
03-07-86	24.7	23.7	25.4	24.4	22.5	23.6
04-07-86	24.3	23.7	24.6	24.0	22.5	23.2
05-07-86	25.7	24.5	25.6	25.3	22.8	24.0
06-07-86	19.0	19.1	20.0	19.2	17.4	18.2
07-07-86	14.5	14.7	15.2	13.9	13.0	13.7
08-07-86	14.1	13.6	15.2	12.9	11.8	12.9
09-07-86	13.6	13.7	14.9	12.9	12.8	14.0
10-07-86	13.9	13.5	15.1	13.0	12.3	13.0
11-07-86	14.8	14.4	15.6	14.0	11.9	14.1
12-07-86	14.6	13.6	15.4	14.0	12.3	14.0
13-07-86	14.5	13.7	15.5	13.5	12.6	14.0
14-07-86	15.7	14.7	15.8	15.1	12.7	15.3

Table III.21. (Continued).

Date	Daily average temperature [oC] Praha – Karlov	Praha – Kbely	Praha – Klementinum	Praha – Libuš	Praha – Ruzyně	Praha – Uhříněves
15-07-86	19.2	17.8	18.9	17.9	16.0	16.2
16-07-86	20.7	19.8	21.1	20.0	19.2	19.2
17-07-86	23.2	22.3	22.9	22.4	22.0	22.1
18-07-86	18.6	17.8	19.2	18.2	17.3	17.4
19-07-86	13.5	13.1	14.3	12.8	12.3	12.7
20-07-86	15.4	14.6	16.1	14.4	13.1	14.3
21-07-86	18.8	16.8	18.6	17.2	15.8	17.1
22-07-86	20.6	19.4	21.2	19.9	17.5	20.7
23-07-86	21.5	20.4	21.8	20.7	20.4	20.3
24-07-86	13.5	13.9	14.8	12.8	12.0	13.0
25-07-86	16.4	15.7	17.4	15.9	15.0	15.5
26-07-86	17.4	15.9	18.5	16.7	16.1	16.2
27-07-86	21.6	19.4	21.5	20.2	18.4	19.6
28-07-86	22.8	20.6	22.9	21.8	20.8	20.8
29-07-86	24.5	23.3	24.7	23.1	22.2	23.6
30-07-86	23.2	20.9	23.6	21.9	20.3	21.2
31-07-86	23.1	21.2	23.2	22.2	21.5	22.4

Table III.22. Average daily temperature measured by meteorological stations Čechtice, Ondřejov, Brandýs nad Labem and tuhaň during the period 1 January – 31 July 1986.

Date	temperature - daily average [°C] Čechtice	Ondřejov	Brandýs nad Labem	Tuhaň
01-01-86	-6.2	-7.1	-6.8	-6.8
02-01-86	-1.9	-3.1	-3.1	-3.1
03-01-86	2.1	1.5	1	0.3
04-01-86	-3.3	-3.5	-1.3	-2.1
05-01-86	-3.1	-3	-1.3	-0.9
06-01-86	-2.8	-2.9	-1	-1.1
07-01-86	-3.3	-4.1	-3.8	-4.1
08-01-86	-4.8	-4.7	-3.1	-3.4
09-01-86	-6.4	-8.1	-6.8	-8.1
10-01-86	-8.8	-8.7	-10.5	-11.4
11-01-86	1.7	0.7	-2.7	-3
12-01-86	0.7	0.5	3.4	2.7
13-01-86	1.6	1.1	3.6	3.3
14-01-86	2	2.1	4.5	3.7
15-01-86	0.4	0.3	2.5	2.3
16-01-86	-2	-2.6	-0.6	-1.3
17-01-86	-5	-5	-2.8	-3.2
18-01-86	-2.3	-3	-1.5	-2.8
19-01-86	4.6	4.8	7.5	6.6
20-01-86	2.3	1.8	4	4.1
21-01-86	0.6	1.8	4.4	3.7
22-01-86	1.5	1.4	4.1	4.1
23-01-86	3.8	3.8	6.2	6.3
24-01-86	0.9	0.3	2.8	3.1
25-01-86	-1.9	-1.9	0.8	0.9
26-01-86	-3.7	-3.9	-1.8	-1.5
27-01-86	-5.6	-5.9	-2	-1.6
28-01-86	-4.5	-5.3	-2.4	-2.3
29-01-86	-1.6	-1.9	0.3	0.1
30-01-86	-0.3	0.4	3.3	2.8
31-01-86	1.2	1.2	3.1	3.4

Table III.22. (Continued).

Date	temperature - daily average [°C]			
	Čechtice	Ondřejov	Brandýs nad Labem	Tuhaň
01-02-86	2.4	2.8	5.8	6
02-02-86	0.7	0	1.4	2.4
03-02-86	-2.2	-2.3	-1.5	-0.6
04-02-86	-5	-4.6	-2.9	-1.7
05-02-86	-7.5	-7.5	-5.6	-5.1
06-02-86	-7.9	-8.2	-6.6	-6.5
07-02-86	-10.1	-11.8	-9.6	-10.2
08-02-86	-11.2	-13.4	-11.8	-11.6
09-02-86	-13	-14.3	-12.9	-12.6
10-02-86	-8.4	-9.3	-9.2	-7.3
11-02-86	-9.2	-7.1	-9.9	-10
12-02-86	-7.4	-6.6	-8.7	-9.5
13-02-86	-6	-7.9	-5.8	-4.7
14-02-86	-4.3	-5.3	-3.6	-3.3
15-02-86	-4.1	-3.7	-1.4	-1
16-02-86	-1.4	-4.1	-1.4	-0.8
17-02-86	-5.8	-7.3	-4.4	-4.8
18-02-86	-3.5	-4.4	-2.7	-2.7
19-02-86	-1.6	-4.1	-2.4	-2.1
20-02-86	-9.8	-10.1	-8.9	-9
21-02-86	-10.9	-11.1	-11.2	-11.1
22-02-86	-9.2	-8.8	-9.3	-8.9
23-02-86	-10.1	-11.4	-10.3	-9.2
24-02-86	-13.3	-10.8	-13.2	-12.6
25-02-86	-12.1	-12.2	-11.3	-10.2
26-02-86	-12.4	-11.6	-12.9	-11.5
27-02-86	-11.3	-9.6	-13.1	-13
28-02-86	-10.5	-9.5	-11.5	-10
01-03-86	-7	-7.6	-5.4	-4.6
02-03-86	-4.3	-5.4	-2.9	-2.5
03-03-86	-3.3	-4	-2.9	-3.3
04-03-86	-1.5	-2	0.2	-0.1
05-03-86	3	2.8	3.4	3
06-03-86	1.8	2.9	4.2	4.4
07-03-86	0.9	1.1	2.2	2.2
08-03-86	1	0.8	3.3	3.6
09-03-86	1.7	1.6	3.2	3.4
10-03-86	3.8	4.2	4.3	4
11-03-86	1.2	2.7	2.6	2.8
12-03-86	1.9	2.1	4.1	4.6
13-03-86	2.9	2.8	6.1	6.4
14-03-86	2.8	3.3	5.8	6
15-03-86	2.6	3.2	5.4	5.6
16-03-86	2.6	2.8	5.2	5.9
17-03-86	0	2.2	3.5	4
18-03-86	3.3	3.9	4.6	4.4
19-03-86	0.9	2.6	4.4	4.6
20-03-86	2.8	3.8	3	4.4
21-03-86	1	1.3	3.2	3.7
22-03-86	1.5	1.4	3.6	4.3
23-03-86	2.6	1	3.9	3.3
24-03-86	3.7	3.5	5.2	5.1
25-03-86	3.7	4.1	6.6	6.2
26-03-86	3.2	3.1	5.8	5.9
27-03-86	6.5	6.3	8.9	8.1
28-03-86	9.8	10.5	13.3	13.5

Table III.22. (Continued).

Date	temperature - daily average [°C] Čechtice	Ondřejov	Brandýs nad Labem	Tuhaň
29-03-86	4.3	5.5	7.6	7.8
30-03-86	2.8	3.1	5.4	6
31-03-86	7.5	7.4	11	9.9
01-04-86	6	5.8	7.7	7.4
02-04-86	6.4	6.3	7	8.4
03-04-86	9.2	9.3	10	10.8
04-04-86	4	3.6	6	5.9
05-04-86	2.7	2.9	6.2	6.4
06-04-86	2.8	3	6.4	6.4
07-04-86	12.2	12.8	13.4	13.9
08-04-86	14.6	16.8	14.2	13.4
09-04-86	14	14.1	16.8	16.2
10-04-86	3.9	2.9	4.5	4.6
11-04-86	-3.1	-3.3	-0.9	-1
12-04-86	-3.4	-3.8	-1	-1.3
13-04-86	-1.8	-1.3	0.4	-0.4
14-04-86	1.8	4.5	4.7	4.5
15-04-86	6.7	7.8	9.4	9.7
16-04-86	6.9	8.1	9.9	10.5
17-04-86	9.2	8.9	9.9	10
18-04-86	5.4	4.9	7.7	8.1
19-04-86	1.8	3.1	6.3	6.6
20-04-86	3.6	4	6.7	7.1
21-04-86	8.2	9.6	10.7	10.6
22-04-86	11.9	13	13.2	12.9
23-04-86	11.4	12.7	13.1	12.4
24-04-86	15.3	16.8	16.9	17.2
25-04-86	14.5	12.5	13.7	13.2
26-04-86	13.7	15.4	15.9	15.3
27-04-86	13.5	13.6	14.6	14.2
28-04-86	14.8	15	16.9	17
29-04-86	15.8	15.7	17.5	17.4
30-04-86	13.6	15.7	17.3	17.7
01-05-86	11.4	14.8	15	16.1
02-05-86	13.7	14.4	16.2	16.5
03-05-86	16.3	17.6	18.5	19.2
04-05-86	16.3	18.4	19.9	21.5
05-05-86	16.5	17.9	19.5	20.4
06-05-86	17.4	17.6	19.3	19.7
07-05-86	16.4	16.8	17.3	18.1
08-05-86	9.2	8.5	11.5	11.4
09-05-86	8.9	9.6	9.6	9.3
10-05-86	11.5	12	13.5	13.3
11-05-86	13.7	14.2	15.3	15.3
12-05-86	12.1	13.3	14.8	14.8
13-05-86	17	17.4	18.5	18.5
14-05-86	15.6	15.5	17.7	16.9
15-05-86	15.2	15.9	17.2	17.3
16-05-86	13.7	12.7	14.6	14.5
17-05-86	13.3	14.8	16.7	16.7
18-05-86	17.9	18.1	19.1	19.8
19-05-86	17.1	17.1	18.9	18.9
20-05-86	14.2	14.3	17.1	16.3
21-05-86	16.5	17.6	18.1	18.4
22-05-86	16	15.8	17.2	17.7
23-05-86	16.3	18	17.8	19.9

Table III.22. (Continued).

Date	temperature - daily average [°C]			
	Čechtice	Ondřejov	Brandýs nad Labem	Tuhaň
24-05-86	14	14.3	16.1	16.8
25-05-86	11.4	13.3	16	15.2
26-05-86	16.5	17.8	18.9	19.3
27-05-86	20.2	21.2	22.7	22.1
28-05-86	15.2	12.7	14.3	14.8
29-05-86	10.5	9.4	12.4	12.7
30-05-86	7.3	6.4	8.4	9
31-05-86	6.2	5.6	8.8	9.5
01-06-86	9	8.5	11.4	12.4
02-06-86	10.3	10.9	13.4	12.3
03-06-86	10.4	11	13.2	13
04-06-86	9.6	8.8	11.2	11.5
05-06-86	7	6.9	9.9	10.2
06-06-86	8.5	8.3	11.1	11.1
07-06-86	9.4	9.3	11.1	11
08-06-86	10.6	10.7	13.7	13.9
09-06-86	12.7	14.2	16.4	15.7
10-06-86	14.8	16	18.3	18.4
11-06-86	16.9	13.9	17.9	18.1
12-06-86	9.3	9	11.7	11.9
13-06-86	11.9	12	14.4	14.5
14-06-86	17.7	16.8	20.4	20.5
15-06-86	19.7	19.7	22.5	22.1
16-06-86	22.1	22.8	24.4	24.1
17-06-86	22.4	23.1	24.1	24.3
18-06-86	20.4	21.1	24.4	24.3
19-06-86	18.7	19.8	21.5	21.6
20-06-86	20.7	21.1	23.2	23.3
21-06-86	17.3	17.4	18.9	19
22-06-86	16.4	16.6	18.7	18.9
23-06-86	15.2	16.3	17.8	17
24-06-86	15.6	16.5	18.6	18.4
25-06-86	16	16.5	19	19.8
26-06-86	17.6	19.6	20	20.1
27-06-86	18.7	20.8	21.9	21.6
28-06-86	20.1	20.8	21.9	21.9
29-06-86	15.9	17.1	19.6	20.9
30-06-86	14.4	16.4	19.1	19.6
01-07-86	18.3	20	21.6	21.3
02-07-86	19.6	21.5	22.6	23
03-07-86	19.6	23.3	24.1	24.6
04-07-86	21.9	23.5	24.2	23.1
05-07-86	22.3	23.2	23.7	25
06-07-86	19.1	17.8	19.6	19
07-07-86	13.2	12.1	14.3	14.8
08-07-86	12	11.6	13.6	15.3
09-07-86	12	12.8	14.5	14.5
10-07-86	10.9	10.4	13.8	14.1
11-07-86	12.5	11	13.8	14.4
12-07-86	12	11.3	14.8	15
13-07-86	11.9	11.5	14.4	14.9
14-07-86	12.5	12.3	14.7	15.2
15-07-86	14.1	16.3	17.7	17.7
16-07-86	17	18.3	19.8	20.3
17-07-86	18	21.6	22	22
18-07-86	14.8	15.2	18.1	18.8

Table III.22. (Continued).

Date	temperature - daily average [°C]			
	Čechtice	Ondřejov	Brandýs nad Labem	Tuhaň
19-07-86	10.7	10.9	13.7	13.9
20-07-86	11.9	12.8	15.2	15
21-07-86	14	15.7	17.9	17.7
22-07-86	16.2	18.5	20	19.7
23-07-86	19.8	19.5	20.6	23.8
24-07-86	11.4	10.9	13.9	14.9
25-07-86	13.8	13.6	16.4	16.9
26-07-86	15.9	14.8	16.7	17.8
27-07-86	16.4	17.8	19.9	20.3
28-07-86	17.2	19.8	20.4	21.4
29-07-86	21.3	22.2	23	23.1
30-07-86	18.3	19	21.5	21.4
31-07-86	21.5	21	22.4	21.4

Table III.23. Meteorological stations in gathering regions of three chosen dairies.

DAIRY	PRAHA - TROJA	PRAHA - KYJE	BENEŠOV
Meteorological station	Praha – Klementinum Praha - Ruzyně Praha - Karlov Tuhaň	Praha – Kbely Praha - Uhříněves Ondřejov Brandýs nad Labem	Čechtice

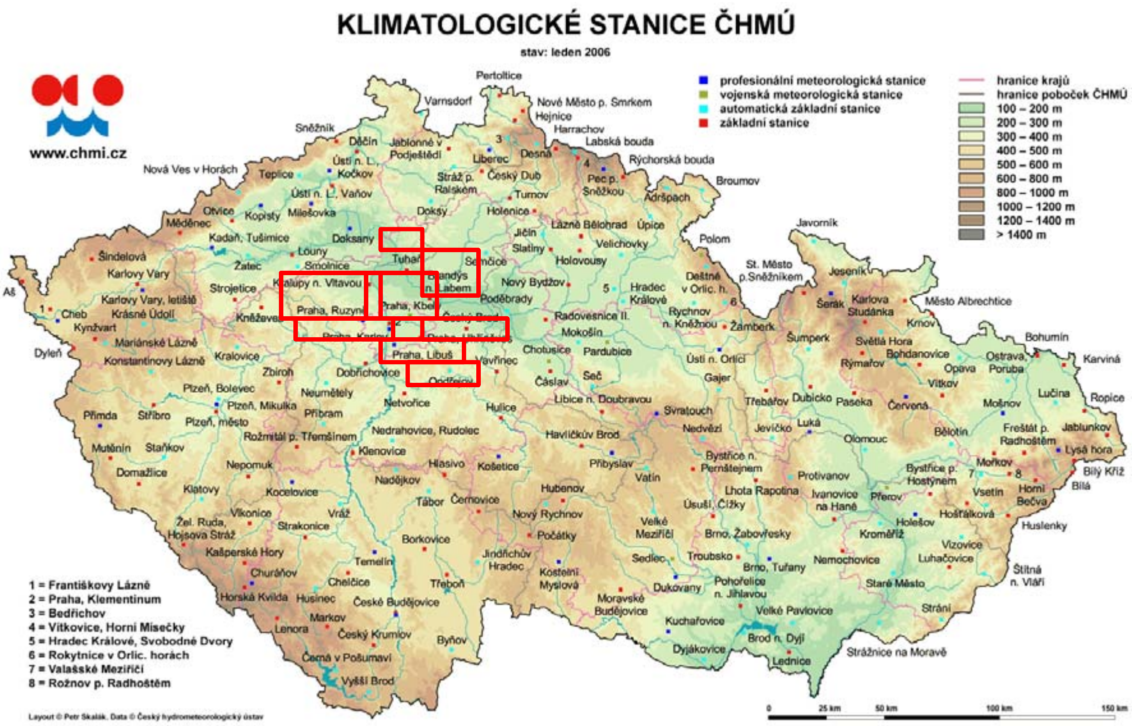


Fig. III.14. Location of meteorological stations in the Czech Republic working in year 2006.

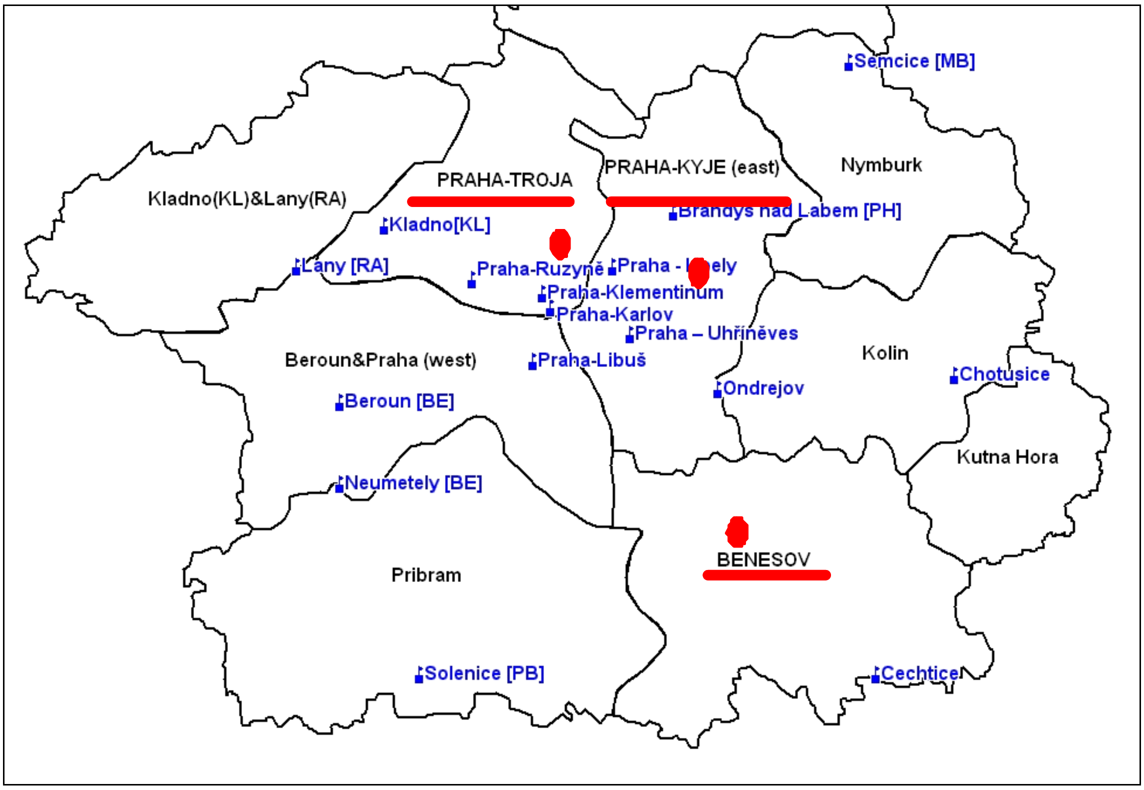


Fig. III.15. Meteorological stations located in gathering regions of the three chosen dairies.

Table III.24. Wind speed and directions in the Praha–ruzyně during the period 29 April – 11 May 1986.

Date	7 a.m.		2 p.m.		9 p.m.	
	Wind direction [°]	Wind speed [m.s^{-1}]	Wind direction [°]	Wind speed [m.s^{-1}]	Wind direction [°]	Wind speed [m.s^{-1}]
29-04-86	340	4	30	6	350	4
30-04-86	330	7	310	8	350	8
01-05-86	360	6	60	5	90	2
02-05-86	80	2	90	6	120	5
03-05-86	90	3	100	5	130	5
04-05-86	90	2	130	8	130	4
05-05-86	100	5	130	6	130	5
06-05-86	100	3	130	9	140	6
07-05-86	120	3	210	6	70	2
08-05-86	280	6	300	8	230	5
09-05-86	250	6	290	8	90	2
10-05-86	230	4	240	5	230	7
11-05-86	210	2	240	9	330	9

Table III.25. Wind speed and directions in Praha–Libuš during the period 1 January – 31 July 1986.

Date	Wind direction [in tenth of grades]				Wind speed [m.s^{-1}]		
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
01-01-86	7	0	0	1	3	0	0
02-01-86	16	16	18	2	1	3	2
03-01-86	20	18	0	2	4	2	0
04-01-86	16	27	20	3.7	3	4	4
05-01-86	20	16	0	3	5	4	0
06-01-86	20	18	18	3.3	4	3	3
07-01-86	0	0	0	0	0	0	0
08-01-86	0	0	0	0	0	0	0
09-01-86	36	36	0	1.3	3	1	0
10-01-86	0	22	0	1	0	3	0
11-01-86	22	22	20	2.7	4	2	2
12-01-86	20	25	25	5.3	5	5	6
13-01-86	22	22	22	4.7	8	5	1
14-01-86	22	27	25	4	1	3	8
15-01-86	20	25	29	9.7	10	12	7
16-01-86	27	20	34	2.7	2	2	4
17-01-86	20	34	31	4	3	8	1
18-01-86	20	18	25	7.3	3	7	12
19-01-86	25	22	20	5.3	2	7	7
20-01-86	27	27	22	8.3	12	10	3
21-01-86	18	22	25	4.3	5	6	2
22-01-86	18	20	18	3.7	4	3	4
23-01-86	18	20	20	9.3	10	8	10
24-01-86	0	27	0	1.3	0	4	0
25-01-86	22	29	27	2.7	3	3	2
26-01-86	27	29	27	3	3	4	2
27-01-86	25	25	22	4.7	3	5	6
28-01-86	18	20	16	1.7	1	2	2
29-01-86	9	13	14	4	2	6	4
30-01-86	15	11	9	7.7	7	9	7
31-01-86	9	9	9	7.7	7	8	8
01-02-86	11	9	9	9.3	12	9	7
02-02-86	7	7	4	4.3	2	3	8
03-02-86	7	7	7	8	8	9	7
04-02-86	7	9	7	6.3	8	7	4
05-02-86	4	9	7	5	5	6	4
06-02-86	0	0	0	0	0	0	0
07-02-86	36	36	36	4.7	7	2	5
08-02-86	22	36	0	2.3	4	3	0
09-02-86	0	34	34	3	0	7	2
10-02-86	22	25	36	3.3	3	5	2
11-02-86	0	36	36	2.7	0	6	2
12-02-86	0	0	34	1	0	0	3
13-02-86	0	7	0	0.7	0	2	0
14-02-86	7	7	4	5	4	7	4
15-02-86	36	9	9	4	3	5	4
16-02-86	7	7	4	6	7	7	4
17-02-86	7	7	0	1.7	2	3	0
18-02-86	36	36	0	1.7	2	3	0
19-02-86	7	0	29	2	3	0	3
20-02-86	29	22	25	3.3	4	4	2
21-02-86	0	0	11	0.7	0	0	2
22-02-86	0	18	0	0.7	0	2	0
23-02-86	36	36	31	2.7	1	5	2
24-02-86	0	0	0	0	0	0	0

Table III.25. (Continued).

Date	Wind direction [in tenth of grades]				Wind speed [$m.s^{-1}$]		
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
25-02-86	0	4	4	1.3	0	1	3
26-02-86	0	9	7	1.7	0	3	2
27-02-86	27	0	11	1.3	1	0	3
28-02-86	36	7	7	3.3	2	5	3
01-03-86	4	13	11	4.7	5	6	3
02-03-86	7	7	7	5	4	6	5
03-03-86	0	9	0	0.7	0	2	0
04-03-86	22	25	18	6	4	6	8
05-03-86	18	25	18	6	4	10	4
06-03-86	0	16	20	3.7	0	7	4
07-03-86	18	29	0	1.3	3	1	0
08-03-86	36	4	7	4	2	4	6
09-03-86	7	20	0	1.7	3	2	0
10-03-86	0	0	0	0	0	0	0
11-03-86	0	0	20	1	0	0	3
12-03-86	7	9	9	3	3	4	2
13-03-86	7	9	11	2.7	3	3	2
14-03-86	7	7	0	1.7	2	3	0
15-03-86	0	11	13	2.7	0	2	6
16-03-86	11	11	13	8	6	10	8
17-03-86	7	9	0	3.7	5	6	0
18-03-86	0	9	16	2.3	0	3	4
19-03-86	7	13	9	4.7	3	8	3
20-03-86	0	22	0	1.3	0	4	0
21-03-86	16	0	22	2	4	0	2
22-03-86	0	20	20	2.7	0	5	3
23-03-86	18	18	25	7.7	6	11	6
24-03-86	20	18	20	6.3	4	8	7
25-03-86	22	25	20	6.3	6	7	6
26-03-86	20	25	18	5	3	9	3
27-03-86	18	22	18	5	2	9	4
28-03-86	20	25	27	6	3	9	6
29-03-86	20	20	18	4.3	3	8	2
30-03-86	19	22	16	7	6	10	5
31-03-86	18	22	20	8	10	11	3
01-04-86	22	25	18	7	6	11	4
02-04-86	22	20	7	3	3	4	2
03-04-86	0	0	31	2	0	0	6
04-04-86	29	36	0	1.7	3	2	0
05-04-86	22	27	29	3.3	3	2	5
06-04-86	0	36	7	2.3	0	2	5
07-04-86	7	34	0	2.3	5	2	0
08-04-86	0	0	36	1	0	0	3
09-04-86	0	18	11	4	0	8	4
10-04-86	36	34	34	8	6	10	8
11-04-86	34	34	36	5.3	6	6	4
12-04-86	36	36	36	4.3	3	6	4
13-04-86	25	29	0	1.3	2	2	0
14-04-86	20	20	16	2.7	2	4	2
15-04-86	18	16	13	5	5	5	5
16-04-86	11	7	18	1.7	2	2	1
17-04-86	0	16	9	1.7	0	3	2
18-04-86	0	7	22	1.7	0	2	3
19-04-86	25	34	34	5.7	4	7	6
20-04-86	25	27	18	3.7	4	4	3
21-04-86	22	25	16	5	6	5	4

Table III.25. (Continued).

Date	Wind direction [in tenth of grades]				Wind speed [$m.s^{-1}$]		
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
22-04-86	0	4	36	3	0	3	6
23-04-86	0	0	7	1	0	0	3
24-04-86	0	0	16	1.3	0	0	4
25-04-86	31	34	36	2	2	2	2
26-04-86	36	0	0	1	3	0	0
27-04-86	25	34	36	2.3	3	2	2
28-04-86	34	36	36	2.7	2	3	3
29-04-86	0	2	36	2.3	0	3	4
30-04-86	0	34	34	5	0	8	7
01-05-86	36	0	9	2.7	3	0	5
02-05-86	0	7	7	3	0	4	5
03-05-86	0	11	13	2	0	2	4
04-05-86	7	13	11	4.3	3	6	4
05-05-86	11	16	9	5	3	8	4
06-05-86	4	11	11	5.7	2	9	6
07-05-86	18	20	7	3.7	3	5	3
08-05-86	22	24	18	2.7	4	2	2
09-05-86	22	31	0	2	3	3	0
10-05-86	22	25	22	2.3	2	3	2
11-05-86	20	20	34	5.7	3	8	6
12-05-86	0	27	13	1.7	0	1	4
13-05-86	0	18	0	2.7	0	8	0
14-05-86	20	25	0	2	1	5	0
15-05-86	0	18	18	3	0	5	4
16-05-86	4	9	9	2.7	2	3	3
17-05-86	0	9	13	1.7	0	3	2
18-05-86	24	25	0	1	1	2	0
19-05-86	0	34	0	0.7	0	2	0
20-05-86	7	7	13	4	3	5	4
21-05-86	0	0	13	1	0	0	3
22-05-86	22	25	0	2.3	5	2	0
23-05-86	0	16	0	2	0	6	0
24-05-86	22	25	27	5.3	4	9	3
25-05-86	20	25	20	1.7	1	2	2
26-05-86	0	16	18	3.3	0	5	5
27-05-86	18	18	27	3	3	3	3
28-05-86	22	34	34	3.7	2	7	2
29-05-86	0	4	31	1.7	0	3	2
30-05-86	36	34	34	4	5	4	3
31-05-86	34	31	0	2.3	3	4	0
01-06-86	25	0	22	1.7	3	0	2
02-06-86	0	0	0	0	0	0	0
03-06-86	20	22	18	2.3	2	3	2
04-06-86	20	20	0	3.3	4	6	0
05-06-86	27	34	20	3.7	2	6	3
06-06-86	22	20	18	8	9	10	5
07-06-86	18	20	25	8	6	8	10
08-06-86	22	25	0	5	6	9	0
09-06-86	0	36	9	1.3	0	2	2
10-06-86	0	7	9	4	0	9	3
11-06-86	0	4	34	4.7	0	5	9
12-06-86	34	34	34	6.3	7	6	6
13-06-86	34	34	31	3.3	4	3	3
14-06-86	36	9	7	6.7	4	9	7
15-06-86	4	4	7	4.7	3	5	6
16-06-86	7	11	7	4.7	3	8	3

Table III.25. (Continued).

Date	Wind direction [in tenth of grades]				Wind speed [$m.s^{-1}$]		
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
17-06-86	7	16	0	1.7	2	3	0
18-06-86	22	25	0	1.7	2	3	0
19-06-86	34	0	11	1.3	2	0	2
20-06-86	4	36	7	2.3	2	2	3
21-06-86	0	34	34	4	0	8	4
22-06-86	34	34	0	2.7	3	5	0
23-06-86	22	13	9	3.3	3	3	4
24-06-86	0	25	25	3.3	0	7	3
25-06-86	31	34	4	2.7	3	4	1
26-06-86	25	34	0	3.7	3	8	0
27-06-86	27	34	34	3.7	2	6	3
28-06-86	25	31	34	4.7	3	7	4
29-06-86	31	36	2	6.7	6	12	2
30-06-86	31	36	0	2.3	4	3	0
01-07-86	25	36	0	2.3	2	5	0
02-07-86	31	4	7	2.7	2	5	1
03-07-86	0	17	11	3	0	7	2
04-07-86	22	25	34	2.7	4	1	3
05-07-86	22	20	20	3.3	2	5	3
06-07-86	25	27	20	5.7	4	7	6
07-07-86	23	29	20	4.7	2	10	2
08-07-86	25	34	25	3.3	3	5	2
09-07-86	22	20	22	2.7	3	2	3
10-07-86	22	20	22	4.3	5	4	4
11-07-86	22	27	0	2.7	3	5	0
12-07-86	25	31	34	3	4	3	2
13-07-86	22	31	0	2.7	3	5	0
14-07-86	25	31	34	3.3	3	5	2
15-07-86	0	34	0	1	0	3	0
16-07-86	0	16	0	1.3	0	4	0
17-07-86	0	7	0	0.7	0	2	0
18-07-86	34	36	34	5	7	5	3
19-07-86	36	36	24	5	8	4	3
20-07-86	0	7	0	0.7	0	2	0
21-07-86	25	0	13	1.3	2	0	2
22-07-86	0	31	0	1	0	3	0
23-07-86	18	16	18	7	5	8	8
24-07-86	22	25	20	5.3	6	8	2
25-07-86	22	22	9	4.3	4	7	2
26-07-86	22	27	9	4	3	7	2
27-07-86	0	36	4	2	0	4	2
28-07-86	0	0	11	0.7	0	0	2
29-07-86	18	16	18	4.7	3	6	5
30-07-86	0	9	7	1.7	0	3	2
31-07-86	0	11	0	1	0	3	0

Table III.26. Wind speed and directions in Brandýs Nad Labem during the period 1 January – 31 July 1986.

Date	Wind direction [in tenth of grades]			Wind speed [m.s^{-1}]			
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
01-01-86	0	9	11	1.7	0	3	2
02-01-86	13	9	11	2	2	2	2
03-01-86	16	18	13	1.7	2	1	2
04-01-86	16	31	25	2.3	2	1	4
05-01-86	0	20	13	1.7	0	2	3
06-01-86	13	13	16	2	2	2	2
07-01-86	13	27	0	1	2	1	0
08-01-86	29	29	0	0.7	1	1	0
09-01-86	29	34	34	1.3	1	2	1
10-01-86	0	13	13	1.3	0	1	3
11-01-86	13	9	9	1.7	2	2	1
12-01-86	27	25	29	4.3	5	3	5
13-01-86	27	22	29	6	7	6	5
14-01-86	25	27	27	6.3	9	4	6
15-01-86	25	27	29	7	8	9	4
16-01-86	27	22	34	1.3	1	1	2
17-01-86	27	34	36	4.3	6	5	2
18-01-86	18	18	29	5	1	6	8
19-01-86	27	18	25	6	4	6	8
20-01-86	29	31	25	9	12	12	3
21-01-86	20	25	20	3.3	3	4	3
22-01-86	18	20	18	5.7	5	7	5
23-01-86	20	20	18	7.3	9	8	5
24-01-86	29	29	27	4	5	4	3
25-01-86	27	29	29	4.3	3	6	4
26-01-86	29	29	27	2.3	2	4	1
27-01-86	25	27	25	4.7	3	6	5
28-01-86	13	13	13	1	1	1	1
29-01-86	11	13	11	7	5	9	7
30-01-86	11	11	13	10.7	9	11	12
31-01-86	11	9	13	7.3	8	4	10
01-02-86	13	13	11	7.7	9	8	6
02-02-86	11	9	11	5.3	5	6	5
03-02-86	7	11	13	7.3	6	7	9
04-02-86	7	13	13	5	8	5	2
05-02-86	13	13	9	3.3	2	6	2
06-02-86	0	27	0	0.3	0	1	0
07-02-86	4	34	0	1	1	2	0
08-02-86	18	36	0	1	1	2	0
09-02-86	0	36	27	2	0	5	1
10-02-86	0	22	0	0.3	0	1	0
11-02-86	0	36	0	0.7	0	2	0
12-02-86	0	0	27	0.7	0	0	2
13-02-86	27	0	4	0.7	1	0	1
14-02-86	0	13	13	2	0	2	4
15-02-86	7	9	13	5.7	4	7	6
16-02-86	13	7	9	1.7	2	2	1
17-02-86	11	13	7	1.7	1	3	1
18-02-86	0	2	0	0.7	0	2	0
19-02-86	9	9	27	2	2	2	2
20-02-86	27	29	0	1.3	1	3	0
21-02-86	0	36	0	0.3	0	1	0
22-02-86	0	18	0	0.7	0	2	0
23-02-86	9	36	0	1.7	1	4	0
24-02-86	0	34	0	1	0	3	0

Table III.26. (Continued).

Date	Wind direction [in tenth of grades]				Wind speed [$m.s^{-1}$]		
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
25-02-86	0	16	0	0.7	0	2	0
26-02-86	0	25	0	0.7	0	2	0
27-02-86	0	13	0	1	0	3	0
28-02-86	0	13	0	1.3	0	4	0
01-03-86	13	13	11	5	1	8	6
02-03-86	11	9	7	1.3	1	2	1
03-03-86	0	13	13	1	0	2	1
04-03-86	0	27	25	1.3	0	1	3
05-03-86	25	29	0	1.7	4	1	0
06-03-86	9	9	9	2	2	3	1
07-03-86	9	0	29	1	2	0	1
08-03-86	31	9	9	2.3	1	2	4
09-03-86	0	11	0	0.7	0	2	0
10-03-86	31	20	0	0.7	1	1	0
11-03-86	0	9	0	0.3	0	1	0
12-03-86	13	13	13	3	2	4	3
13-03-86	13	11	13	2	2	2	2
14-03-86	13	13	0	0.7	1	1	0
15-03-86	36	13	13	1.7	1	2	2
16-03-86	9	16	13	5	4	6	5
17-03-86	11	13	11	3	3	5	1
18-03-86	0	13	13	1.3	0	2	2
19-03-86	13	13	13	3.7	3	6	2
20-03-86	0	13	0	0.7	0	2	0
21-03-86	0	13	29	1.7	0	4	1
22-03-86	31	29	25	1.7	2	1	2
23-03-86	18	21	27	4.7	3	5	6
24-03-86	22	13	13	4.7	3	6	5
25-03-86	25	25	25	6.7	8	9	3
26-03-86	22	25	25	4	5	6	1
27-03-86	20	22	22	5	3	8	4
28-03-86	22	27	29	5.3	2	8	6
29-03-86	25	20	22	3.3	5	4	1
30-03-86	31	29	18	4	3	7	2
31-03-86	18	22	22	5	1	10	4
01-04-86	29	27	27	5	4	8	3
02-04-86	0	18	18	1	0	1	2
03-04-86	9	18	34	1.7	1	2	2
04-04-86	29	36	36	1.7	2	2	1
05-04-86	0	31	31	1	0	2	1
06-04-86	0	9	11	1.7	0	1	4
07-04-86	0	36	0	0.3	0	1	0
08-04-86	0	25	36	0.7	0	1	1
09-04-86	0	13	16	4	0	4	8
10-04-86	0	34	36	4.7	0	6	8
11-04-86	34	31	36	3.3	4	4	2
12-04-86	36	36	0	1	2	1	0
13-04-86	0	31	0	1	0	3	0
14-04-86	0	31	18	1	0	1	2
15-04-86	13	9	11	2.7	2	3	3
16-04-86	11	9	4	3	2	3	4
17-04-86	20	36	9	1.7	2	2	1
18-04-86	27	11	29	2	1	2	3
19-04-86	31	34	27	5.3	4	7	5
20-04-86	25	29	29	3.7	3	6	2
21-04-86	27	27	13	3.7	3	5	3

Table III.26. (Continued).

Date	Wind direction [in tenth of grades]				Wind speed [m.s^{-1}]		
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
22-04-86	11	11	34	2.7	3	3	2
23-04-86	0	29	36	1	0	2	1
24-04-86	0	13	11	0.7	0	1	1
25-04-86	29	25	0	0.7	1	1	0
26-04-86	0	11	25	1	0	1	2
27-04-86	27	36	0	1	1	2	0
28-04-86	36	9	4	1	1	1	1
29-04-86	34	4	2	2.3	1	3	3
30-04-86	31	4	36	4	2	3	7
01-05-86	36	9	0	1.7	3	2	0
02-05-86	11	7	9	1.7	2	2	1
03-05-86	13	16	0	2.7	3	5	0
04-05-86	9	13	11	3.7	2	7	2
05-05-86	9	11	13	3.7	3	6	2
06-05-86	7	13	9	3.7	2	7	2
07-05-86	13	4	0	1.3	3	1	0
08-05-86	29	29	0	1	1	2	0
09-05-86	20	2	0	0.7	1	1	0
10-05-86	7	31	25	2	2	2	2
11-05-86	20	22	31	2.3	1	3	3
12-05-86	0	27	0	0.7	0	2	0
13-05-86	9	16	0	1	1	2	0
14-05-86	0	9	0	0.3	0	1	0
15-05-86	9	13	31	2.3	2	4	1
16-05-86	29	9	0	1.7	2	3	0
17-05-86	7	16	0	1	1	2	0
18-05-86	13	13	0	1.3	2	2	0
19-05-86	29	36	0	1	1	2	0
20-05-86	9	9	13	2.7	2	5	1
21-05-86	9	9	9	1.3	1	2	1
22-05-86	27	31	0	1.7	3	2	0
23-05-86	0	11	0	1	0	3	0
24-05-86	9	25	31	3.3	1	6	3
25-05-86	29	2	0	0.7	1	1	0
26-05-86	11	13	11	2.3	3	2	2
27-05-86	16	13	27	2.7	2	2	4
28-05-86	27	34	36	1.3	1	2	1
29-05-86	0	7	2	0.7	0	1	1
30-05-86	4	29	34	1.3	1	2	1
31-05-86	31	34	36	2.3	3	3	1
01-06-86	0	29	0	0.3	0	1	0
02-06-86	29	29	0	1	1	2	0
03-06-86	25	34	18	2.3	2	2	3
04-06-86	20	20	27	2	2	3	1
05-06-86	31	34	29	2.3	2	3	2
06-06-86	27	27	25	3.7	3	5	3
07-06-86	20	25	27	7.7	6	9	8
08-06-86	27	29	27	5	6	8	1
09-06-86	0	20	0	0.7	0	2	0
10-06-86	0	9	0	1	0	3	0
11-06-86	11	13	29	2.7	1	1	6
12-06-86	34	36	36	4	2	6	4
13-06-86	31	36	31	2.7	2	3	3
14-06-86	34	4	9	1.7	1	3	1
15-06-86	36	7	9	1.7	1	3	1
16-06-86	13	7	11	3.7	2	6	3

Table III.26. (Continued).

Date	Wind direction [in tenth of grades]			Wind speed [m.s^{-1}]			
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
17-06-86	7	7	0	2.3	1	6	0
18-06-86	34	36	0	1	1	2	0
19-06-86	34	36	2	1.3	1	2	1
20-06-86	9	9	0	0.7	1	1	0
21-06-86	31	31	31	2.3	1	4	2
22-06-86	34	36	4	1	1	1	1
23-06-86	0	4	0	1	0	3	0
24-06-86	9	25	31	1.3	2	1	1
25-06-86	34	36	25	2	1	3	2
26-06-86	29	34	29	3.3	2	6	2
27-06-86	34	34	25	2	2	3	1
28-06-86	22	31	25	2.7	2	5	1
29-06-86	29	36	34	3.7	2	7	2
30-06-86	34	4	0	1	1	2	0
01-07-86	0	31	36	1	0	2	1
02-07-86	31	36	0	1	1	2	0
03-07-86	0	7	9	1	0	2	1
04-07-86	9	18	22	1.3	1	1	2
05-07-86	25	22	0	0.7	1	1	0
06-07-86	34	29	25	2.3	1	4	2
07-07-86	0	31	29	2	0	5	1
08-07-86	22	31	25	1.7	1	3	1
09-07-86	25	25	29	2.7	2	4	2
10-07-86	22	27	25	3.7	2	6	3
11-07-86	34	31	25	2.3	1	4	2
12-07-86	9	29	0	2.3	2	5	0
13-07-86	34	31	0	2.3	1	6	0
14-07-86	36	29	36	2.7	2	5	1
15-07-86	25	36	0	1.3	1	3	0
16-07-86	0	7	0	0.3	0	1	0
17-07-86	4	13	0	1	1	2	0
18-07-86	31	4	36	2.7	2	5	1
19-07-86	31	34	0	2	4	2	0
20-07-86	0	13	0	1	0	3	0
21-07-86	4	2	18	1	1	1	1
22-07-86	9	22	20	2	1	3	2
23-07-86	11	18	9	3.7	1	4	6
24-07-86	27	25	27	4.3	1	6	6
25-07-86	25	31	29	3	3	5	1
26-07-86	22	31	22	2.3	4	2	1
27-07-86	29	9	0	1	1	2	0
28-07-86	9	9	9	1.3	1	2	1
29-07-86	9	18	13	1.7	1	3	1
30-07-86	0	4	9	0.7	0	1	1
31-07-86	9	18	13	1.3	1	1	2

Table III.27. Wind speed and directions in Čechtice during the period 1 January – 31 July 1986.

Date	Wind direction [in tenth of grades]				Wind speed [$m.s^{-1}$]		
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
01-01-86	0	0	0	0	0	0	0
02-01-86	13	18	18	2.7	2	2	4
03-01-86	22	22	22	4	4	4	4
04-01-86	13	31	27	2.3	1	2	4
05-01-86	0	13	22	2	0	4	2
06-01-86	18	13	0	2	4	2	0
07-01-86	22	0	0	0.3	1	0	0
08-01-86	31	0	0	0.3	1	0	0
09-01-86	0	36	0	0.3	0	1	0
10-01-86	0	0	0	0	0	0	0
11-01-86	27	22	22	5	7	4	4
12-01-86	18	27	22	3.3	4	2	4
13-01-86	27	22	22	5	7	4	4
14-01-86	27	27	22	5	7	4	4
15-01-86	22	27	31	7.7	7	9	7
16-01-86	31	22	21	4	4	1	7
17-01-86	27	31	27	6.7	4	9	7
18-01-86	0	18	27	5.3	0	4	12
19-01-86	27	27	22	5	4	7	4
20-01-86	27	31	27	9.3	12	9	7
21-01-86	18	0	0	0.7	2	0	0
22-01-86	18	18	18	5	7	7	1
23-01-86	18	18	18	4.3	2	4	7
24-01-86	27	31	27	6	7	7	4
25-01-86	27	31	31	5	4	4	7
26-01-86	27	31	27	5.3	6	6	4
27-01-86	27	27	0	2	2	4	0
28-01-86	22	18	18	2.3	2	1	4
29-01-86	18	13	13	9.3	7	9	12
30-01-86	13	13	13	13	15	12	12
31-01-86	13	13	13	11	12	9	12
01-02-86	13	13	13	10	9	12	9
02-02-86	13	13	9	5.7	9	4	4
03-02-86	13	13	13	8.3	7	9	9
04-02-86	13	9	13	6	7	7	4
05-02-86	13	13	13	4.3	2	7	4
06-02-86	13	0	0	0.7	2	0	0
07-02-86	4	4	4	3.3	4	4	2
08-02-86	0	22	31	1.3	0	2	2
09-02-86	31	31	31	3.3	2	4	4
10-02-86	0	31	0	1.3	0	4	0
11-02-86	31	4	0	1.3	2	2	0
12-02-86	31	36	36	4	2	4	6
13-02-86	0	0	0	0	0	0	0
14-02-86	13	13	13	5	4	4	7
15-02-86	13	13	13	6	7	4	7
16-02-86	13	0	0	1.3	4	0	0
17-02-86	4	4	4	2	2	2	2
18-02-86	0	4	0	0.7	0	2	0
19-02-86	0	0	0	0	0	0	0
20-02-86	31	31	31	3.3	4	4	2
21-02-86	0	0	0	0	0	0	0
22-02-86	0	0	0	0	0	0	0
23-02-86	0	31	0	0.7	0	2	0
24-02-86	0	0	0	0	0	0	0

Table III.27. (Continued).

Date	Wind direction [in tenth of grades]				Wind speed [m.s^{-1}]		
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
25-02-86	0	4	0	0.7	0	2	0
26-02-86	0	9	0	0.7	0	2	0
27-02-86	0	0	18	0.3	0	0	1
28-02-86	0	13	0	0.7	0	2	0
01-03-86	13	13	13	7	7	7	7
02-03-86	13	4	0	2	4	2	0
03-03-86	0	0	0	0	0	0	0
04-03-86	22	27	22	1.7	1	2	2
05-03-86	18	27	0	1.7	4	1	0
06-03-86	13	13	13	3.3	4	4	2
07-03-86	0	18	0	0.3	0	1	0
08-03-86	0	4	0	0.3	0	1	0
09-03-86	0	4	0	0.3	0	1	0
10-03-86	0	0	0	0	0	0	0
11-03-86	0	13	18	2	0	4	2
12-03-86	0	13	13	0.7	0	1	1
13-03-86	13	13	13	5.7	7	9	1
14-03-86	0	9	0	0.7	0	2	0
15-03-86	0	9	13	1	0	2	1
16-03-86	13	13	13	8.3	4	12	9
17-03-86	13	13	0	2.7	4	4	0
18-03-86	0	13	18	1	0	2	1
19-03-86	13	13	0	1.7	1	4	0
20-03-86	0	0	18	0.7	0	0	2
21-03-86	18	18	0	3	7	2	0
22-03-86	31	0	0	1.3	4	0	0
23-03-86	18	18	27	5.7	6	7	4
24-03-86	22	18	18	5	2	9	4
25-03-86	22	27	22	3.3	4	2	4
26-03-86	22	18	18	2.3	2	4	1
27-03-86	18	22	22	4.3	2	7	4
28-03-86	0	13	31	1.7	0	4	1
29-03-86	22	18	18	1.3	1	1	2
30-03-86	22	27	18	3	4	4	1
31-03-86	18	22	22	5	9	4	2
01-04-86	22	22	22	5.7	9	4	4
02-04-86	27	27	0	1.3	2	2	0
03-04-86	0	31	0	0.7	0	2	0
04-04-86	27	0	0	0.3	1	0	0
05-04-86	0	0	0	0	0	0	0
06-04-86	0	4	0	0.3	0	1	0
07-04-86	0	18	18	4.3	0	9	4
08-04-86	18	18	0	2	4	2	0
09-04-86	18	18	13	6.7	1	12	7
10-04-86	0	27	31	2.7	0	1	7
11-04-86	31	31	0	2.7	4	4	0
12-04-86	0	0	0	0	0	0	0
13-04-86	0	0	0	0	0	0	0
14-04-86	36	36	22	2	2	2	2
15-04-86	13	13	13	5	4	7	4
16-04-86	18	13	18	3.3	2	4	4
17-04-86	0	0	0	0	0	0	0
18-04-86	0	31	27	1.3	0	2	2
19-04-86	27	27	0	1	2	1	0
20-04-86	27	27	22	2.3	4	2	1

Table III.27. (Continued).

Date	Wind direction [in tenth of grades]				Wind speed [m.s^{-1}]		
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
21-04-86	27	22	18	3.7	2	7	2
22-04-86	13	13	0	2	2	4	0
23-04-86	22	31	0	1	1	2	0
24-04-86	13	0	22	1	1	0	2
25-04-86	0	31	0	1.3	0	4	0
26-04-86	0	18	0	0.3	0	1	0
27-04-86	27	4	0	0.7	1	1	0
28-04-86	0	4	0	0.3	0	1	0
29-04-86	0	4	0	1.3	0	4	0
30-04-86	31	27	0	2	4	2	0
01-05-86	31	36	0	2	2	4	0
02-05-86	13	9	18	2	1	4	1
03-05-86	18	18	13	2	1	4	1
04-05-86	18	18	18	3	4	4	1
05-05-86	13	13	18	4.3	7	4	2
06-05-86	18	13	13	5	4	7	4
07-05-86	13	22	18	4	7	4	1
08-05-86	0	31	31	0.7	0	1	1
09-05-86	0	0	0	0	0	0	0
10-05-86	0	27	0	0.7	0	2	0
11-05-86	22	22	0	3	2	7	0
12-05-86	0	0	0	0	0	0	0
13-05-86	0	22	18	1	0	2	1
14-05-86	0	0	0	0	0	0	0
15-05-86	0	13	27	2.7	0	4	4
16-05-86	0	0	0	0	0	0	0
17-05-86	18	0	0	0.3	1	0	0
18-05-86	0	27	0	1.3	0	4	0
19-05-86	31	0	0	0.3	1	0	0
20-05-86	0	4	0	0.7	0	2	0
21-05-86	18	13	0	0.7	1	1	0
22-05-86	31	27	0	1	1	2	0
23-05-86	13	13	0	1.7	1	4	0
24-05-86	0	27	31	2	0	4	2
25-05-86	31	0	0	0.3	1	0	0
26-05-86	13	13	18	2.3	2	4	1
27-05-86	0	18	18	2	0	2	4
28-05-86	0	0	0	0	0	0	0
29-05-86	0	31	31	1	0	1	2
30-05-86	31	31	31	2	4	1	1
31-05-86	31	0	0	0.3	1	0	0
01-06-86	31	36	27	1.7	2	2	1
02-06-86	0	0	0	0	0	0	0
03-06-86	0	0	0	0	0	0	0
04-06-86	18	22	0	1.3	2	2	0
05-06-86	31	0	0	0.3	1	0	0
06-06-86	22	22	22	2.7	4	2	2
07-06-86	22	22	22	5	7	7	1
08-06-86	27	31	0	1.7	4	1	0
09-06-86	0	4	0	0.3	0	1	0
10-06-86	9	9	0	1.7	1	4	0
11-06-86	0	31	31	1.7	0	1	4
12-06-86	31	31	31	4	4	4	4
13-06-86	31	31	31	3	4	4	1
14-06-86	36	4	0	2.7	4	4	0

Table III.27. (Continued).

Date	Wind direction [in tenth of grades]				Wind speed [m.s^{-1}]		
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
15-06-86	0	4	0	0.7	0	2	0
16-06-86	18	13	0	1.7	1	4	0
17-06-86	0	13	18	0.7	0	1	1
18-06-86	0	0	0	0	0	0	0
19-06-86	0	36	0	1.3	0	4	0
20-06-86	0	13	0	0.7	0	2	0
21-06-86	0	31	31	1	0	2	1
22-06-86	0	31	0	1.3	0	4	0
23-06-86	31	9	0	1.7	1	4	0
24-06-86	18	31	0	0.7	1	1	0
25-06-86	31	27	0	1	1	2	0
26-06-86	31	31	31	2	1	4	1
27-06-86	31	36	0	2.7	4	4	0
28-06-86	31	31	31	2	1	4	1
29-06-86	31	31	31	2.3	2	4	1
30-06-86	0	36	0	1.3	0	4	0
01-07-86	0	31	0	0.7	0	2	0
02-07-86	31	0	0	0.3	1	0	0
03-07-86	0	22	0	1.3	0	4	0
04-07-86	0	0	27	0.3	0	0	1
05-07-86	0	0	22	0.7	0	0	2
06-07-86	18	31	27	2.3	4	1	2
07-07-86	22	27	27	3.3	4	4	2
08-07-86	31	31	27	2	1	4	1
09-07-86	27	27	27	1.3	1	2	1
10-07-86	0	22	22	2	0	2	4
11-07-86	0	31	27	2.7	0	4	4
12-07-86	31	36	0	2	4	2	0
13-07-86	0	31	31	1	0	2	1
14-07-86	31	27	0	2.7	4	4	0
15-07-86	0	36	0	0.3	0	1	0
16-07-86	0	22	0	0.7	0	2	0
17-07-86	0	0	0	0	0	0	0
18-07-86	0	31	31	0.7	0	1	1
19-07-86	0	36	0	0.7	0	2	0
20-07-86	0	4	0	0.3	0	1	0
21-07-86	0	0	0	0	0	0	0
22-07-86	0	0	0	0	0	0	0
23-07-86	13	13	18	2.3	1	4	2
24-07-86	31	27	0	1	1	2	0
25-07-86	27	27	0	1.7	1	4	0
26-07-86	27	27	36	3.3	4	2	4
27-07-86	0	31	0	0.3	0	1	0
28-07-86	0	0	0	0	0	0	0
29-07-86	0	0	18	0.7	0	0	2
30-07-86	31	0	0	0.3	1	0	0
31-07-86	0	0	0	0	0	0	0

Table III.28. Wind speed and directions in Tuhaň during the period 1 January – 31 July 1986.

Date	Wind direction [in tenth of grades]				Wind speed [m.s^{-1}]		
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
01-01-86	9	11	9	2	1	1	4
02-01-86	13	9	13	4	4	4	4
03-01-86	11	9	9	1.3	2	1	1
04-01-86	9	27	22	2.3	2	4	1
05-01-86	22	18	11	1.7	2	1	2
06-01-86	9	9	13	4	6	2	4
07-01-86	9	31	0	0.7	1	1	0
08-01-86	0	31	9	0.7	0	1	1
09-01-86	31	36	0	0.7	1	1	0
10-01-86	9	9	13	1	1	1	1
11-01-86	9	4	9	1	1	1	1
12-01-86	18	27	22	1.3	1	1	2
13-01-86	27	25	25	6.7	9	7	4
14-01-86	25	22	31	4	9	2	1
15-01-86	31	27	31	4.3	7	4	2
16-01-86	27	9	31	1.3	1	1	2
17-01-86	25	34	31	4	4	7	1
18-01-86	11	18	27	3.7	1	1	9
19-01-86	27	25	22	2.3	1	2	4
20-01-86	27	27	27	11.7	16	12	7
21-01-86	18	25	18	2.3	1	4	2
22-01-86	22	27	22	3.3	2	7	1
23-01-86	18	18	18	3.3	4	4	2
24-01-86	25	31	27	1.7	2	2	1
25-01-86	27	27	31	4	1	7	4
26-01-86	27	27	27	2.3	1	2	4
27-01-86	27	27	22	2.3	4	2	1
28-01-86	11	13	13	2.3	1	2	4
29-01-86	9	13	9	8.3	7	9	9
30-01-86	13	11	13	11	12	12	9
31-01-86	11	9	9	12	12	12	12
01-02-86	11	9	13	7	7	7	7
02-02-86	9	11	9	8.3	7	9	9
03-02-86	11	9	9	12	12	12	12
04-02-86	9	9	9	9	9	9	9
05-02-86	9	11	11	6.7	4	9	7
06-02-86	9	31	31	1.3	2	1	1
07-02-86	34	36	36	1.3	2	1	1
08-02-86	25	36	36	1	1	1	1
09-02-86	31	36	31	1	1	1	1
10-02-86	27	0	36	1	2	0	1
11-02-86	0	0	0	0	0	0	0
12-02-86	0	31	22	0.7	0	1	1
13-02-86	31	31	31	1	1	1	1
14-02-86	0	11	11	4.7	0	7	7
15-02-86	9	9	11	9	9	9	9
16-02-86	9	11	9	4	7	4	1
17-02-86	11	4	9	1.3	1	2	1
18-02-86	34	2	0	0.7	1	1	0
19-02-86	9	9	31	2.3	2	4	1
20-02-86	31	27	0	1.3	2	2	0
21-02-86	9	34	0	0.7	1	1	0
22-02-86	2	13	9	1.3	1	2	1
23-02-86	31	0	0	0.3	1	0	0
24-02-86	0	31	13	1	0	2	1
25-02-86	31	0	9	1	1	0	2

Table III.28. (Continued).

Date	Wind direction [in tenth of grades]				Wind speed [$m.s^{-1}$]		
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
26-02-86	31	22	9	1.3	1	2	1
27-02-86	0	0	22	0.3	0	0	1
28-02-86	0	11	2	1	0	2	1
01-03-86	9	11	11	7.3	4	9	9
02-03-86	7	9	4	2	4	1	1
03-03-86	9	0	9	0.7	1	0	1
04-03-86	0	25	18	1	0	2	1
05-03-86	22	22	0	0.7	1	1	0
06-03-86	9	9	9	2.7	4	2	2
07-03-86	11	31	0	0.7	1	1	0
08-03-86	0	4	11	1.7	0	4	1
09-03-86	0	13	0	0.3	0	1	0
10-03-86	29	11	0	1	1	2	0
11-03-86	4	22	11	1.3	1	1	2
12-03-86	9	9	9	4.3	4	7	2
13-03-86	9	11	13	4	4	4	4
14-03-86	11	11	4	2	1	4	1
15-03-86	27	13	9	1.7	1	2	2
16-03-86	11	11	16	6.7	4	7	9
17-03-86	11	11	11	4	4	4	4
18-03-86	0	9	9	1.7	0	4	1
19-03-86	11	13	11	3.3	2	7	1
20-03-86	0	27	9	1	0	2	1
21-03-86	9	13	27	4	4	7	1
22-03-86	31	22	25	1.3	1	2	1
23-03-86	18	18	27	3.3	4	4	2
24-03-86	9	11	13	3	1	4	4
25-03-86	22	22	9	6	7	9	2
26-03-86	18	31	22	4	4	7	1
27-03-86	9	22	20	3	1	7	1
28-03-86	0	22	27	3.7	0	4	7
29-03-86	13	22	27	2.3	2	4	1
30-03-86	18	22	18	4.3	2	9	2
31-03-86	11	13	22	3.7	1	9	1
01-04-86	25	31	20	4	4	7	1
02-04-86	25	29	9	1.3	1	2	1
03-04-86	9	11	31	1	1	1	1
04-04-86	31	36	31	1.3	2	1	1
05-04-86	31	27	31	1.7	2	2	1
06-04-86	4	4	4	1	1	1	1
07-04-86	27	13	11	1.7	1	2	2
08-04-86	13	22	22	1	1	1	1
09-04-86	25	16	13	6.7	1	12	7
10-04-86	36	36	36	8.3	1	12	12
11-04-86	31	31	36	4.7	1	9	4
12-04-86	0	34	0	2.3	0	7	0
13-04-86	0	36	0	0.3	0	1	0
14-04-86	9	22	18	2	2	2	2
15-04-86	11	13	13	3.3	2	4	4
16-04-86	13	13	13	3.7	2	2	7
17-04-86	9	18	9	2	2	2	2
18-04-86	29	4	31	2	1	1	4
19-04-86	31	31	31	2	2	2	2
20-04-86	27	27	18	2.3	2	4	1
21-04-86	27	31	13	2.7	2	4	2

Table III.28. (Continued).

Date	Wind direction [in tenth of grades] 07:00	14:00	21:00	AVG	Wind speed [m.s^{-1}] 07:00	14:00	21:00
22-04-86	9	9	4	5	4	9	2
23-04-86	18	18	31	1.3	1	2	1
24-04-86	0	18	9	2.7	0	4	4
25-04-86	31	27	0	2	2	4	0
26-04-86	0	4	0	0.7	0	2	0
27-04-86	29	31	31	1.7	2	2	1
28-04-86	0	4	4	2	0	2	4
29-04-86	0	31	2	0.7	0	1	1
30-04-86	31	36	31	1.7	1	2	2
01-05-86	31	4	9	1	1	1	1
02-05-86	22	13	9	2.7	2	4	2
03-05-86	13	11	9	2	1	4	1
04-05-86	11	11	13	2.3	2	4	1
05-05-86	11	13	13	6.7	4	12	4
06-05-86	11	13	13	6	2	12	4
07-05-86	9	18	0	3.7	4	7	0
08-05-86	0	31	9	1	0	2	1
09-05-86	0	27	0	0.3	0	1	0
10-05-86	11	22	0	2	4	2	0
11-05-86	16	22	27	2.7	2	2	4
12-05-86	31	31	9	1	1	1	1
13-05-86	11	9	4	2	1	4	1
14-05-86	4	13	0	0.7	1	1	0
15-05-86	11	18	0	1.3	2	2	0
16-05-86	0	9	9	1	0	2	1
17-05-86	4	9	0	1	1	2	0
18-05-86	9	9	11	1	1	1	1
19-05-86	27	0	27	0.7	1	0	1
20-05-86	4	4	13	2	1	1	4
21-05-86	13	9	9	3.7	2	7	2
22-05-86	31	31	0	3.7	4	7	0
23-05-86	9	9	9	3.3	2	7	1
24-05-86	27	27	27	6.3	1	9	9
25-05-86	27	18	0	0.7	1	1	0
26-05-86	9	13	11	2.3	2	4	1
27-05-86	9	13	9	1.7	2	2	1
28-05-86	31	31	27	1.3	1	1	2
29-05-86	9	36	36	1	1	1	1
30-05-86	27	31	31	1.3	1	2	1
31-05-86	31	31	31	1.7	2	2	1
01-06-86	0	20	0	0.3	0	1	0
02-06-86	31	27	0	1.7	1	4	0
03-06-86	22	31	13	1.3	1	2	1
04-06-86	11	13	0	2	2	4	0
05-06-86	31	27	27	1	1	1	1
06-06-86	27	27	31	5.3	7	7	2
07-06-86	22	22	22	6.7	4	9	7
08-06-86	22	27	27	5	7	7	1
09-06-86	0	13	9	1	0	2	1
10-06-86	11	13	9	1.3	1	1	2
11-06-86	34	22	34	2	1	1	4
12-06-86	4	31	31	4.3	2	9	2
13-06-86	31	31	27	1.7	2	2	1
14-06-86	4	2	9	1	1	1	1
15-06-86	31	9	0	1	1	2	0

Table III.28. (Continued).

Date	Wind direction [in tenth of grades]				Wind speed [m.s^{-1}]		
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
16-06-86	9	9	9	5	1	7	7
17-06-86	13	9	0	2	2	4	0
18-06-86	31	31	0	1	1	2	0
19-06-86	31	27	27	3.3	1	7	2
20-06-86	13	9	9	4	1	7	4
21-06-86	27	31	31	1.3	1	2	1
22-06-86	25	27	27	1.3	1	2	1
23-06-86	31	31	9	1.3	1	2	1
24-06-86	13	22	27	1	1	1	1
25-06-86	31	4	0	1	1	2	0
26-06-86	31	31	0	0.7	1	1	0
27-06-86	31	31	0	1	2	1	0
28-06-86	31	31	27	1	1	1	1
29-06-86	27	27	31	2.3	2	4	1
30-06-86	31	4	0	1.7	1	4	0
01-07-86	22	31	31	2.3	2	4	1
02-07-86	0	9	0	0.3	0	1	0
03-07-86	16	13	0	1	1	2	0
04-07-86	9	18	0	0.7	1	1	0
05-07-86	0	22	0	2.3	0	7	0
06-07-86	27	27	27	4.3	2	7	4
07-07-86	31	31	27	1.3	1	2	1
08-07-86	31	31	31	1.3	1	2	1
09-07-86	22	27	28	1.3	1	2	1
10-07-86	27	25	27	1	1	1	1
11-07-86	27	31	31	1.7	2	2	1
12-07-86	31	31	0	1.7	1	4	0
13-07-86	0	31	31	1	0	2	1
14-07-86	31	27	0	1.7	1	4	0
15-07-86	9	31	0	1.7	1	4	0
16-07-86	0	31	0	1.3	0	4	0
17-07-86	9	31	0	1.7	1	4	0
18-07-86	0	31	31	3.7	0	9	2
19-07-86	36	27	26	1.3	2	1	1
20-07-86	31	13	31	1.3	1	2	1
21-07-86	0	18	0	0.3	0	1	0
22-07-86	9	22	0	1	1	2	0
23-07-86	9	9	9	2.3	2	4	1
24-07-86	22	27	22	2.3	1	2	4
25-07-86	22	31	27	5	4	7	4
26-07-86	25	31	4	2.7	4	2	2
27-07-86	0	22	4	1	0	2	1
28-07-86	13	36	0	0.7	1	1	0
29-07-86	13	13	13	1.3	1	2	1
30-07-86	31	13	4	1.3	1	2	1
31-07-86	13	13	13	4	1	7	4

Table III.29. Wind speed and directions in Ondřejov during the period 1 January – 31 July 1986.

Date	wind direction [in tenth of grades]				Wind speed [m.s^{-1}]		
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
01-01-86	2	3	0	0.7	1	1	0
02-01-86	12	18	16	2.7	3	2	3
03-01-86	18	19	16	1.3	2	1	1
04-01-86	16	26	20	3.3	3	4	3
05-01-86	19	16	12	2	4	1	1
06-01-86	16	0	20	1.3	3	0	1
07-01-86	21	0	0	1	3	0	0
08-01-86	27	26	0	0.7	1	1	0
09-01-86	0	34	0	0.3	0	1	0
10-01-86	0	18	17	0.7	0	1	1
11-01-86	23	22	25	3	3	4	2
12-01-86	16	23	26	4	3	3	6
13-01-86	20	18	20	4	7	3	2
14-01-86	22	26	24	6.3	11	3	5
15-01-86	20	26	27	6	7	5	6
16-01-86	25	24	23	4.7	6	5	3
17-01-86	19	20	0	2	3	3	0
18-01-86	0	25	25	3.7	0	4	7
19-01-86	25	20	19	5.3	4	5	7
20-01-86	25	27	25	7.7	11	6	6
21-01-86	19	21	18	2	1	4	1
22-01-86	19	26	20	3.7	3	4	4
23-01-86	20	20	26	5.7	7	3	7
24-01-86	27	26	20	3.3	3	3	4
25-01-86	25	27	25	3.7	3	5	3
26-01-86	26	28	26	3	3	3	3
27-01-86	25	27	20	2.7	3	3	2
28-01-86	17	16	0	1.3	1	3	0
29-01-86	9	20	16	5	3	4	8
30-01-86	10	9	10	7.3	3	11	8
31-01-86	9	9	8	9.3	6	12	10
01-02-86	9	9	9	6.7	7	9	4
02-02-86	9	9	4	5.3	6	3	7
03-02-86	9	7	9	6.3	7	5	7
04-02-86	4	8	11	3.7	5	3	3
05-02-86	3	8	6	3	3	3	3
06-02-86	0	2	0	0.3	0	1	0
07-02-86	2	2	34	3	4	3	2
08-02-86	20	0	2	1	2	0	1
09-02-86	34	33	27	2	1	4	1
10-02-86	27	29	2	2	1	2	3
11-02-86	36	36	35	4.7	3	5	6
12-02-86	34	36	35	3	1	3	5
13-02-86	0	0	36	0.7	0	0	2
14-02-86	7	6	9	3.7	4	3	4
15-02-86	9	9	9	6.3	6	7	6
16-02-86	7	5	2	4.3	4	5	4
17-02-86	3	4	2	3.3	4	2	4
18-02-86	2	3	3	2	3	2	1
19-02-86	3	3	2	2.3	3	1	3
20-02-86	27	27	27	3.7	3	5	3
21-02-86	26	4	3	1.3	1	2	1
22-02-86	0	0	0	0	0	0	0
23-02-86	0	29	0	0.7	0	2	0
24-02-86	0	0	0	0	0	0	0

Table III.29. (Continued).

Date	wind direction [in tenth of grades]				Wind speed [m.s^{-1}]		
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
25-02-86	0	0	2	0.3	0	0	1
26-02-86	3	0	2	1	1	0	2
27-02-86	0	2	7	1.7	0	2	3
28-02-86	3	4	9	3.7	4	3	4
01-03-86	9	9	36	5.3	6	7	3
02-03-86	8	4	2	3.7	3	4	4
03-03-86	0	0	0	0	0	0	0
04-03-86	0	21	23	3	0	4	5
05-03-86	22	22	0	3	3	6	0
06-03-86	17	0	0	1	3	0	0
07-03-86	18	20	30	3.7	6	2	3
08-03-86	3	2	4	3.3	3	4	3
09-03-86	2	0	0	1	3	0	0
10-03-86	30	0	9	1	2	0	1
11-03-86	0	0	9	0.3	0	0	1
12-03-86	3	3	0	1.3	2	2	0
13-03-86	11	10	0	2.7	3	5	0
14-03-86	9	8	0	1	1	2	0
15-03-86	0	9	0	1.7	0	5	0
16-03-86	10	11	10	5.7	7	7	3
17-03-86	8	10	0	2.7	3	5	0
18-03-86	8	10	10	1.3	1	2	1
19-03-86	9	10	10	1.3	1	2	1
20-03-86	3	6	0	1	1	2	0
21-03-86	10	0	20	1.7	3	0	2
22-03-86	27	0	0	0.3	1	0	0
23-03-86	17	18	20	3	3	5	1
24-03-86	19	18	20	5	2	6	7
25-03-86	25	18	20	5.3	7	6	3
26-03-86	20	20	18	2.7	1	4	3
27-03-86	20	22	0	2.3	1	6	0
28-03-86	0	22	23	3	0	4	5
29-03-86	20	18	0	2	2	4	0
30-03-86	19	21	20	3	1	6	2
31-03-86	20	21	20	4.3	6	4	3
01-04-86	19	25	0	4	7	5	0
02-04-86	25	20	4	2.3	3	2	2
03-04-86	7	8	0	1	2	1	0
04-04-86	25	31	0	2	4	2	0
05-04-86	0	0	31	0.7	0	0	2
06-04-86	0	3	2	3	0	3	6
07-04-86	3	13	2	4.7	4	8	2
08-04-86	0	13	4	2.3	0	5	2
09-04-86	3	10	8	5	6	6	3
10-04-86	10	30	30	6	4	7	7
11-04-86	30	0	25	2	4	0	2
12-04-86	0	30	0	0.7	0	2	0
13-04-86	0	0	0	0	0	0	0
14-04-86	20	30	0	1.3	1	3	0
15-04-86	0	12	9	1.7	0	4	1
16-04-86	11	11	13	4	3	5	4
17-04-86	0	0	36	1.3	0	0	4
18-04-86	20	0	36	1	2	0	1
19-04-86	27	26	0	3	4	5	0
20-04-86	27	26	0	2	4	2	0
21-04-86	22	0	16	3	4	0	5

Table III.29. (Continued).

Date	wind direction [in tenth of grades]				Wind speed [m.s^{-1}]		
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
22-04-86	9	8	4	3.7	3	5	3
23-04-86	12	27	4	2.7	2	2	4
24-04-86	10	0	0	0.3	1	0	0
25-04-86	26	36	36	3.3	2	4	4
26-04-86	4	8	36	3.7	4	3	4
27-04-86	26	3	34	3.3	3	3	4
28-04-86	0	3	2	3	0	3	6
29-04-86	5	3	2	4.3	4	6	3
30-04-86	33	36	33	5	5	4	6
01-05-86	33	33	0	3	3	6	0
02-05-86	0	2	34	1.3	0	1	3
03-05-86	3	0	2	2	2	0	4
04-05-86	4	8	2	3.7	3	4	4
05-05-86	10	10	2	4.3	4	6	3
06-05-86	10	10	2	4	3	5	4
07-05-86	9	3	2	4.3	4	5	4
08-05-86	25	26	0	1.7	2	3	0
09-05-86	20	27	0	1	1	2	0
10-05-86	25	25	0	1.3	2	2	0
11-05-86	22	29	30	2.7	3	2	3
12-05-86	0	25	0	0.3	0	1	0
13-05-86	0	25	0	0.3	0	1	0
14-05-86	26	27	0	1	2	1	0
15-05-86	9	12	0	1	1	2	0
16-05-86	0	0	9	0.3	0	0	1
17-05-86	12	12	0	0.7	1	1	0
18-05-86	12	21	0	1.3	2	2	0
19-05-86	0	30	29	1	0	1	2
20-05-86	0	3	20	1	0	2	1
21-05-86	0	9	0	0.3	0	1	0
22-05-86	35	21	0	2	2	4	0
23-05-86	10	20	0	1.7	1	4	0
24-05-86	25	26	25	4	1	6	5
25-05-86	28	0	0	0.7	2	0	0
26-05-86	0	12	0	0.7	0	2	0
27-05-86	0	18	25	2.3	0	4	3
28-05-86	0	0	35	1	0	0	3
29-05-86	36	9	0	1.3	1	3	0
30-05-86	36	0	36	0.7	1	0	1
31-05-86	33	27	0	1.3	2	2	0
01-06-86	27	2	0	1.3	2	2	0
02-06-86	2	34	36	1.3	1	2	1
03-06-86	26	0	0	0.3	1	0	0
04-06-86	16	0	0	0.7	2	0	0
05-06-86	0	30	24	1	0	1	2
06-06-86	19	20	18	2.7	2	3	3
07-06-86	19	20	20	5.3	6	4	6
08-06-86	27	26	0	2	2	4	0
09-06-86	19	20	36	1.3	1	2	1
10-06-86	0	9	0	1	0	3	0
11-06-86	0	30	32	2.3	0	2	5
12-06-86	30	30	30	4	3	4	5
13-06-86	30	28	30	3.3	6	1	3
14-06-86	2	4	5	3.3	5	3	2
15-06-86	3	4	4	3.7	2	4	5
16-06-86	3	8	7	3.3	3	4	3

Table III.29. (Continued).

Date	wind direction [in tenth of grades]				Wind speed [$m.s^{-1}$]		
	07:00	14:00	21:00	AVG	07:00	14:00	21:00
17-06-86	0	12	10	2	0	3	3
18-06-86	26	25	0	1.3	1	3	0
19-06-86	29	2	2	2.7	1	3	4
20-06-86	7	0	2	1.7	1	0	4
21-06-86	30	30	30	3	1	5	3
22-06-86	0	0	0	0	0	0	0
23-06-86	32	5	9	2.7	2	4	2
24-06-86	10	9	27	1	1	1	1
25-06-86	33	0	0	0.3	1	0	0
26-06-86	29	36	31	2.3	1	2	4
27-06-86	30	29	28	1.7	3	1	1
28-06-86	0	27	28	1.7	0	3	2
29-06-86	27	35	30	4	4	6	2
30-06-86	30	2	0	2	3	3	0
01-07-86	27	7	36	1.7	1	1	3
02-07-86	25	35	0	0.7	1	1	0
03-07-86	0	0	0	0	0	0	0
04-07-86	25	18	29	2.7	1	3	4
05-07-86	20	0	0	0.3	1	0	0
06-07-86	27	25	27	3	5	2	2
07-07-86	0	27	0	0.3	0	1	0
08-07-86	27	29	28	1.7	2	1	2
09-07-86	25	27	0	2	1	5	0
10-07-86	20	18	23	1.7	1	3	1
11-07-86	26	28	0	2.3	2	5	0
12-07-86	25	25	0	1.7	3	2	0
13-07-86	0	28	0	1.7	0	5	0
14-07-86	26	27	0	1	1	2	0
15-07-86	25	27	0	1.7	1	4	0
16-07-86	0	4	0	0.7	0	2	0
17-07-86	0	16	0	0.7	0	2	0
18-07-86	29	29	29	4.3	5	5	3
19-07-86	33	35	0	4	5	7	0
20-07-86	29	35	0	1	1	2	0
21-07-86	28	35	0	0.7	1	1	0
22-07-86	0	0	0	0	0	0	0
23-07-86	0	18	28	1.7	0	1	4
24-07-86	20	20	30	3.7	3	5	3
25-07-86	20	4	27	3	4	2	3
26-07-86	20	25	0	2	1	5	0
27-07-86	29	0	0	0.7	2	0	0
28-07-86	0	29	0	1	0	3	0
29-07-86	0	0	18	0.7	0	0	2
30-07-86	0	9	2	1.7	0	2	3
31-07-86	10	18	0	1	1	2	0

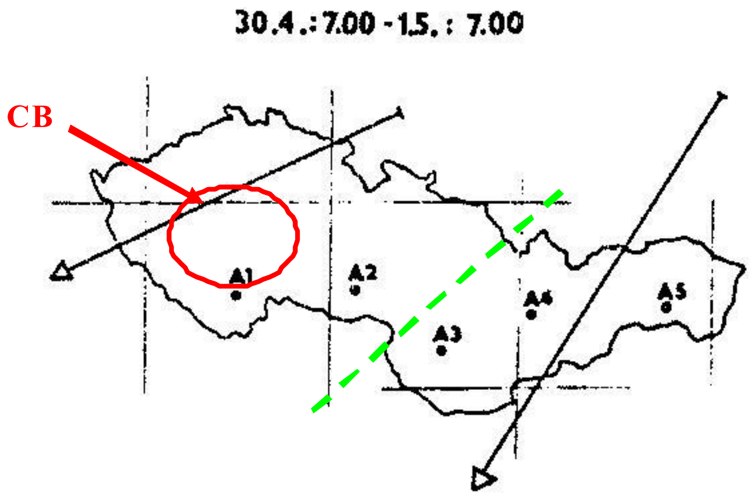


Fig. III.16. Passage trajectories of the first plume through the former ČSSR area.

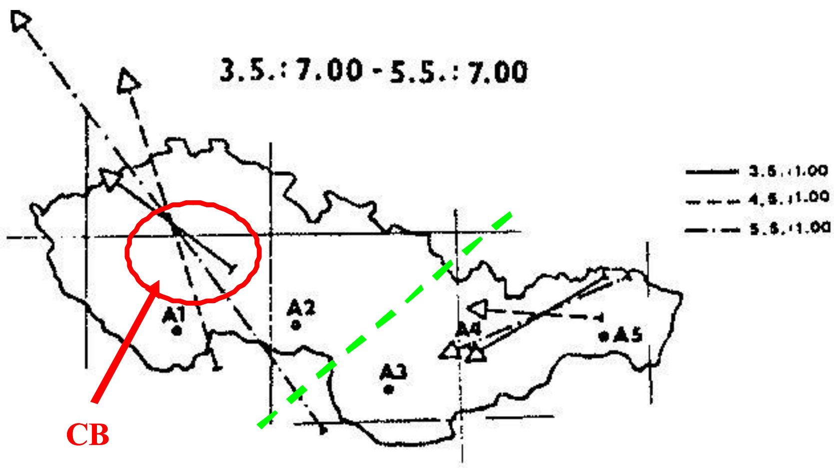


Fig. III.17. Passage trajectories of the second plume through the former ČSSR area.

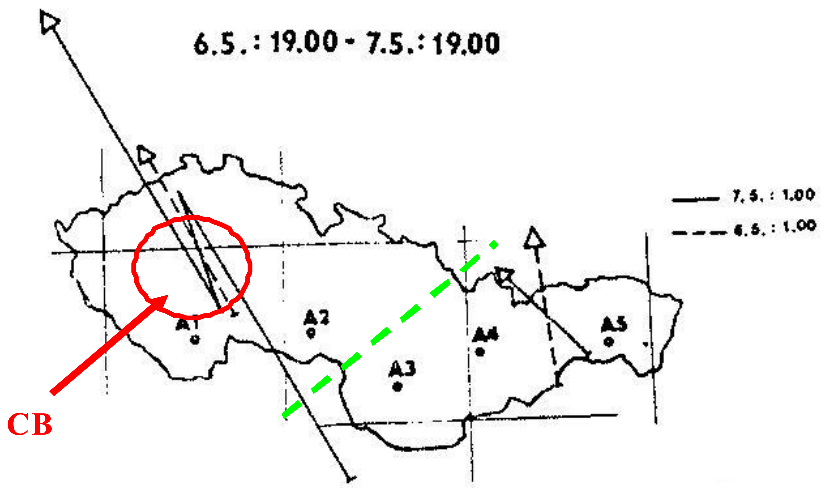


Fig. III.18. Passage trajectories of the third plume through the former ČSSR area.

III.4.2.1. Rainfall data for the first days after the accident

The meteorological data for weather conditions from 26 April – 31 May 1986 were obtained from 10 meteorological stations in Central Bohemia and 6 meteorological station in Prague: PRAHA – KARLOV, PRAHA – KBELY, PRAHA – KLEMENTINUM, PRAHA – LIBUŠ, PRAHA – RUZYNĚ and PRAHA - UHŘÍNĚVES. Code, geographical coordinates and sea level meteorological stations in Central Bohemia and in Prague can be seen above in Table III.20. The locations of the meteorological stations in Prague are given in Figure III.19. Precipitations data for Prague - city for the period 1 January – 31 May 1986 are given in Table III.30. Daily precipitation records from meteorological stations outside of Prague, namely ČECHTICE, ONDŘEJOV, BRANDÝS NAD LABEM and TUHAŇ during the period 1 January – 30 July 1986 are given in Table III.31. The location of all meteorological stations in Central Bohemia, outside of Prague, are given in Figures III.20 and III.21, with chosen stations given in blue. Graphically, the precipitations in area of the former ČSSR during the period 30 April – 1 May 1986, 4–5 May 1986, 7–8 May 1986 and 8–9 May 1986 are given in Figures III.22, III.23, III.24 and III.25, respectively.

Table III.30. Total daily precipitation measured by meteorological stations in Prague-City during the period 1 January –31 May 1986.

Date	Daily precipitation [mm] Praha - Karlov	Praha - Kbely	Praha - Klementinum	Praha - Libuš	Praha - Ruzyně	Praha - Uhříněves
01-01-86	0.0	0.0	0.0	0.0	0.0	0.0
02-01-86	0.0	0.2	0.0	0.0	0.1	0.0
03-01-86	0.0	0.0	0.0	0.0	0.0	0.0
04-01-86	1.0	0.7	0.8	1.2	1.6	1.5
05-01-86	0.0	0.0	0.0	0.0	0.0	0.0
06-01-86	0.0	0.0	0.0	0.0	0.0	0.0
07-01-86	0.1	0.7	0.1	0.0	0.7	0.7
08-01-86	0.0	0.0	0.0	0.0	0.1	0.0
09-01-86	0.0	0.0	0.0	0.0	0.0	0.0
10-01-86	0.9	0.6	1.2	1.1	0.8	0.9
11-01-86	1.0	1.0	1.3	0.0	1.8	0.5
12-01-86	0.4	0.3	0.6	0.9	0.3	0.6
13-01-86	1.2	2.5	1.4	1.3	1.7	1.9
14-01-86	2.9	3.6	4.0	5.8	6.0	3.9
15-01-86	2.8	4.1	3.9	2.2	3.6	4.2
16-01-86	0.1	1.6	0.2	0.4	0.0	2.0
17-01-86	1.3	2.6	0.8	1.5	1.6	2.5
18-01-86	2.9	2.4	3.4	4.6	3.1	2.4
19-01-86	1.4	2.4	0.8	2.1	1.2	2.6
20-01-86	0.0	3.4	0.0	0.1	0.4	0.0
21-01-86	0.0	0.0	0.0	0.0	0.0	0.0
22-01-86	0.0	0.0	0.0	0.0	0.0	0.0
23-01-86	1.3	1.2	1.3	2.7	0.6	3.4
24-01-86	5.4	1.7	5.5	5.4	5.3	7.2
25-01-86	1.0	1.7	2.0	0.8	2.1	1.9
26-01-86	0.0	0.0	0.1	0.0	0.1	0.8
27-01-86	0.0	0.1	0.0	0.0	0.0	0.0
28-01-86	0.0	0.0	0.0	0.0	0.0	0.0
29-01-86	0.0	0.0	0.0	0.0	0.0	0.0
30-01-86	0.0	0.0	0.0	0.0	0.0	0.0
31-01-86	0.0	0.0	0.0	0.0	0.0	0.0

Table III.30. (Conitnued).

Date	Daily precipitation [mm]					
	Praha - Karlov	**Praha - Kbely**	**Praha - Klementinum**	**Praha - Libuš**	**Praha - Ruzyně**	**Praha - Uhříněves**
01-02-86	3.0	3.0	2.5	1.6	3.6	1.5
02-02-86	0.2	0.4	0.1	0.1	0.4	0.3
03-02-86	0.0	0.0	0.0	0.0	0.0	0.0
04-02-86	0.0	0.0	0.0	0.0	0.2	0.0
05-02-86	0.0	0.0	0.0	0.0	0.1	0.0
06-02-86	0.1	0.0	0.1	0.1	0.3	0.3
07-02-86	0.1	0.1	0.1	0.0	0.0	0.0
08-02-86	0.2	0.1	0.2	0.2	0.2	1.0
09-02-86	4.8	13.0	4.3	2.5	3.8	7.6
10-02-86	0.1	0.4	0.1	0.0	0.2	0.0
11-02-86	0.0	0.0	0.0	0.0	0.1	0.0
12-02-86	0.0	0.0	0.0	0.0	0.0	0.0
13-02-86	0.0	0.0	0.0	0.0	0.0	0.0
14-02-86	0.0	0.0	0.0	0.0	0.0	0.0
15-02-86	0.0	0.0	0.0	0.0	0.0	0.0
16-02-86	0.0	0.0	0.0	0.0	0.0	0.0
17-02-86	0.0	0.0	0.0	0.0	0.0	0.0
18-02-86	2.1	1.0	0.8	1.0	0.9	0.3
19-02-86	7.6	4.0	4.9	6.1	4.2	6.7
20-02-86	0.0	0.0	0.0	0.0	0.0	0.0
21-02-86	0.0	0.4	0.0	0.4	0.2	0.0
22-02-86	0.5	0.5	0.2	0.5	0.4	0.1
23-02-86	0.2	0.4	0.2	0.3	0.2	0.2
24-02-86	0.0	0.0	0.0	0.0	0.0	0.0
25-02-86	0.0	0.0	0.0	0.0	0.1	0.0
26-02-86	0.0	0.0	0.0	0.0	0.1	0.0
27-02-86	0.0	0.0	0.0	0.0	0.0	0.0
28-02-86	0.0	0.0	0.0	0.0	0.0	0.0
01-03-86	0.0	0.0	0.0	0.0	0.0	0.0
02-03-86	2.3	2.2	1.2	2.3	1.6	3.0
03-03-86	0.0	0.2	0.1	0.0	0.2	0.0
04-03-86	2.2	0.6	2.6	0.1	2.0	2.5
05-03-86	0.4	0.2	0.4	2.6	1.1	0.6
06-03-86	2.4	1.2	1.2	1.0	0.5	0.8
07-03-86	1.2	2.2	1.1	1.5	0.7	1.6
08-03-86	0.1	0.0	0.0	0.0	0.2	0.0
09-03-86	0.0	0.0	0.0	0.0	0.0	0.0
10-03-86	0.0	0.0	0.0	0.0	0.0	0.0
11-03-86	0.0	0.0	0.0	0.0	0.0	0.0
12-03-86	0.0	0.0	0.0	0.0	0.0	0.0
13-03-86	0.0	0.0	0.0	0.0	0.0	0.0
14-03-86	0.3	0.3	0.0	0.3	0.3	0.4
15-03-86	0.1	0.2	0.4	0.3	0.5	0.0
16-03-86	0.0	0.0	0.0	0.0	0.0	0.0
17-03-86	0.0	0.0	0.0	0.0	0.0	0.0
18-03-86	0.0	0.0	0.0	0.0	0.0	0.0
19-03-86	0.0	0.0	0.0	0.0	0.0	0.0
20-03-86	0.0	0.0	0.0	0.0	0.0	0.0
21-03-86	2.4	2.2	2.2	2.4	2.3	3.2
22-03-86	0.0	0.0	0.0	0.0	0.0	0.0
23-03-86	4.4	5.1	3.8	5.5	5.3	5.0
24-03-86	3.2	4.2	5.1	8.6	5.5	4.2
25-03-86	0.0	0.0	0.0	0.0	0.1	0.0
26-03-86	0.0	0.0	0.0	0.0	0.0	0.0
27-03-86	0.0	0.0	0.0	0.0	0.0	0.0

Table III.30. (Conitnued).

Date	Daily precipitation [mm] Praha - Karlov	Praha - Kbely	Praha - Klementinum	Praha - Libuš	Praha - Ruzyně	Praha - Uhříněves
28-03-86	0.9	2.1	1.0	1.3	0.4	1.5
29-03-86	0.2	0.0	0.4	0.0	2.4	0.2
30-03-86	0.5	0.1	0.4	0.4	0.3	0.6
31-03-86	0.6	0.5	0.4	0.8	0.8	0.4
01-04-86	0.0	0.0	0.0	0.0	0.0	0.0
02-04-86	0.0	0.0	0.0	0.0	0.0	0.0
03-04-86	1.5	0.8	2.2	0.8	2.9	0.8
04-04-86	0.4	2.0	0.4	2.4	0.5	2.0
05-04-86	0.5	0.5	0.9	1.3	1.8	0.3
06-04-86	0.0	0.0	0.0	0.0	0.0	0.0
07-04-86	0.0	0.0	0.0	0.0	0.0	0.0
08-04-86	0.0	0.0	0.0	0.0	0.0	0.0
09-04-86	0.0	0.1	0.0	0.0	0.1	0.0
10-04-86	0.9	0.3	1.2	0.6	1.5	6.7
11-04-86	0.0	0.3	0.1	0.0	0.3	1.0
12-04-86	0.0	0.3	0.0	0.1	0.1	0.0
13-04-86	0.0	0.0	0.0	0.0	0.0	0.0
14-04-86	0.0	0.0	0.0	0.0	0.0	0.0
15-04-86	0.0	0.0	0.0	0.0	0.0	0.0
16-04-86	0.0	0.1	0.0	0.0	0.0	0.0
17-04-86	5.6	3.2	5.3	8.4	4.9	4.2
18-04-86	12.6	8.4	13.9	15.1	9.6	16.3
19-04-86	0.8	3.2	1.7	0.9	0.4	4.3
20-04-86	0.0	0.3	0.0	0.3	0.1	0.0
21-04-86	0.0	0.0	0.0	0.0	0.0	0.0
22-04-86	0.0	0.0	0.0	0.0	0.1	0.3
23-04-86	0.0	0.0	0.0	0.0	0.0	0.0
24-04-86	0.0	0.0	0.0	0.0	0.0	0.0
25-04-86	0.0	0.0	0.0	0.0	0.0	0.0
26-04-86	0.0	0.0	0.0	0.0	0.0	0.0
27-04-86	0.0	0.0	0.0	0.0	0.0	0.0
28-04-86	0.0	0.0	0.0	0.0	0.0	0.0
29-04-86	0.0	0.0	0.0	0.0	0.0	0.0
30-04-86	2.0	0.0	2.9	0.6	0.0	0.0

Table III.31. Total daily precipitation measured by meteorological stations outside of Prague: Čechtice, Ondřejov, Brandýs Nad Labem and Tuhaň during the period 1 January – 31 July 1986.

Date	daily precipitation [mm] Čechtice	Ondřejov	Brandýs nad Labem	Tuhaň
01-01-86	0	0	0	0
02-01-86	0	0	0	0.1
03-01-86	0	0	0	0
04-01-86	1.4	1.3	0.7	0.7
05-01-86	0	0	0	0
06-01-86	0	0	0	0.1
07-01-86	1.4	0	0	0
08-01-86	0.2	0	0	0
09-01-86	0	0	0	0
10-01-86	3.6	1.5	1.6	1
11-01-86	1.8	1.2	2.1	2
12-01-86	3.6	0.9	0.7	1.5

Table III.31. (Continued).

Date	daily precipitation [mm]			
	Čechtice	**Ondřejov**	**Brandýs nad Labem**	**Tuhaň**
13-01-86	8.9	4.9	2.9	2.6
14-01-86	6.4	9.9	1.6	4.1
15-01-86	7.9	7.8	2.7	3.5
16-01-86	4.6	4	0.9	1.5
17-01-86	6.6	4.1	6.1	2.5
18-01-86	9.8	9.3	6.9	7.1
19-01-86	4.7	3.5	3.2	2.1
20-01-86	0.4	0	0.2	0.2
21-01-86	0	0	0	0
22-01-86	0	0	0	0
23-01-86	5.7	5.3	0.3	1.8
24-01-86	1.6	6.1	2.6	1.3
25-01-86	3.3	4.6	0.6	0.4
26-01-86	0.7	1	0.8	0.7
27-01-86	0.3	0.1	0	0
28-01-86	0	0	0	0
29-01-86	0	0	0	0
30-01-86	0	0	0	0
31-01-86	0	0	0	0
01-02-86	0.9	2.4	2.7	2.6
02-02-86	0	1.5	0.4	0.1
03-02-86	0	0	0	0
04-02-86	0	0	0	0
05-02-86	0	0	0	0
06-02-86	0.3	0.1	0	0
07-02-86	0	0	0	0
08-02-86	0.2	1	0.5	0.6
09-02-86	11.4	7.9	10.6	8.7
10-02-86	0	0.1	0	0
11-02-86	0	0	0	0
12-02-86	0	0	0	0
13-02-86	0.3	0	0	0
14-02-86	0	0	0	0
15-02-86	0	0	0	0
16-02-86	0	0	0	0
17-02-86	0.3	0.1	0	0
18-02-86	0.2	0.2	0.7	0.5
19-02-86	0.2	4.9	6.7	6.6
20-02-86	0.3	0	0	0
21-02-86	0	0.1	0	0
22-02-86	0.1	0.1	0	0.1
23-02-86	2.3	0.1	0	0
24-02-86	0	0	0	0
25-02-86	0	0	0	0
26-02-86	0	0	0	0
27-02-86	0	0	0	0
28-02-86	0	0	0	0
01-03-86	0.1	0	0	0
02-03-86	4.8	3.8	2.9	2.3
03-03-86	0	0.2	0	0
04-03-86	0	0.4	0	1.7
05-03-86	1.4	1	2.5	0.8
06-03-86	3.6	0.6	0	0.3
07-03-86	6.9	3.8	1.4	1.2
08-03-86	0	0	0	0
09-03-86	0	0	0	0

Table III.31. (Continued).

Date	daily precipitation [mm]			
	Čechtice	Ondřejov	Brandýs nad Labem	Tuhaň
10-03-86	0	0	0	0
11-03-86	0	0	0	0
12-03-86	0	0	0	0
13-03-86	0	0.1	0	0
14-03-86	0	0.7	0.2	2.2
15-03-86	0.6	0.1	0.2	0.1
16-03-86	0	0	0	0
17-03-86	0	0	0	0
18-03-86	0	0	0	0
19-03-86	0	0	0	0
20-03-86	0	0	0	0
21-03-86	2.4	3.2	2.9	2.2
22-03-86	0.4	0.1	0	0
23-03-86	5.6	6	10.1	7
24-03-86	5.7	4.8	3.9	5.2
25-03-86	0	0	0	0
26-03-86	0	0	0	0
27-03-86	0	0	0	0
28-03-86	7.2	6.2	3.1	1.1
29-03-86	0	0	3.3	0.2
30-03-86	1.8	0.5	2.6	2.1
31-03-86	3.8	0.6	0	0
01-04-86	0	0	0	0
02-04-86	0	0	0	0
03-04-86	0.4	0.1	0	2.2
04-04-86	2.4	1.6	0.9	0.9
05-04-86	0.6	0.1	0.2	0.9
06-04-86	0	0	0	0
07-04-86	0	0	0	0
08-04-86	0	0	0	0
09-04-86	0.4	0	0	0
10-04-86	11.4	6.5	4.1	0.9
11-04-86	0	0	0	0.2
12-04-86	0	0	0	0
13-04-86	0	0	0	0
14-04-86	0	0	0	0
15-04-86	0	0	0	0
16-04-86	0	0	0	0
17-04-86	1.4	1.7	3.6	6.2
18-04-86	18.8	19.7	5.3	3.4
19-04-86	21.8	9.6	4.4	4.2
20-04-86	1.2	0.7	0.5	0.3
21-04-86	0	0	0	0
22-04-86	0	0.4	0.5	0
23-04-86	0	0	0	0
24-04-86	0	0	0	0
25-04-86	0	0	0	0
26-04-86	0	0	0	0
27-04-86	0	0.7	0	0
28-04-86	0	0	0	0
29-04-86	0	0	0	0
30-04-86	1.6	0	0.4	0
01-05-86	0	0	0	0
02-05-86	0	0	0	0
03-05-86	0	0	0	0
04-05-86	0	0	0	0

Table III.31. (Continued).

Date	daily precipitation [mm]			
	Čechtice	Ondřejov	Brandýs nad Labem	Tuhaň
05-05-86	0	0	0	0
06-05-86	0	0	0	0
07-05-86	0	4.2	1.1	8.4
08-05-86	3.8	4.6	2.1	1.8
09-05-86	0.9	6	14.6	9.8
10-05-86	1.3	0.2	0.1	0
11-05-86	0.2	0.2	5.7	1.5
12-05-86	0	0	0	0
13-05-86	4.2	4.4	4.7	0.8
14-05-86	5.2	1.1	0.4	0.5
15-05-86	0.4	0.1	1.5	6.6
16-05-86	10.9	4.3	1.8	1.9
17-05-86	0	0	0	0
18-05-86	0	0.7	1	0.3
19-05-86	17.9	12.5	4.2	4
20-05-86	2.9	4.6	0.1	0
21-05-86	4.9	3.3	6.5	8.6
22-05-86	0	0	0	0
23-05-86	0	0	0	0
24-05-86	6.1	17.1	1	0
25-05-86	0	0	0	0
26-05-86	0	0	0	0
27-05-86	0	15.5	11.2	15.3
28-05-86	6.9	10.8	11.4	7.6
29-05-86	22.8	16.4	19.1	22.2
30-05-86	10.1	16.4	11.7	11.1
31-05-86	3.4	1.2	4.6	2.7
01-06-86	0	0	0	0
02-06-86	0.6	0	0.9	0.1
03-06-86	4.2	6.6	0.1	1.9
04-06-86	3.4	5.2	4.8	4
05-06-86	2	0.8	0.2	0
06-06-86	0	0	0	0
07-06-86	0.5	0.1	0.3	0
08-06-86	0	0	0	0
09-06-86	0	0	0	0
10-06-86	0	0	0	0
11-06-86	0	0	0	0
12-06-86	13.9	5.3	10	4.6
13-06-86	1.3	0.6	0.2	2.5
14-06-86	0	0	0	0
15-06-86	0	0	0	0
16-06-86	0	0	0	0
17-06-86	0	0	0	0
18-06-86	19.7	1.8	0	0
19-06-86	1.3	0.1	68.6	18.4
20-06-86	0	0	0	0
21-06-86	0	0	0	0
22-06-86	0	0	0	0
23-06-86	0	0	0	0
24-06-86	0	0	0	0
25-06-86	0	0	0	0
26-06-86	0	0	0	0
27-06-86	0	0	0	0
28-06-86	0	0	0	0
29-06-86	0.8	0.6	0	0

Table III.31. (Continued).

Date	daily precipitation [mm]			
	Čechtice	**Ondřejov**	**Brandýs nad Labem**	**Tuhaň**
30-06-86	0	0	0	0
01-07-86	0	0	0	0
02-07-86	0	0	0	0
03-07-86	0	0	0	0
04-07-86	0	0	0	0.2
05-07-86	0	0	0.3	0.5
06-07-86	8.9	6.3	7.5	9.5
07-07-86	10.3	12.7	21.1	15.3
08-07-86	2.5	0.4	0.4	0.7
09-07-86	5.1	4.8	3.9	3.9
10-07-86	9.4	2.6	0.8	0.6
11-07-86	0	0.1	0	0
12-07-86	0	0	0	0
13-07-86	0	0	0	0
14-07-86	0	0	0	0
15-07-86	0	0	0	0
16-07-86	0	0	0	0
17-07-86	0	0	0	0
18-07-86	16.3	8.2	0	0
19-07-86	19.3	12.2	8.5	7.6
20-07-86	0.2	0	0	0
21-07-86	0	0	0	0
22-07-86	0	0	0	0
23-07-86	8.2	7.5	8.6	16.5
24-07-86	4.2	2.2	1.3	0.5
25-07-86	0.4	4.2	2.6	2.9
26-07-86	0.2	0.2	0	0.2
27-07-86	0	0	0	0
28-07-86	0	0	0	0
29-07-86	0	0	0	0
30-07-86	0	0	0	0
31-07-86	22	12.5	6.6	20.5

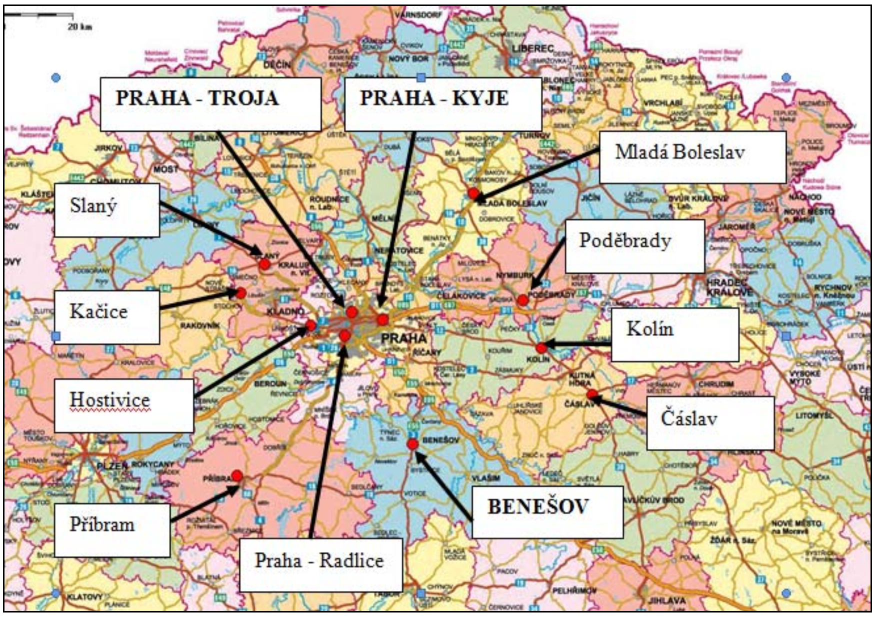


Fig. III.19. Location of meteorological stations in Prague.

Fig. III.20. Location of meteorological station in central bohemia without Prague.

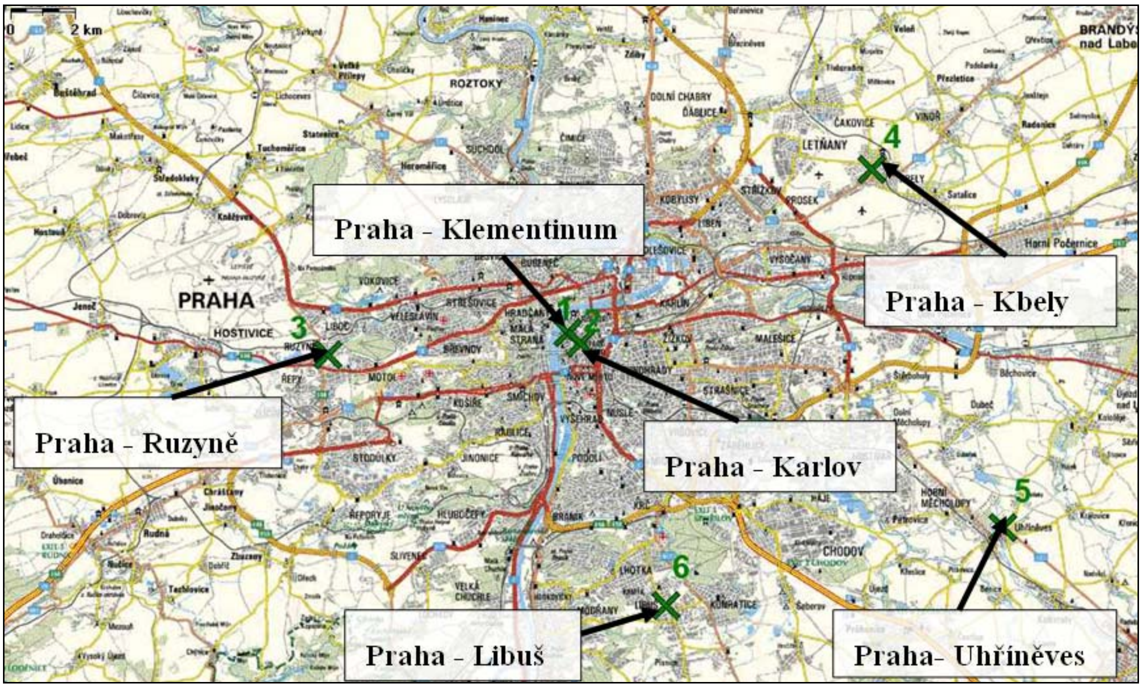


Fig. III.21. Location of meteorological stations in central Bohemia region, excluding Prague.

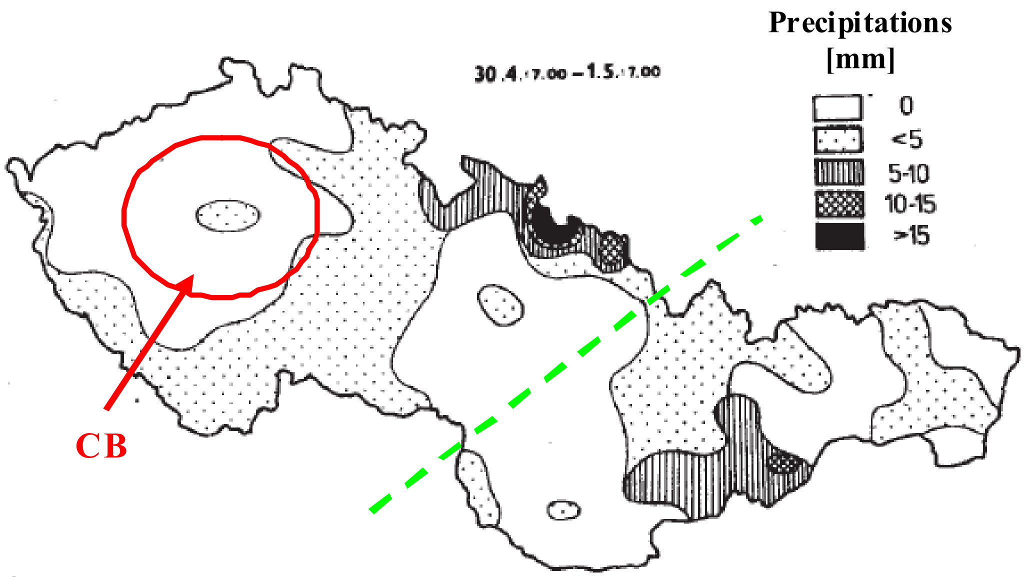


Fig. III.22. Precipitations in the former ČSSR area during the period 30.4. – 1.5.1986.

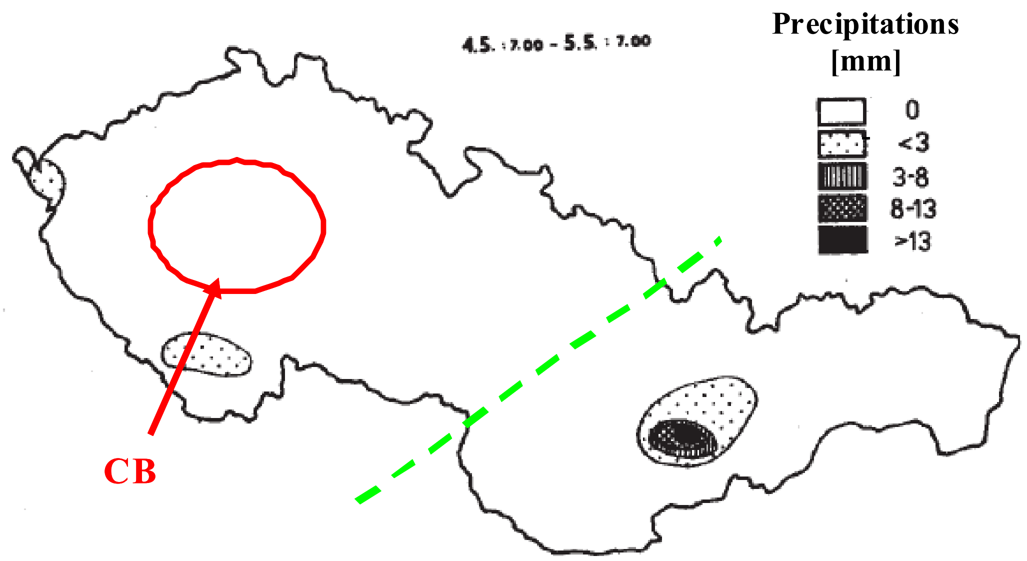


Fig. III.23. Precipitations in the area of the former ČSSR during the period 4.5. – 5.5.1986.

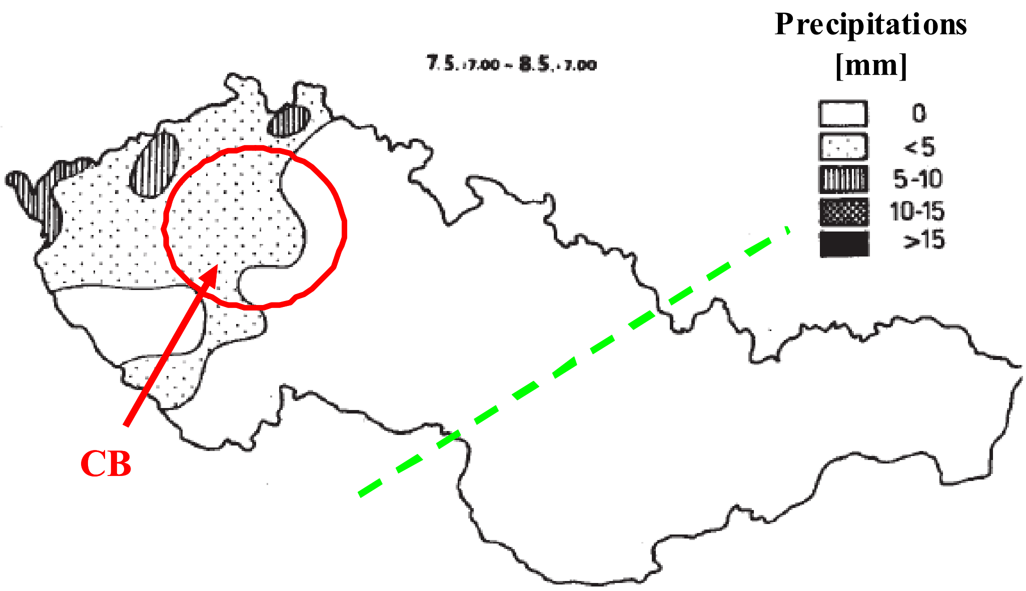


Fig. III.24. Precipitations in the area of the former ČSSR during the period 7.5. – 8.5.1986.

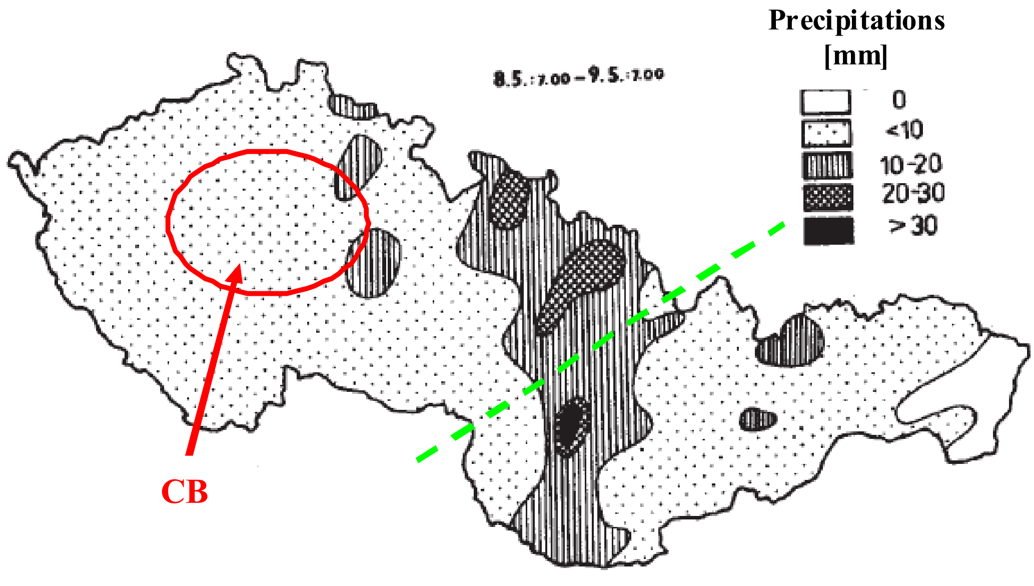


Fig. III.25. Precipitations in the area of the former ČSSR during the period 8.5. – 9.5.1986.

III.4.2.2. Isotopic composition of deposition

The measurements of the ^{131}I deposition indicated that it was considerably varied, even over short distances. One could explain this phenomenon by the variation in time of the physicochemical composition of the radioiodine in air and by substantial differences in deposition velocities of different physicochemical forms. The variation of the $^{131}I/^{137}Cs$ ratio on air sampling filters was also observed. That it indicated at a quick transformation of particulate form of radioiodine to reactive or organic phase.

III.4.2.3. Food consumption rates

The average annual consumption of milk per adult person in the former ČSSR in the year 1989 was 248 L (milk products are calculated in this amount). The annual consumption of milk, vegetable and fruits for different age groups is given in Table III.33. There are not essential seasonal variations in the milk consumption. The age specifications shown in Table III.32 should be used in assessments.

Average annual consumption per person for leafy vegetable is given in Table III.34.

III.4.3. Protective measures

Between 6–8 May 1986, it was recommended that dairy cows should be kept on winter fodder – if available. The consumption of milk with an activity of $^{131}I > 1000$ $Bq.L^{-1}$ was banned. As these countermeasures were not announced publicly, it is most probable that people voluntary decreased consumption of milk and vegetables.

III.4.4. Radioiodine measurements

III.4.4.1. I-131 concentration in air

Activity concentrations of ^{131}I in the air in Prague were measured in three places, the stations PRAHA – LIBEŇ (Czechoslovak academy of science), PRAHA – LIBUŠ (Czechoslovak Hydrometeorological Institute) and PRAHA – VINOHRADY (National Radiation Protection Institute). The coordinates for all three places in Prague are given in Table III.35 and their locations are shown on Figure III.26.

In four other places in Czech, outside of the Central Bohemia region, air samples for the determination of ^{131}I were also collected and measured: ČESKÉ BUDĚJOVICE, HRADEC KRÁLOVÉ, MORAVSKÝ KRUMLOV and ÚSTÍ NAD LABEM. Results for these stations are given in Annex IV to this Appendix: coordinates are given in Table IV-1, location of places in Figure IV-1. Data for the ^{131}I, ^{134}Cs and ^{137}Cs air concentration for the station ČESKÉ BUDĚJOVICE during the period 30 April – 26 June 1986 are given in Table IV-2, for HRADEC KRÁLOVÉ during the period 30 April – 9 May 1986 in Table IV-3, for MORAVSKÝ KRUMLOV during the period 30 April – 12 May 1986 in Table IV-4 and for ÚSTÍ NAD LABEM during the period 30 April – 5 June 1986 Table IV5.

Station Praha– Libeň

The station PRAHA– LIBEŇ was situated in the northern part of Prague. A sampling device was placed at the roof of a house with 3 floors.

The collection of samples was carried out in a way enabling the differentiation between aerosol-fixed and gaseous forms of ^{131}I. The sampling device [III.4] consists of a Petriyan's aerosol filter and two beds of coal impregnated by Ag, adsorbing gaseous forms, i.e. elementary and organically bound iodine. According to the paper by Tomášek and Zelinka

[III.5], there are static and dynamic losses of efficiency of such a sampling device during the time. The static loss of efficiency during a storage period of 1 year and more is about 2%. The dynamic loss of efficiency occurs during use of filters, in the polluted atmosphere of the city it was 7.5% during 31 days. Шт measurements of iodine components during 10 days, the overall loss of efficiency was much smaller than 10%.

Continuous sampling of aerosol started at 06:15 GMT on 29 April 1986 and continuous sampling of gaseous forms started at 17:00. The exchange of the filters was always done at 06:15 GMT. The activities of ^{131}I were measured by Ge(Li) spectrometers with the use of the energy peak area of 364.5 keV .The concentrations of ^{131}I as well as ^{134}Cs and ^{137}Cs in aerosols samples starting from 29 April 1986 are shown in Table III.36. Some samples of aerosol filters were re-measured in NRPI.

The results of measurements during the period of 29April 1986 (18:00) –9 May 1986 (06:15) are shown in Table III.37.

The information data about concentrations of iodine forms in JASLOVSKÉ BOHUNICE (Slovakia) during the period 1 May – 13 May 1986 is presented in Annex IV, Table IV-6. Jaslovské Bohunice NPP is located approximately 8 km NNE from the town of Trnava with coordinates: N: 48°22'10.78“, E: 17°35'21.93“.

Station Praha - Libuš

The station PRAHA-LIBUŠ was situated in the south part of Prague at the periphery of a housing estate. The sampling device in the station was placed at the height of 1.5 m above grass surface.

The recorded concentrations of ^{131}I as well as ^{134}Cs and ^{137}Cs in aerosols samples starting from the 30 April 1986 are shown in Table III.38.

Station Praha - Vinohrady

The station PRAHA – VINOHRADY was situated near the centre of Prague. The sampling device was located on the window at the highest floor of a house with 5 floors.

The recorded concentrations of ^{131}I as well as ^{134}Cs and ^{137}Cs in aerosols samples starting from the 1 May 1986 are shown in Table III.39.

Reconstruction of the total ^{131}I concentration for the period of 29 April – 5 May 1986 over the CB region

The ^{131}I activity concentration from all stations in Prague is given in Figure III.27. In the station PRAHA – VINOHRADY for the sampling of aerosols was used a 5 stage cascade impactor (type 235 Sierra Instruments) connected to bulk cargo aerosols sampler. Results of ^{131}I and ^{137}Cs activity concentration in particle fraction are given in Tables III.40 and III.41. Calculated AMAD and GSD for ^{131}I and ^{137}Cs for the sampling period 12–14 May 1986 and during the period 16 May – 5 June 1986 (from all samplings together) are given in the same tables too.

The cascade impactor was used in two more places in ČR, in MORAVSKÝ KRUMLOV (surroundings NPP Dukovany) and in OSTRAVA. Results of ^{131}I and ^{137}Cs activity concentration in particle fraction, calculated AMAD and GSD are given in Annex IV, Tables IV-7 for Moravský Krumlov and in Table IV-8 for Ostrava.

Table III.32. Recommended age groups

Age groups, years		ICRP reference age, , years
0 – 1	→	1
1 – 8	→	5
8 – 12	→	10
12 – 17	→	15
adults	→	adults

Table III.33. Annual consumption of milk, fruits and vegetables in Czechoslovakia in 1986 [kg, L].

Foodstuff	Age category [years]				
	0–1	1–8	8–12	12–18	adults
Milk *	31.1	360.1	383.4	333.8	248.0
Fruit **	9.9	33.6	45.4	55.9	45.0
Vegetables ***	23.0	44.0	55.4	69.4	75.0

* Consumption of milk and milk products (for children up to one year 22.2 kg of baby milk food must be added).
** Without citrus fruit.
*** Distribution: 24% leafy, 34% root and 42% other vegetable.

Table III.34. Average consumption of leafy vegetables and milk in 1984 for adults [kg/ year and person].

Foodstuff	Amount [kg/ year and person]
Milk and milk products (in the value of milk)	244.5
Cabbage	11.4
Cauliflower	5.6
Kale	2.3
Kohlrabi	2.9
Lettuce	1.3
Spinach	0.1

Table III.35. Geographical coordinates of aerosol sampling places samples.

Locality	Geographical coordinates	
	Latitude (°)	Longitude (°)
Praha - Libeň	50°06'53.52"	14°27'54.84"
Praha - Libuš	50°00'24.15"	14°27'40.19"
Praha - Vinohrady	50°04'27.74"	14°27'23.85"

Table III.36. Aerosol fraction of ^{131}I, ^{134}Cs and ^{137}Cs collected on the station Praha–Libeň.

Time of sampling from	to	Aerosol ^{131}I [Bq m^{-3}]	Aerosol ^{137}Cs [Bq m^{-3}]	Aerosol ^{134}Cs [Bq m^{-3}]	Isotopic ratio $^{131}I/^{137}Cs$	$^{137}Cs/^{134}Cs$
29-04-86 07:00	30-04-86 07:00	11	5.6	2.9	1.96	1.93
30-04-86 07:00	01-05-86 07:00	20.5	9.62	4.62	2.13	2.08
01-05-86 07:00	02-05-86 07:00	1.95	0.93	0.45	2.10	2.08
02-05-86 07:00	03-05-86 07:00	1.4	0.79	0.36	1.77	2.22
03-05-86 07:00	04-05-86 07:00	1.3	0.8	0.36	1.63	2.22
04-05-86 07:00	05-05-86 07:00	0.63	0.44	0.19	1.44	2.32
05-05-86 07:00	06-05-86 07:00	0.34	0.23	0.10	1.49	2.21
06-05-86 07:00	07-05-86 07:00	0.65	0.37	0.18	1.73	2.11
07-05-86 07:00	08-05-86 07:00	0.99	0.58	0.29	1.70	2.04
08-05-86 07:00	09-05-86 07:00	0.087	0.053	0.022	1.64	2.41
09-05-86 07:00	10-05-86 07:00	0.021	0.003	0.001	7.00	3.00
10-05-86 07:00	11-05-86 07:00	0.009	0.001	0.001	9.00	1.00
11-05-86 07:00	12-05-86 07:00	0.008	0.001	0.001	8.00	1.00
12-05-86 08:15	19-05-86 08:15	0.003	0.002	0.0008	1.50	2.50
19-05-86 08:15	21-05-86 08:15	0.0025	0.0015	0.0007	1.67	2.14
21-05-86 08:15	23-05-86 08:15	0.0028	0.0016	0.0008	1.75	2.00
23-05-86 08:15	26-05-86 08:15	0.0022	0.002	0.001	1.10	2.00
26-05-86 08:15	28-05-86 08:15	0.0023	0.0027	0.0013	0.85	2.08
28-05-86 08:15	30-05-86 08:15	0.0009	0.0007	0.00037	1.29	1.89
30-05-86 08:15	02-06-86 08:15	0.0004	0.00035	0.00018	1.14	1.94

Table III.37. Specific activity of aerosol and gaseous ^{131}I measured by the station Praha-Libeň.

Time of sampling from	to	aerosol ^{131}I [Bq.m^{-3}]	gaseous ^{131}I [Bq.m^{-3}]
29-04-86 06:15	30-04-86 06:15	11.0	
30-04-86 17:00	01-05-86 06:15	21.0	42.0
01-05-86 06:15	02-05-86 06:15	2.1	9.2
02-05-86 06:15	04-05-86 06:15	3.2	10.0
04-05-86 06:15	05-05-86 06:15	2.1	7.4
05-05-86 06:15	06-05-86 06:15	1.1	4.5
06-05-86 06:15	07-05-86 06:15	1.0	3.1
07-05-86 06:15	08-05-86 06:15	1.6	4.6
08-05-86 06:15	09-05-86 06:15	0.2	0.8

Table III.38. Aerosol fraction of ^{131}I, ^{134}Cs and ^{137}Cs collected by the station Praha-Libuš and measured at NRPI.

Time of sampling from	to	Aerosol ^{131}I [Bq.m^{-3}]	Aerosol ^{137}Cs [Bq.m^{-3}]	Aerosol ^{134}Cs [Bq.m^{-3}]	Isotopic ratio $^{131}I/^{137}Cs$	$^{137}Cs/^{134}Cs$
30-04-86 10:00	30-04-86 13:00	70.0	23.0	14.0	3.04	1.64
30-04-86 13:00	30-04-86 17:00	50.0	20.0	12.0	2.50	1.67
30-04-86 17:00	30-04-86 23:30	45.0	23.0	10.0	1.96	2.30
30-04-86 23:30	01-05-86 05:00	14.7	9.7	4.8	1.52	2.02
01-05-86 05:00	01-05-86 16:00	6.0	1.7	0.9	3.53	1.89
01-05-86 16:00	02-05-86 05:00	2.8	1.0	0.5	2.80	2.00
02-05-86 05:00	02-05-86 16:30	1.1	0.15	0.06	7.33	2.50
02-05-86 16:30	03-05-86 05:30	0.7	0.06	0.03	11.67	2.00
03-05-86 05:30	03-05-86 16:30	4.7	1.20	0.70	3.92	1.71
03-05-86 16:30	04-05-86 05:30	4.6	7.90	3.50	0.58	2.26
04-05-86 05:30	04-05-86 16:30	5.5	3.60	1.80	1.53	2.00
04-05-86 16:30	05-05-86 05:30	2.8	1.40	0.70	2.00	2.00
05-05-86 05:30	05-05-86 16:30	5.5	0.90	0.40	6.11	2.25
05-05-86 16:30	06-05-86 05:30	1.5	0.80	0.30	1.88	2.67
06-05-86 05:30	06-05-86 16:30	0.5	0.20	0.09	2.50	2.22
06-05-86 16:30	07-05-86 05:30	1.5	0.80	0.40	1.88	2.00
07-05-86 05:30	07-05-86 17:10	1.1	0.80	0.40	1.38	2.00
07-05-86 17:10	08-05-86 05:30	0.9	0.70	0.30	1.29	2.33
08-05-86 05:30	08-05-86 17:00	0.10	0.05	0.03	2.00	1.67
08-05-86 17:00	09-05-86 06:00	0.04				

Table III.39. Aerosol fraction of ^{131}I, ^{134}Cs and ^{137}Cs measured by the station Praha–Vinohrady.

Time of sampling from	to	Aerosol ^{131}I [Bq.m^{-3}]	Gaseous ^{131}I [Bq.m^{-3}]	Aerosol ^{137}Cs [Bq.m^{-3}]	Aerosol ^{134}Cs [Bq.m^{-3}]	Isotopic ratio $^{131}I/^{137}Cs$	$^{137}Cs/^{134}Cs$
01-05-86 16:50	01-05-86 17:50	10	11.5	2		5.00	
01-05-86 18:15	01-05-86 20:15	6		2.1	1.1	2.86	1.91
02-05-86 08:10	02-05-86 10:25	1.7		0.1		17.00	
02-05-86 18:50		3		0.4		7.50	
03-05-86 08:00		1.3					
03-05-86 18:15		0.4					
04-05-86 14:30		1.6		0.6	0.3	2.67	2.00
14-05-86 16:00	16-05-86	0.029		0.022	0.010	1.32	2.18
16-05-86 20:30	19-05-86	0.004		0.005	0.002	0.74	2.14
19-05-86 15:00	23-05-86	0.003		0.004	0.002	0.63	2.14
23-05-86 15:30	28-05-86	0.003		0.005	0.002	0.6	2.5

Table III.40. ^{131}I Activity concentration in air, AMAD and GSD of the aerosol size distribution. Data obtained by the station Praha–Vinohrady with the cascade impactor..

Date of sampling from	to	^{131}I in air, cascade impactor [Bq m^{-3}] Particle size [μm] > 7.2	3.0–7.2	1.5–3.0	0.95–1.5	0.49–0.95	< 0.49	AMAD	GSD
12-05-86	14-05-86	1.55E-03	1.83E-03	2.37E-03	3.96E-03	5.46E-03	1.35E-02	0.6	4.8
16-05-86	19-05-86	< MDA	< MDA	1.06E-04	2.01E-04	6.75E-04	2.90E-03		
19-05-86	23-05-86	5.70E-05	5.17E-05	3.09E-04	3.79E-04	6.08E-04	1.29E-03	0.49	5.3
23-05-86	28-05-86	2.73E-05	6.31E-05	1.85E-04	< MDA	2.97E-04	7.14E-04		
28-05-86	05-06-86	< MDA	< MDA	< MDA	< MDA	< MDA	< MDA		

Table III.41. ^{137}Cs activity concentration in air, calculated AMAD and GSD for cascade impactor. Data of the station Praha–Vinohrady.

Date of sampling		^{137}Cs in air, cascade impactor [Bq.m^{-3}] Particle size [μm]						AMAD	GSD
from	**to**	**> 7.2**	**3.0–7.2**	**1.5–3.0**	**0.95–1.5**	**0.49–0.95**	**< 0.49**		
12-05-86	14-05-86	2.28E-04	1.38E-04	1.48E-03	4.52E-03	5.75E-03	9.54E-03	0.5	3.9
16-05-86	19-05-86	1.09E-04	2.81E-04	6.83E-04	9.16E-04	9.50E-04	2.33E-03		
19-05-86	23-05-86	1.90E-04	1.50E-04	4.80E-04	5.91E-04	1.04E-03	1.82E-03	0.72	4.2
23-05-86	28-05-86	2.28E-04	5.48E-04	1.36E-03	9.45E-05	1.08E-03	1.36E-03		
28-05-86	05-06-86	1.00E-04	8.07E-05	1.95E-04	1.13E-05	4.61E-04	1.64E-03		

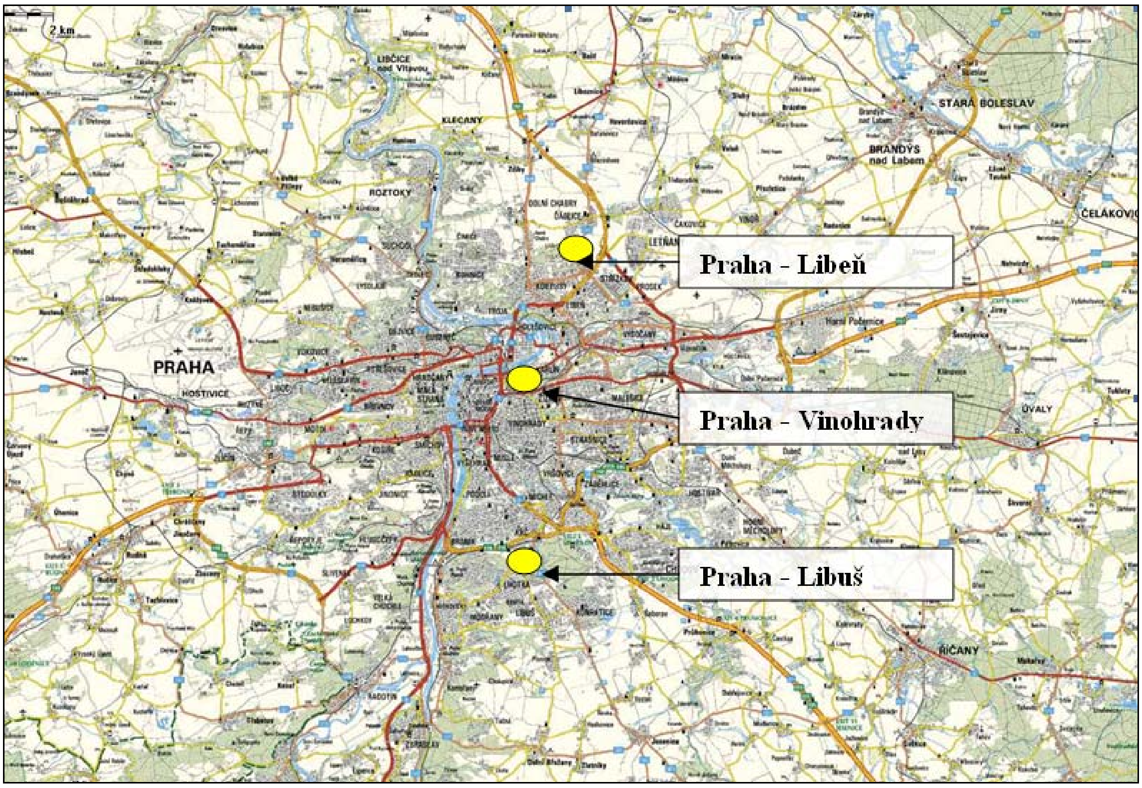


Fig. III.26. Location of the three stations in Prague, where ^{131}I in air was measured – map of Prague.

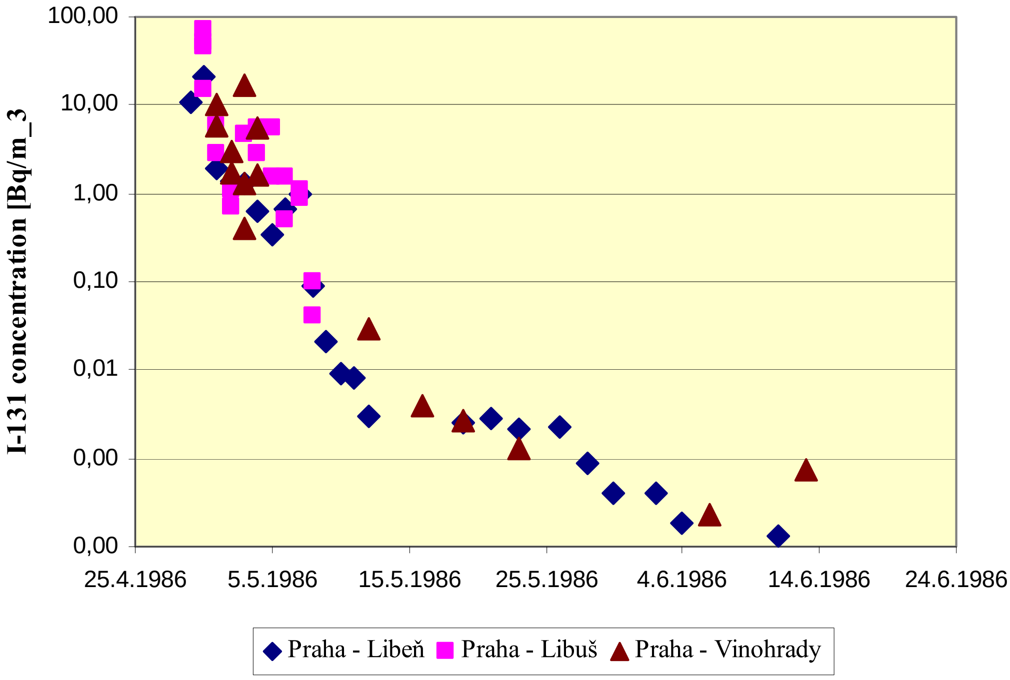


Fig. III.27. ^{131}I concentrations in aerosols, collected in the three parts of Prague, 29 April – 13 July 1986

III.4.4.2. Fallout

There is not any available data for the Central Bohemian region.

Daily fallout activities of ^{131}I, ^{137}Cs and ^{134}Cs in 4 other places in the former Czechoslovakia were measured. The stations MORAVSKÝ KRUMLOV and HRADEC KRÁLOVÉ are nowadays situated in Czechia, the stations BRATISLAVA and KOŠICE in Slovakia. For information, this data is given in Annex IV. The coordinates of stations in the former Czechoslovakia which collected and measured fallout are given in Tables IV-9. Daily fallout activities of ^{131}I, ^{137}Cs and ^{134}Cs for the station MORAVSKÝ KRUMLOV are given in Table IV-10, for the station HRADEC KRÁLOVÉ in Table IV-11, for the station BRATISLAVA in Table IV-12 and for the station KOŠICE in Table IV-13. Data is given for the same time of the end of sampling, 07:00 the day on the row, sampling interval started 24 hours before. Data without mark are for dry fallout, W in the table means wet fallout, value 0.0 means that detected value was lower than MDA.

III.4.4.3. ^{131}I and ^{137}Cs surface concentration in soil

As a part of a nationwide study of fallout and soil contamination, samples of bare soil were collected between 16–18 June 1986. Sites for sampling were chosen to be not shielded by buildings, shrubs and trees, with no grass surface, preferably on agricultural land not tilled since 26 April 1986, on places with a slope less than 30, principally not on sandy soil. Samples were taken as a rule from area 0.09 m^2 to a depth of 3 cm (to check whether the depth was really kept, the data on total mass of samples were requested). Before measurement by semiconductor gamma spectrometry the samples were dried, stones greater than 2 cm in diameter and roots of plants were removed, and then samples were homogenized.

The time of measurements differed for different samples, so in many cases where content of ^{134}Cs in soil was very low, the activity concentration was below the limit of detection. The minimum detectable activity was about 20 Bq.m^{-2}.

In several cases a substantial variation of the surface contamination is observed on small distances. Such phenomenon could be explained by the local rains.

The distribution of ^{137}Cs activity concentration in soils of ČR can be seen in Figure III.28 or on the map in Figure III.29. Examples of inhomogeneity of ^{137}Cs activity concentration in near-by locations is given in Figure III.30.

In Central Bohemia, soil samples were taken during the period 6 May – 17 June 1986. The locations of soil sampling points during the period 6 May – 7 June 1986 with approximation of gathering region of dairy Benešov are given in Figure III.31, the location of soil sampling points on 17 June 1986 with approximation to the gathering regions of all three chosen dairies in Figure III.32. Gathering region bounds are not the same as district line. Measured surface activity concentrations of ^{131}I, ^{137}Cs and ^{134}Cs and isotopic ratio of ^{131}I/^{137}Cs and ^{137}Cs/^{134}Cs are given in Table III.42 . 17th June 1986 samples in 11 parts of Prague were collected too. The activity concentration of other radionuclides in these samples is given in Table III.43.The location of soil samples are given in Figures III.33 and III.34.

The ^{131}I concentration in fresh grass samples from PRAHA - VINOHRADY are given in Annex IV, and results from BRATISLAVA (SLOVAKIA) during the period 1 May – 19 June 1986 are represented in Table IV-14 and on Figure IV-2.

Table III.42. ^{131}I, ^{137}Cs and ^{134}Cs contents in soil in the CB region [bq.m^{-2}], samples collected during the period 6 May – 17 June 1986.

Date of sampling	Number on the picture	District and abbreviation	Locality	Dairy district	geographical coordinates Latitude (°)	geographical coordinates Longitude (°)	I-131 in time of measurement [Bq/m^2]	Cs-137 [Bq/m^2]	Cs-134 [Bq/m^2]	I-131/ Cs-137	Cs-137/ Cs-134
06-05-86	1	Kolín [KO]	Žabonosy	Kolin	50°02'07.32"	15°01'37.94"	705	146	70	4.8	2.1
07-05-86	2	Benešov [BN]	Olbramovice	BENEŠOV	49°40'00.11"	14°37'26.00"	103	17	7	6.1	2.4
25-05-86	3	Kutná Hora [KH]	Zruč nad Sázavou	BENEŠOV	49°44'24.37"	15°06'21.81"	5230	6000	2770	0.9	2.2
25-05-86	4	Kutná Hora [KH]	Čestín	BENEŠOV	49°48'27.04"	15°06'15.83"	340	640	240	0.5	2.7
25-05-86	5	Kutná Hora [KH]	Zbraslavice	Kutná Hora	49°48'42.45"	15°10'59.49"	5520	3500	1980	1.6	1.8
25-05-86	6	Kutná Hora [KH]	Souňov	Kutná Hora	49°52'48.08"	15°18'56.01"	3320	4300	1830	0.8	2.3
25-05-86	7	Kutná Hora [KH]	Uhlířské Janovice	BENEŠOV	49°52'48.68"	15°03'53.33"	10800	13500	6480	0.8	2.1
25-05-86	8	Kutná Hora [KH]	Tupadly	Kutná Hora	49°52'08.41"	15°24'12.44"	4450	8400	3620	0.5	2.3
25-05-86	9	Kutná Hora [KH]	Žleby	outside the region	49°53'22.51"	15°29'18.07"	2790	3600	1290	0.8	2.8
25-05-86	10	Kutná Hora [KH]	Košice	Kolin	49°53'44.87"	15°09'03.02"	12900	17600	8420	0.7	2.1
25-05-86	11	Kutná Hora [KH]	Křesetice	Kutná Hora	49°54'25.87"	15°15'46.91"	6950	12300	5550	0.6	2.2
25-05-86	12	Kutná Hora [KH]	Malešov	Kutná Hora	49°54'39.66"	15°13'27.61"	5380	8180	3660	0.7	2.2
25-05-86	13	Kutná Hora [KH]	Vinice	outside the region	49°55'11.47"	15°29'26.87"	3960	5970	2730	0.7	2.2
25-05-86	14	Kutná Hora [KH]	Bílé Podolí	outside the region	49°57'23.35"	15°29'27.68"	1530	1700	780	0.9	2.2
25-05-86	15	Kutná Hora [KH]	Žehušice	Kutná Hora	49°58'10.04"	15°24'26.59"	3450	4400	2040	0.8	2.2
25-05-86	16	Kutná Hora [KH]	Rohozec	Kutná Hora	49°58'33.67"	15°23'04.71"	2220	3720	1590	0.6	2.3
25-05-86	17	Kutná Hora [KH]	Nové Dvory	Kutná Hora	49°58'05.57"	15°19'40.46"	4420	5660	2570	0.8	2.2
25-05-86	18	Kutná Hora [KH]	Svobodná Ves	outside the region	49°58'52.84"	15°26'53.98"	830	780	360	1.1	2.2
25-05-86	19	Kutná Hora [KH]	Kačina	Kutná Hora	49°58'54.24"	15°20'45.84"	3410	5380	2510	0.6	2.1
04-06-86	20	Kutná Hora [KH]	Karlov u Vysoké	outside the region	49°38'47.08"	15°54'54.62"	4000	11100	4920	0.4	2.3
04-06-86	21	Kutná Hora [KH]	Zbizuby	BENEŠOV	49°49'22.27"	15°01'18.10"	3850	13900	6400	0.3	2.2
04-06-86	22	Kutná Hora [KH]	Ježovice	BENEŠOV	49°49'47.68"	14°59'16.46"					
04-06-86	23	Kutná Hora [KH]	Mitrov	BENEŠOV	49°51'18.45"	15°02'53.12"	2900	13700	6590	0.2	2.1
04-06-86	24	Kutná Hora [KH]	Žandov	Kutná Hora	49°51'33.63"	15°07'39.41"	2050	3990	1660	0.5	2.4
04-06-86	25	Kutná Hora [KH]	Mrchojedy	BENEŠOV	49°51'55.77"	14°56'23.96"	2070	10400	5050	0.2	2.1
04-06-86	26	Kutná Hora [KH]	Mrchojedy	BENEŠOV	49°51'55.77"	14°56'23.96"	1600	3500	1550	0.5	2.3
04-06-86	27	Benešov [BN]	Sázava	BENEŠOV	49°52'17.92"	14°53'48.25"	930	2220	1070	0.4	2.1
04-06-86	28	Kutná Hora [KH]	Staňkovice	BENEŠOV	49°52'31.38"	15°00'54.31"	3100	10040	4970	0.3	2.0
04-06-86	29	Kutná Hora [KH]	Uhlířské Janovice	BENEŠOV	49°52'48.68"	15°03'53.33"	5200	15200	6640	0.3	2.3
04-06-86	30	Kutná Hora [KH]	Uhlířské Janovice	Kutná Hora	49°52'48.68"	15°03'53.33"	11000	34400	15200	0.3	2.3
04-06-86	31	Kutná Hora [KH]	Nepoměřice	Kutná Hora	49°52'50.75"	15°08'55.69"	3660	13970	6580	0.3	2.1
04-06-86	32	Kutná Hora [KH]	Rašovice	Kolin	49°52'57.15"	15°06'08.57"	2300	6600	3300	0.3	2.0
04-06-86	33	Kutná Hora [KH]	Miskovice	Kolin	49°56'46.06"	15°12'16.99"	4000	10800	4980	0.4	2.2
06-06-86	34	Kutná Hora [KH]	Církvice	Kutná Hora	49°56'44.17"	15°20'06.17"	4400	16300	7060	0.3	2.3
06-06-86	35	Kutná Hora [KH]	Církvice	Kutná Hora	49°56'44.17"	15°20'06.17"	4100	11800	5260	0.3	2.2
07-06-86	36	Kutná Hora [KH]	Bludov	Kutná Hora	49°48'26.97"	15°15'18.65"	2100	10800	4800	0.2	2.3
07-06-86	37	Kutná Hora [KH]	Damírov	Kutná Hora	49°48'41.86"	15°19'20.01"	2300	8870	4200	0.3	2.1
07-06-86	38	Kutná Hora [KH]	Opatovice u Zbýšova	Kutná Hora	49°49'31.06"	15°20'58.24"	2800	10900	4500	0.3	2.4
07-06-86	39	Kutná Hora [KH]	Paběnice	Kutná Hora	49°50'29.09"	15°18'08.37"	620	3160	1380	0.2	2.3
07-06-86	40	Kutná Hora [KH]	Červené Janovice	Kutná Hora	49°50'04.06"	15°15'12.00"	2100	5980	3060	0.4	2.0
07-06-86	41	Kutná Hora [KH]	Hraběšín	Kutná Hora	49°51'09.08"	15°19'54.53"	2140	10600	4520	0.2	2.3

Table III.42. (Continued).

Date of sampling	Number on the picture	District and abbreviation	Locality	Dairy district	geographical coordinates		I-131 in time of measurement [Bq/m^2]	Cs-137 [Bq/m^2]	Cs-134 [Bq/m^2]	I-131/ Cs-137	Cs-137/ Cs-134
					Latitude (°)	Longitude (°)					
07-06-86	42	Kutná Hora [KH]	Třebonín	Kutná Hora	49°52‘10.94“	15°18‘46.52“	1100	4170	2100	0.3	2.0
07-06-86	43	Kutná Hora [KH]	Kluky	Kutná Hora	49°54‘28.95“	15°19‘27.03“	1200	3990	1960	0.3	2.0
07-06-86	44	Kutná Hora [KH]	Perštejnec	Kutná Hora	49°55‘42.08“	15°17‘13.72“	2000	13500	6500	0.1	2.1
17-06-86	45	Benešov [BN]	Střezimíř	BENEŠOV	49.5331	14.6117	2960	38600	19300	0.1	2.0
17-06-86	46	Benešov [BN]	Sedlec-Prčice	BENEŠOV	49.5733	14.5333		3120	1290		38.0
17-06-86	47	Benešov [BN]	Načeradec	BENEŠOV	49.6103	14.9081	2680	21600	11400		2.4
17-06-86	48	Benešov [BN]	Loket	BENEŠOV	49.6561	15.1181	1380	8440	3940		2.9
17-06-86	49	Benešov [BN]	Olbramovice	BENEŠOV	49.6681	14.6408		2320	1000		3.4
17-06-86	50	Benešov [BN]	Vlašim	BENEŠOV	49.7042	14.9017	3790	38200	20100		23.5
17-06-86	51	Benešov [BN]	Vlašim	BENEŠOV	49.7042	14.9017	2460	21700	11500	0.1	1.9
17-06-86	52	Benešov [BN]	Trhový Štěpánov	BENEŠOV	49.7117	15.0122	3820	39800	19900		17.0
17-06-86	53	Benešov [BN]	Neveklov	BENEŠOV	49.7531	14.5336		4000	2130		3.4
17-06-86	54	Benešov [BN]	Psáře	BENEŠOV	49.7564	14.9514	2350	24700	12600		2.6
17-06-86	55	Benešov [BN]	Benešov	BENEŠOV	49.7819	14.6886	3320	31600	16700	0.2	2.1
17-06-86	56	Benešov [BN]	Benešov	BENEŠOV	49.7819	14.6886	570	2770	1460		1.9
17-06-86	57	Benešov [BN]	Divišov	BENEŠOV	49.7892	14.8775	3680	36500	19900		2.3
17-06-86	58	Benešov [BN]	Týnec nad Sázavou	BENEŠOV	49.8339	14.5894		4160	1800		11.0
17-06-86	59	Benešov [BN]	Chocerady	BENEŠOV	49.8736	14.8042		7750	3390		2.3
17-06-86	60	Beroun [BE]	Komárov	Beroun&Praha (west)	49.8058	13.8586		590	80	0.1	1.9
17-06-86	61	Beroun [BE]	Horovice	Beroun&Praha (west)	49.8367	13.9053		660	230	0.1	1.9
17-06-86	62	Beroun [BE]	Lochovice	Beroun&Praha (west)	49.8519	13.9819		1180	470	0.1	2.0
17-06-86	63	Beroun [BE]	Všeradice	Beroun&Praha (west)	49.8742	14.1061		910	450		2.0
17-06-86	64	Beroun [BE]	Březová	Beroun&Praha (west)	49.9044	13.8844		1020	420		1.9
17-06-86	65	Beroun [BE]	Tetín	Beroun&Praha (west)	49.9494	14.1036		850	390	0.1	2.0
17-06-86	66	Beroun [BE]	Nižbor	Beroun&Praha (west)	50.0000	14.0025		520	<20		2.0
17-06-86	67	Beroun [BE]	Chrustenice	Beroun&Praha (west)	50.0017	14.1597		7310	3730	0.0	2.1
17-06-86	68	Beroun [BE]	Chyňava	Beroun&Praha (west)	50.0275	14.0753		1250	720	0.1	1.9
17-06-86	69	Kladno [KL]	Bratronice	PRAHA – TROJA	50.0689	14.0208	40	260	150	0.2	1.9
17-06-86	70	Kladno [KL]	Unhošť	PRAHA – TROJA	50.0856	14.1344		90	60		2.3
17-06-86	71	Kladno [KL]	Velká Dobrá	PRAHA – TROJA	50.1125	14.0806	80	630	370		23.5
17-06-86	72	Kladno [KL]	Kladno	PRAHA – TROJA	50.1475	14.1039		100	60	0.1	1.8
17-06-86	73	Kladno [KL]	Sviřov	PRAHA – TROJA	50.1814	14.0497		260	140		43.5
17-06-86	74	Kladno [KL]	Otvovice	PRAHA – TROJA	50.2125	14.2706		220	130		7.4
17-06-86	75	Kladno [KL]	Slaný	Kladno&Rakovník	50.2317	14.0908		60	40		2.2
17-06-86	76	Kladno [KL]	Slaný	Kladno&Rakovník	50.2317	14.0908		90	50		3.2
17-06-86	77	Kladno [KL]	Pozdeň	Kladno&Rakovník	50.2417	13.9442	40	400	230		2.3
17-06-86	78	Kladno [KL]	Velvary	Kladno&Rakovník	50.2822	14.2383		120	70		2.9
17-06-86	79	Kladno [KL]	Velvary	Kladno&Rakovník	50.2822	14.2383		390	220		1.9
17-06-86	80	Kladno [KL]	Zlonice	Kladno&Rakovník	50.2861	14.0928		20	20		2.1
17-06-86	81	Kladno [KL]	Vraný	Kladno&Rakovník	50.3267	14.0186		50	30		2.5
17-06-86	82	Kolín [KO]	Stříbrná Skalice	Kolín	49.8983	14.8525		200	180	0.2	2.1

Table III.42. (Continued).

Date of sampling	Number on the picture	District and abbreviation	Locality	Dairy district	geographical coordinates		I-131 in time of measurement [Bq/m^2]	Cs-137 [Bq/m^2]	Cs-134 [Bq/m^2]	I-131/ Cs-137	Cs-137/ Cs-134
					Latitude (°)	Longitude (°)					
17-06-86	83	Kolín [KO]	Zásmuky	Kolín	49.9539	15.0381	570	1640	740		2.3
17-06-86	84	Kolín [KO]	Nučice	Kolín	49.9558	14.8858		1310	540		2.0
17-06-86	85	Kolín [KO]	Kolín	Kolín	50.0283	15.2017	270	1290	610		3.5
17-06-86	86	Kolín [KO]	Žabonosy	Kolín	50.0367	15.0297		2840	1470		1.1
17-06-86	87	Kolín [KO]	Týnec nad Sázavou	outside the region	50.0458	15.3617		3860	1770		2.4
17-06-86	88	Kolín [KO]	Tuchoraz	Kolín	50.0489	14.8514		900	430		2.2
17-06-86	89	Kolín [KO]	Plaňany	Kolín	50.0506	15.0325	35	1930	910		2.1
17-06-86	90	Kolín [KO]	Velim	Kolín	50.0611	15.1053		3270	1470		2.1
17-06-86	91	Kolín [KO]	Český Brod	Kolín	50.0753	14.8642		1930	650		2.1
17-06-86	92	Kolín [KO]	Český Brod	Kolín	50.0753	14.8642		160	20		2.1
17-06-86	93	Kolín [KO]	Pečky	Kolín	50.0911	15.0314		2160	980		2.1
17-06-86	94	Kolín [KO]	Velký Osek	Kolín	50.0989	15.1906		1170	540		2.3
17-06-86	95	Kutná Hora [KH]	Zruč nad Sázavou	BENEŠOV	49.7419	15.1053		4830	2470		2.0
17-06-86	96	Kutná Hora [KH]	Kácov	BENEŠOV	49.7781	15.0283		5190	2590		2.2
17-06-86	97	Kutná Hora [KH]	Bohdaneč	Kutná Hora	49.7789	15.2242		23100	11000		2.7
17-06-86	98	Kutná Hora [KH]	Zbýšov	Kutná Hora	49.8142	15.3558		4250	1970	0.3	2.2
17-06-86	99	Kutná Hora [KH]	Černíny	Kutná Hora	49.8383	15.2194		8870	4600		2.4
17-06-86	100	Kutná Hora [KH]	Ledečko	BENEŠOV	49.8497	14.9508		11300	5270		2.1
17-06-86	101	Kutná Hora [KH]	Miskovice	Kolín	49.9469	15.2064		1430	620		2.0
17-06-86	102	Kutná Hora [KH]	Kutná Hora	Kutná Hora	49.9486	15.2694		12200	5960		1.9
17-06-86	103	Kutná Hora [KH]	Chotusice	Kutná Hora	49.9497	15.3969		1590	580		2.2
17-06-86	104	Kutná Hora [KH]	Církvice	Kutná Hora	49.9631	15.3369		11800	5800		
17-06-86	105	Mělník [ME]	Kralupy nad Vltavou	PRAHA – TROJA	50.2417	14.3136		1060	590		2.0
17-06-86	106	Mělník [ME]	Neratovice	PRAHA – KYJE (east)	50.2597	14.5192		770	270		2.3
17-06-86	107	Mělník [ME]	Tišice	PRAHA – TROJA	50.2694	14.5569		6370	2640		1.7
17-06-86	108	Mělník [ME]	Veltrusy	PRAHA – TROJA	50.2711	14.3300		1320	620	0.2	2.1
17-06-86	109	Mělník [ME]	Obříství	PRAHA – TROJA	50.2953	14.4792	1040	4050	1750		2.1
17-06-86	110	Mělník [ME]	Kly	PRAHA – TROJA	50.3094	14.5058		2030	1750		1.9
17-06-86	111	Mělník [ME]	Ledčice	PRAHA – TROJA	50.3417	14.2947		1100	440		2.0
17-06-86	112	Mělník [ME]	Horní Počaply	Mělník&Ml. Boleslav	50.4256	14.3903		2110	1010		60.0
17-06-86	113	Mělník [ME]	Mšeno	Mělník&Ml. Boleslav	50.4383	14.6331		880	240		39.5
17-06-86	114	Mělník [ME]	Vidim	Mělník&Ml. Boleslav	50.4675	14.5275	1240	5940	2530		2.2
17-06-86	115	Mladá Boleslav [MB]	Sojovice	PRAHA – KYJE (east)	50.2228	14.7633		2000	920		2.1
17-06-86	116	Mladá Boleslav [MB]	Benátky nad Jizerou	PRAHA – KYJE (east)	50.2917	14.8256		1170	460	0.0	2.1
17-06-86	117	Mladá Boleslav [MB]	Dolní Slivno	PRAHA – KYJE (east)	50.3094	14.7353		2560	1300		2.2
17-06-86	118	Mladá Boleslav [MB]	Kosořice	Nymburk	50.3353	14.9694		5530	2770		2.2
17-06-86	119	Mladá Boleslav [MB]	Jizerní Vtelno	Nymburk	50.3703	14.8547		2600	1260	0.2	1.8
17-06-86	120	Mladá Boleslav [MB]	Velké Všelisy	Mělník&Ml. Boleslav	50.3792	14.7464		4360	1990	0.2	1.7
17-06-86	121	Mladá Boleslav [MB]	Nová Telib	Mělník&Ml. Boleslav	50.3928	15.0372		3540	1670		2.0
17-06-86	122	Mladá Boleslav [MB]	Sukorady	Mělník&Ml. Boleslav	50.4267	15.0317		3750	1480		3.0
17-06-86	123	Mladá Boleslav [MB]	Dalovice	Mělník&Ml. Boleslav	50.4269	14.8811		2930	1290		8.0

Table III.42. (Continued).

Date of sampling	Number on the picture	District and abbreviation	Locality	Dairy district	geographical coordinates		I-131 in time of measurement [Bq/m^2]	Cs-137 [Bq/m^2]	Cs-134 [Bq/m^2]	I-131/ Cs-137	Cs-137/ Cs-134
					Latitude (°)	Longitude (°)					
17-06-86	124	Mladá Boleslav [MB]	Dolní Bousov	outside the region	50.4383	15.1300		4310	1830		2.0
17-06-86	125	Mladá Boleslav [MB]	Dolní Bousov	outside the region	50.4383	15.1300		950	490		2.2
17-06-86	126	Mladá Boleslav [MB]	Střehom	outside the region	50.4389	15.1464		950	490		1.9
17-06-86	127	Mladá Boleslav [MB]	Bakov nad Jizerou	Mělník&Ml. Boleslav	50.4781	14.9417		2890	1300		2.0
17-06-86	128	Mladá Boleslav [MB]	Bělá pod Bezdězem	Mělník&Ml. Boleslav	50.5017	14.8103		2460	1060		2.1
17-06-86	129	Mladá Boleslav [MB]	Boseň	Mělník&Ml. Boleslav	50.5050	15.0244		1790	750		1.5
17-06-86	130	Mladá Boleslav [MB]	Neveklovice	outside the region	50.5722	14.9508		3330	1560		2.2
17-06-86	131	Nymburk [NB]	Poděbrady	Nymburk	50.1450	15.1222		1120	560		2.1
17-06-86	132	Nymburk [NB]	Vlkov pod Oškobrhem	Nymburk	50.1567	15.2214		2570	1190		2.2
17-06-86	133	Nymburk [NB]	Kostomlaty nad Labem	PRAHA – KYJE (east)	50.1853	14.9617	740	3440	1680		2.0
17-06-86	134	Nymburk [NB]	Budiměřice	Nymburk	50.1964	15.0978		1380	390	0.1	1.7
17-06-86	135	Nymburk [NB]	Lysá nad Labem	PRAHA – KYJE (east)	50.2017	14.8342	1090	8980	4040		2.0
17-06-86	136	Nymburk [NB]	Městec Králové	Nymburk	50.2075	15.3003		1280	480		2.1
17-06-86	137	Nymburk [NB]	Benátecká Vrutice	PRAHA – KYJE (east)	50.2314	14.8422		6700	3310		2.2
17-06-86	138	Nymburk [NB]	Loučeň	Nymburk	50.2864	15.0219		9150	4940		25.0
17-06-86	139	Nymburk [NB]	Rožďalovice	outside the region	50.3058	15.1722	6050	5040	2170		2.0
17-06-86	140	Praha – east [PH]	Ondřejov	PRAHA – KYJE (east)	49.9047	14.7867		4790	2220		1.7
17-06-86	141	Praha – east [PH]	Velké Popovice	PRAHA – KYJE (east)	49.9228	14.6411		12300	5770		2.2
17-06-86	142	Praha – east [PH]	Křížkový Újezdec	PRAHA – KYJE (east)	49.9308	14.5872		6890	3340		2.1
17-06-86	143	Praha – east [PH]	Říčany	PRAHA – KYJE (east)	49.9922	14.6547		3280	1460		1.7
17-06-86	144	Praha – east [PH]	Šestajovice	PRAHA – KYJE (east)	50.1069	14.6828		4630	2290		2.1
17-06-86	145	Praha – east [PH]	Jirny	PRAHA – KYJE (east)	50.1150	14.7008		950	460		2.1
17-06-86	146	Praha – east [PH]	Mochov	PRAHA – KYJE (east)	50.1592	14.8131		8010	3870		1.8
17-06-86	147	Praha – east [PH]	Čelákovice	PRAHA – KYJE (east)	50.1611	14.7519		9850	4780		2.1
17-06-86	148	Praha – east [PH]	Klecany	PRAHA – TROJA	50.1778	14.4122		12800	7050		1.9
17-06-86	149	Praha – east [PH]	Káraný	PRAHA – KYJE (east)	50.1806	14.7367		2040	980	0.2	2.0
17-06-86	150	Praha – east [PH]	Čakovičky	PRAHA – KYJE (east)	50.2319	14.5336		6740	3260		49.5
17-06-86	151	Praha – west [PZ]	Mníšek pod Brdy	Příbram	49.8667	14.2625	530	3180	1550		1.4
17-06-86	152	Praha – west [PZ]	Jílové u Prahy	Beroun&Praha (west)	49.8956	14.4950		1140	330		2.5
17-06-86	153	Praha – west [PZ]	Jíloviště	Beroun&Praha (west)	49.9275	14.3447		3710	1770		2.5
17-06-86	154	Praha – west [PZ]	Zvole	Beroun&Praha (west)	49.9350	14.4178		3190	1540		3.5
17-06-86	155	Praha – west [PZ]	Libeň	Beroun&Praha (west)	49.9422	14.4978		3960	1850	0.2	2.0
17-06-86	156	Praha – west [PZ]	Černošice	Beroun&Praha (west)	49.9608	14.3208		1400	660	0.1	2.2
17-06-86	157	Praha – west [PZ]	Jesenice	PRAHA – KYJE (east)	49.9689	14.5147		6060	3120		2.7
17-06-86	158	Praha – west [PZ]	Chýně	Beroun&Praha (west)	50.0617	14.2314	1030	6010	3360		1.7
17-06-86	159	Praha – west [PZ]	Hostivice	PRAHA – TROJA	50.0817	14.2608		2690	1250		2.2
17-06-86	160	Praha – west [PZ]	Velké Přílepy	PRAHA – TROJA	50.1603	14.3172		7810	4630		2.0
17-06-86	161	Praha – west [PZ]	Libčice nad Vltavou	PRAHA – TROJA	50.1981	14.3656	120	770	380		1.5
17-06-86	162	Praha city [AB]	Lochkov	Beroun&Praha (west)	50.0033	14.3547		2250	960		1.8
17-06-86	163	Praha city [AB]	Šeberov	PRAHA – KYJE (east)	50.0303	14.5283		3510	1710		2.1
17-06-86	164	Praha city [AB]	Petrovice	PRAHA – KYJE (east)	50.0378	14.5756		4360	2140		1.8

Table III.42. (Continued).

Date of sampling	Number on the picture	District and abbreviation	Locality	Dairy district	geographical coordinates Latitude (°)	Longitude (°)	I-131 in time of measurement [Bq/m²]	Cs-137 [Bq/m²]	Cs-134 [Bq/m²]	I-131/ Cs-137	Cs-137/ Cs-134
17-06-86	165	Praha city [AB]	Řepy	PRAHA – TROJA	50.0714	14.3019		2660	1330	0.1	1.7
17-06-86	166	Praha city [AB]	Dolní Měcholupy	PRAHA – KYJE (east)	50.0764	14.5764		4340	2180		2.9
17-06-86	167	Praha city [AB]	Ruzyně	PRAHA – TROJA	50.0836	14.3178		620	320		2.4
17-06-86	168	Praha city [AB]	Malá Strana	PRAHA – TROJA	50.0844	14.4161		7630	3880		2.1
17-06-86	169	Praha city [AB]	Staré Město	PRAHA – TROJA	50.0853	14.4189		8580	4130		1.7
17-06-86	170	Praha city [AB]	Vinohrady	PRAHA – TROJA	50.0969	14.4592		6970	3350		1.8
17-06-86	171	Praha city [AB]	Holešovice	PRAHA – TROJA	50.1131	14.4208		9420	4670		1.0
17-06-86	172	Praha city [AB]	Ďáblice	PRAHA – TROJA	50.1631	14.4836		9020	4400		1.9
17-06-86	173	Příbram [PB]	Březnice	outside the region	49.5583	13.9517		760	20		2.5
17-06-86	174	Příbram [PB]	Petrovice	outside the region	49.5792	14.3383		1270	440	0.3	2.3
17-06-86	175	Příbram [PB]	Rožmitál pod Třemšínem	Příbram	49.6008	13.8711		790	230	1.2	2.3
17-06-86	176	Příbram [PB]	Rožmitál pod Třemšínem	Příbram	49.6008	13.8711		470	20		2.0
17-06-86	177	Příbram [PB]	Solenice	Příbram	49.6183	14.1969		340	20		1.2
17-06-86	178	Příbram [PB]	Milín	Příbram	49.6344	14.0453		1180	350		1.7
17-06-86	179	Příbram [PB]	Kosova Hora	Příbram	49.6544	14.4758		1430	560		2.0
17-06-86	180	Příbram [PB]	Sedlčany	Příbram	49.6611	14.4283		850	440		2.5
17-06-86	181	Příbram [PB]	Dubno	Příbram	49.6969	14.0539		220	20		2.1
17-06-86	182	Příbram [PB]	Drásov	Příbram	49.7014	14.1231		320	140		2.2
17-06-86	183	Příbram [PB]	Dobříš	Příbram	49.7819	14.1686		990	440		2.1
17-06-86	184	Příbram [PB]	Nový Knín	Příbram	49.7889	14.2947		470	20		2.1
17-06-86	185	Příbram [PB]	Jince	Příbram	49.7892	13.9803		870	20		2.5
17-06-86	186	Příbram [PB]	Vozice	Příbram	49.8172	14.2183		1700	530		2.3
17-06-86	187	Rakovník [RA]	Křivoklát	Beroun&Praha (west)	50.0381	13.8742		1200	20		2.4
17-06-86	188	Rakovník [RA]	Klíčava	Beroun&Praha (west)	50.0411	13.9222		790	20		1.9
17-06-86	189	Rakovník [RA]	Městečko	Beroun&Praha (west)	50.0508	13.8656		2560	1190		3.7
17-06-86	190	Rakovník [RA]	Lány	Kladno&Rakovník	50.1244	13.9522		1410	630		1.9
17-06-86	191	Rakovník [RA]	Ruda	Kladno&Rakovník	50.1392	13.8781		500	20	0.2	2.3
17-06-86	192	Rakovník [RA]	Třtice	Kladno&Rakovník	50.1853	13.8661		990	20		2.2
17-06-86	193	Rakovník [RA]	Řevničov	Kladno&Rakovník	50.1858	13.8111		560	410		2.3
17-06-86	194	Rakovník [RA]	Řevničov	Kladno&Rakovník	50.1858	13.8111		1710	680		2.4
17-06-86	195	Rakovník [RA]	Hředle	Kladno&Rakovník	50.1886	13.7503		1800	720		2.1

Table III.43. Activity concentration of several radionuclides in soil samples from Prague.

Date of sampling	Part of Prague	Geographical coordinates		Activity concentration [Bq m^{-2}]				
		Latitude (°)	Longitude (°)	^{137}Cs	^{134}Cs	^{103}Ru	^{95}Nb	^{140}La
17-06-86	Ďáblice	50.1631	14.4836	9020	4400	2770		
17-06-86	Dolní Měcholupy	50.0764	14.5764	4340	2180	1550	200	
17-06-86	Holešovice	50.1131	14.4208	9420	4670	2630	120	
17-06-86	Lochkov	50.0033	14.3547	2250	960	1040		
17-06-86	Malá Strana	50.0844	14.4161	7630	3880	2210	130	
17-06-86	Petrovice	50.0378	14.5756	4360	2140	1670		
17-06-86	Ruzyně	50.0836	14.3178	620	320	200		
17-06-86	Řepy	50.0714	14.3019	2660	1330	940		
17-06-86	Staré Město	50.0853	14.4189	8580	4130	2550	220	
17-06-86	Šeberov	50.0303	14.5283	3510	1710	1140		
17-06-86	Vinohrady	50.0969	14.4592	6970	3350	1740	150	110

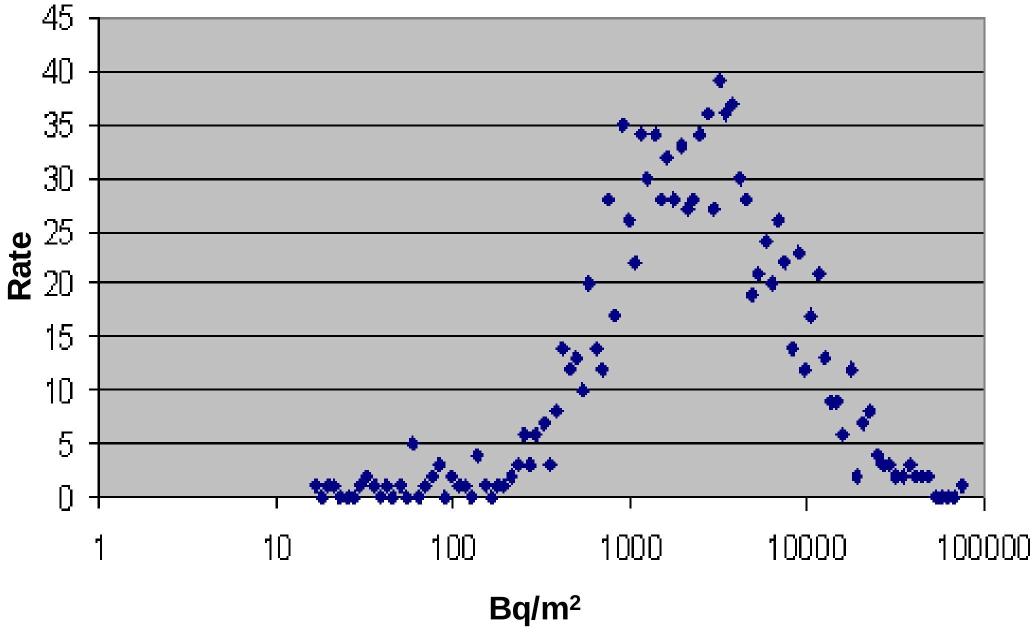


Fig. III.28. ^{137}Cs distribution in soils in ČR – values.

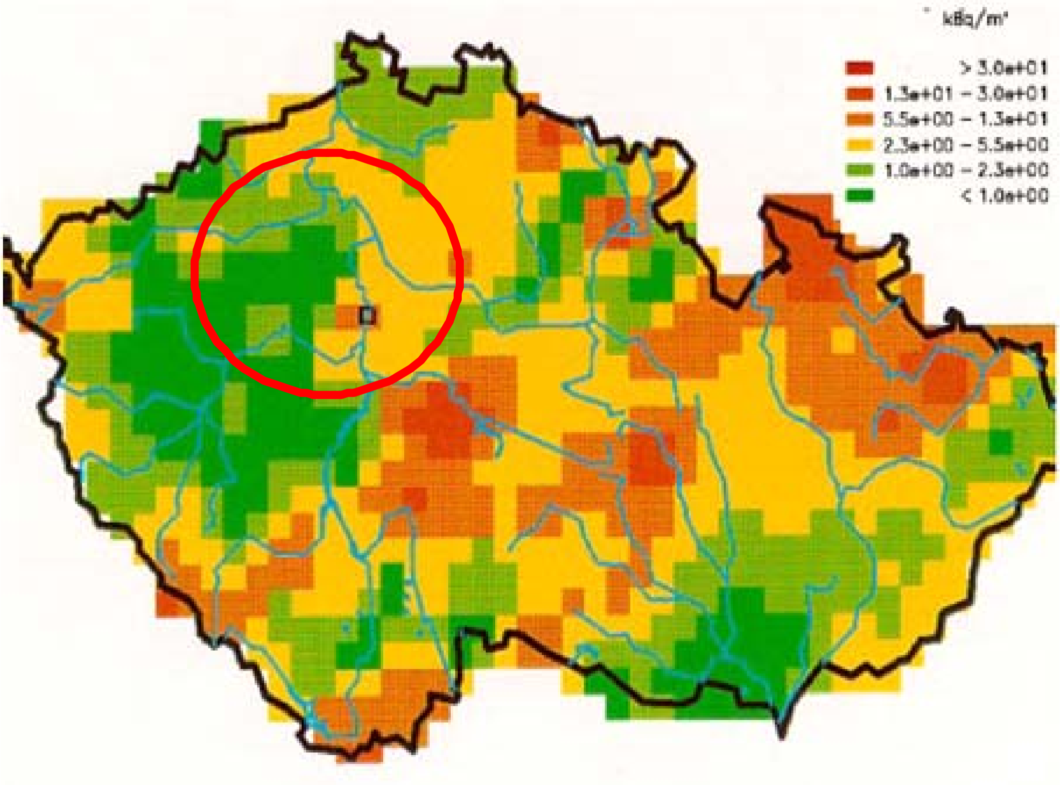


Fig. III.29. ^{137}Cs distribution in soils in ČR – map.

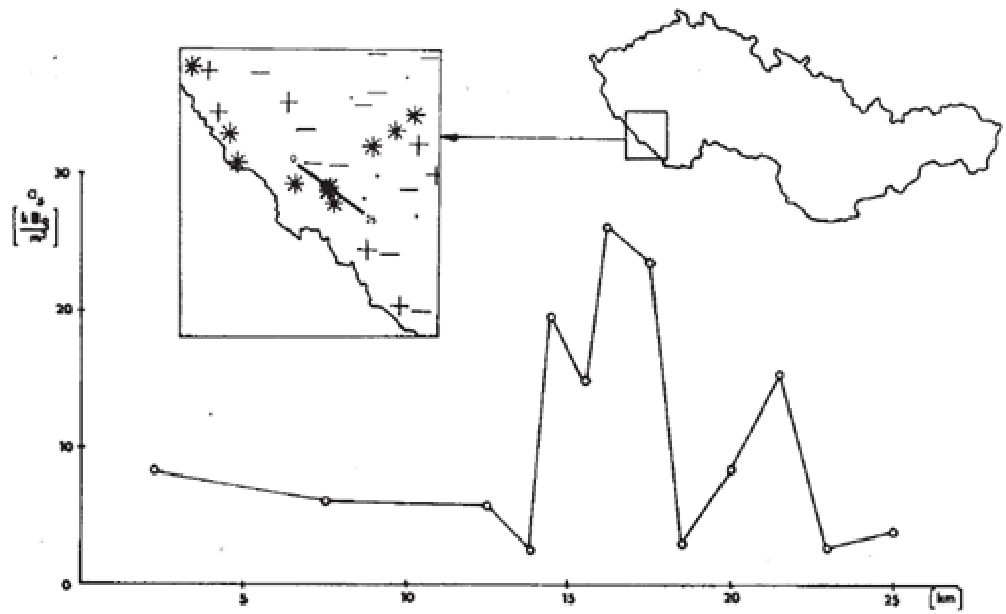


Fig. III.30. Example of inhomogeneity in activity concentration of ^{137}Cs of near-by locations.

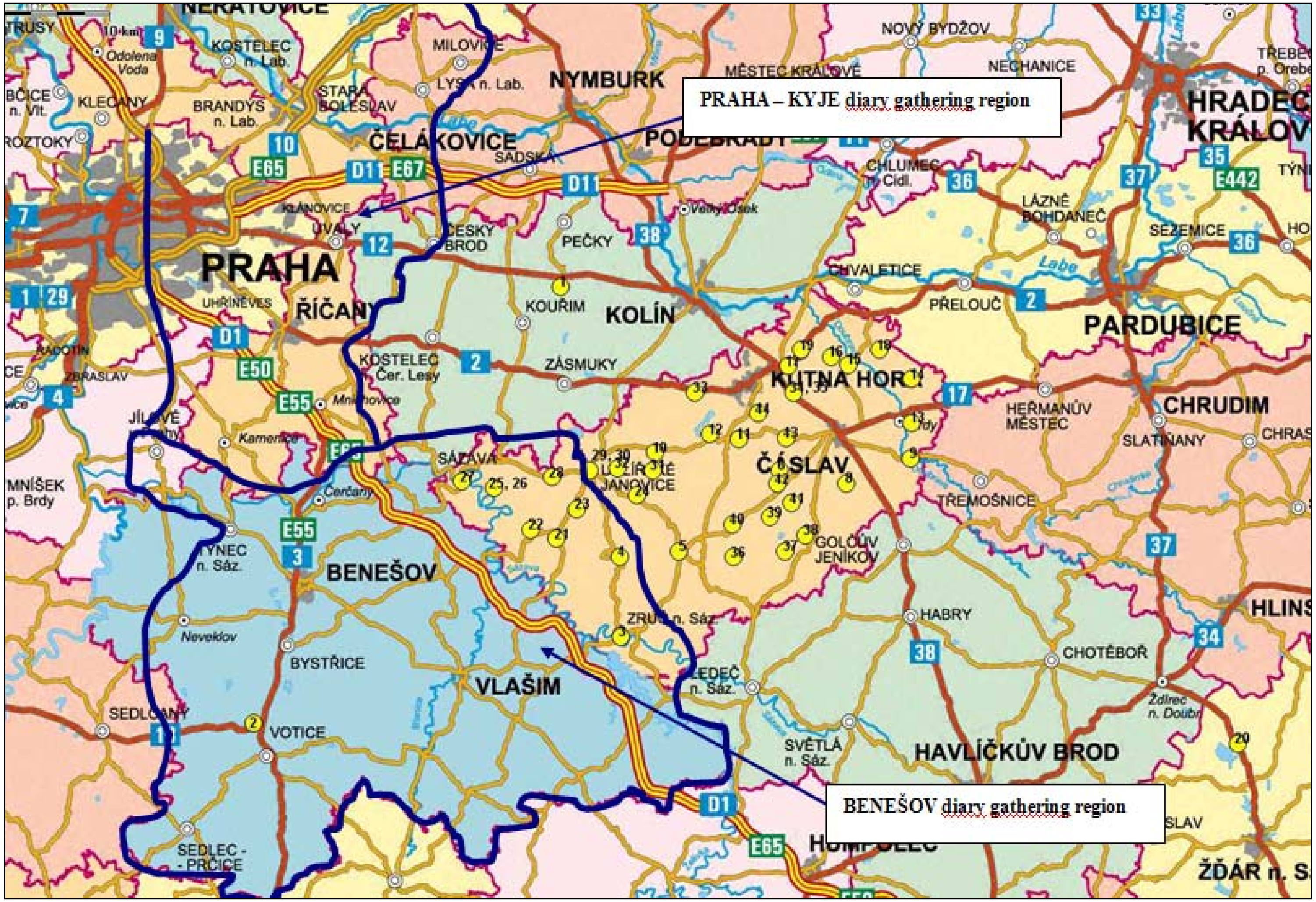


Fig. III.31. Location of soil sampling points during the period 6 May – 7 June 1986.

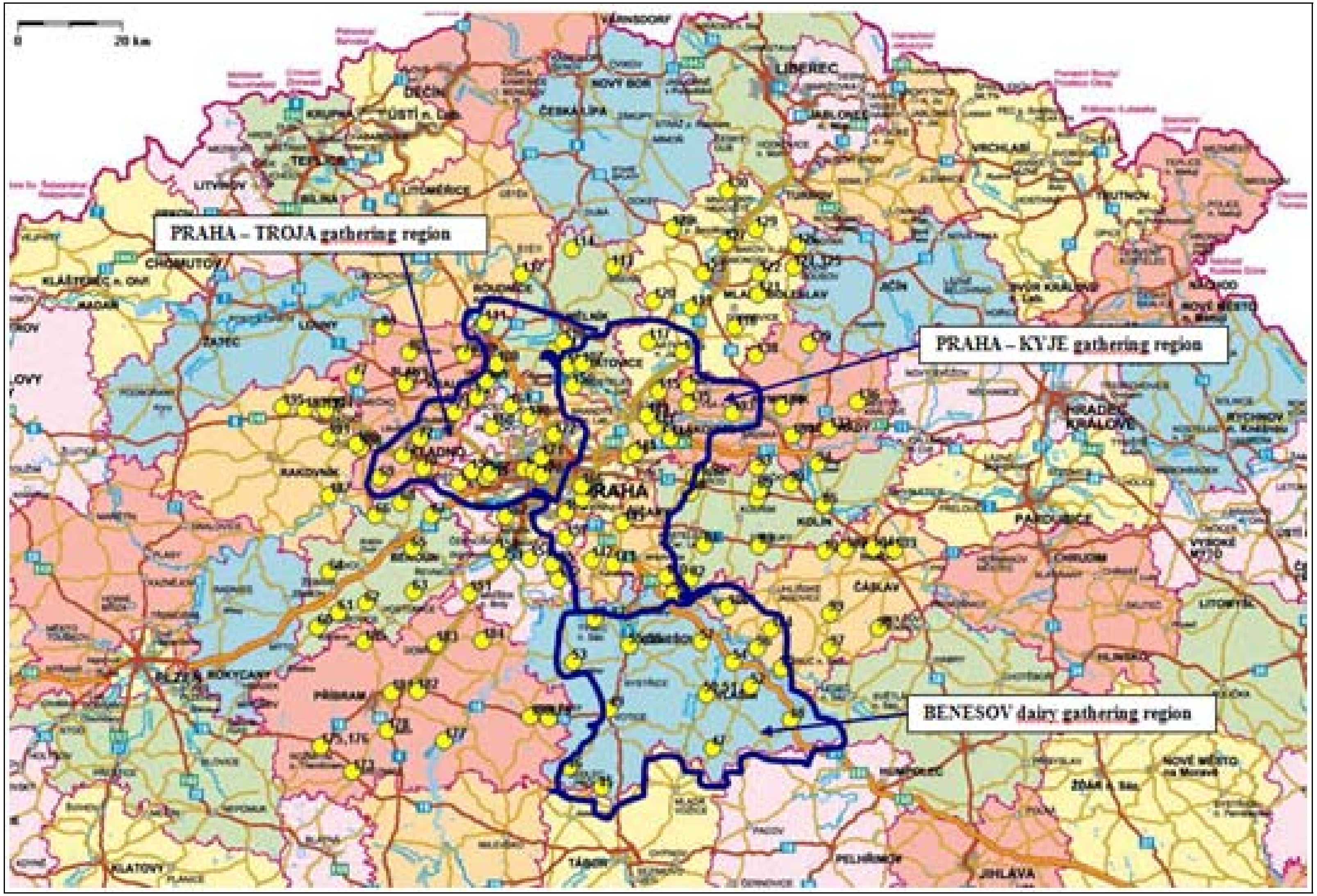


Fig. III.32. Location of soil sampling points on 17 June 1986.

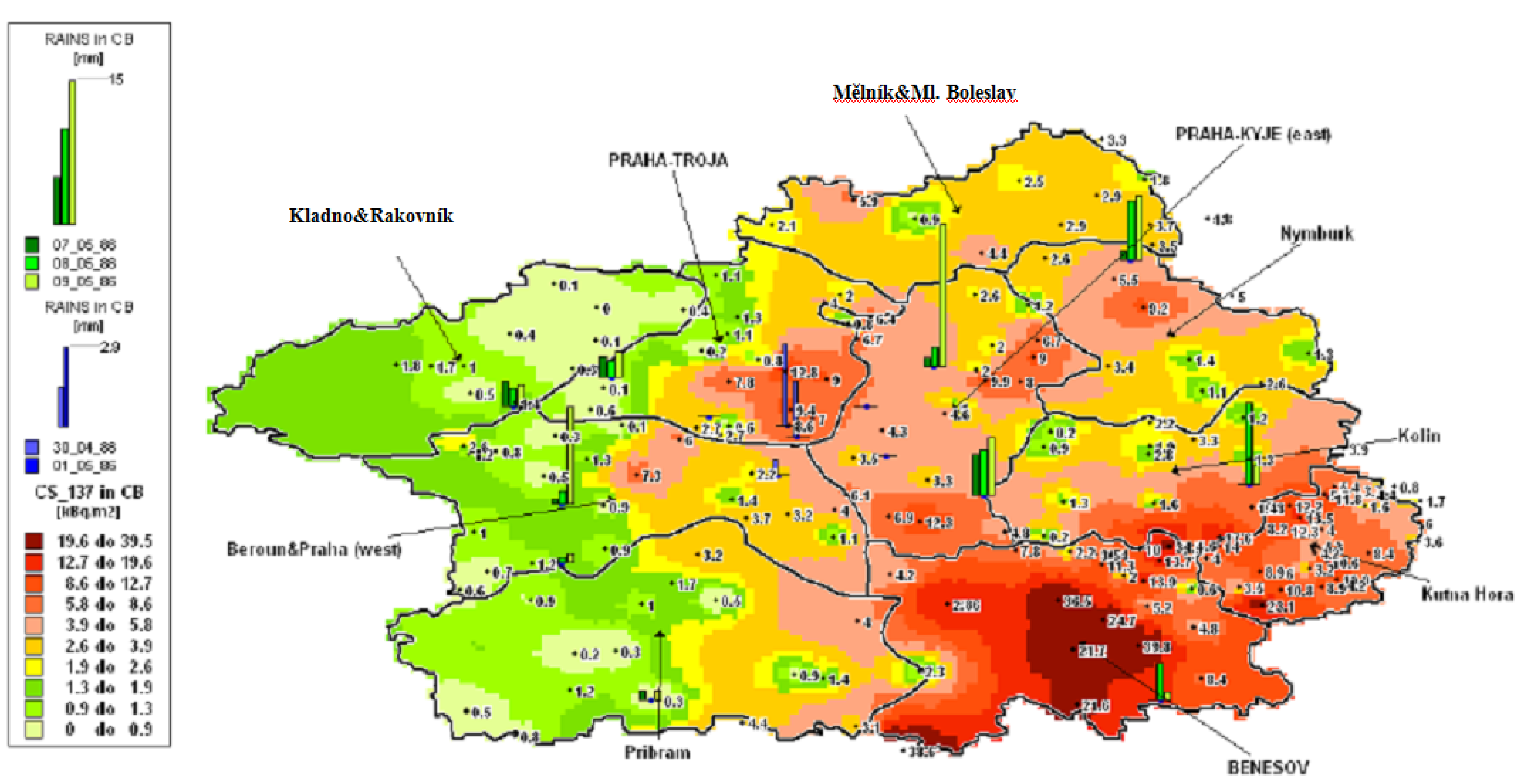


Fig. III.33. Assessment of ^{137}Cs deposition for the CB region; the numbers show measured values of ^{137}Cs surface contamination.

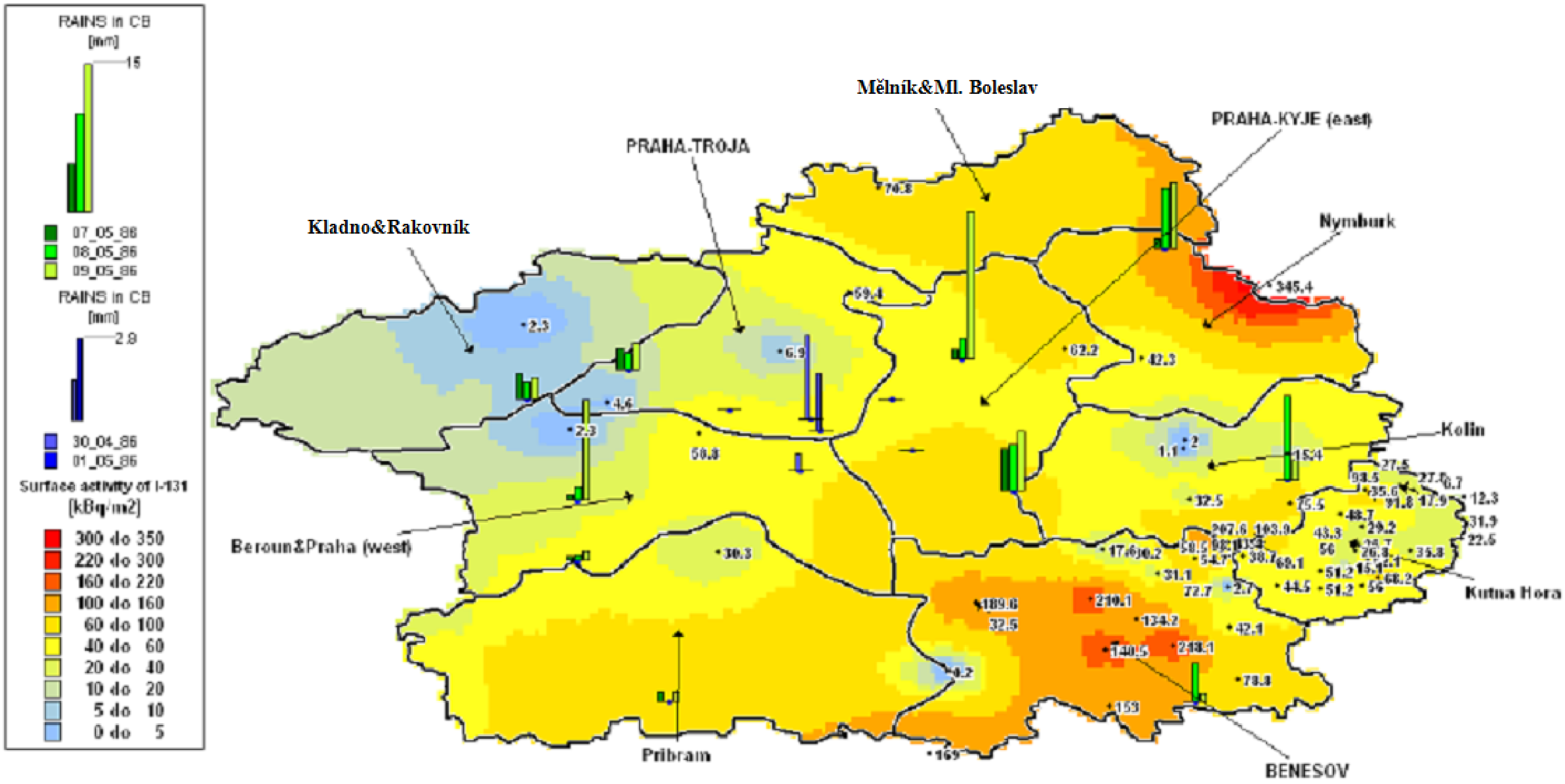


Fig. III.34. Assessment of ^{131}I deposition for the CB region; the numbers show measured values of ^{131}I surface concentrations.

III.4.4.4. ^{131}I concentration in milk samples

Samples of milk were taken from storage tanks in dairies or from storage tanks in the big milk producing co-operatives, which supplied the corresponding dairy. The location of the dairies and their gathering regions are shown in Figure III.13. The production of milk in 1986 are shown in Table III.44.

Results of ^{131}I activity concentration in milk from dairies PRAHA – KYJE, PRAHA – TROJA and BENEŠOV during the period 30 May – 16 June 1986 are given in Annex IV, in Tables IV-15, IV-16 and IV-17 respectively. The results for all three dairies are given in Figure IV-3.

III.4.4.5. Measurements of ^{131}I content in thyroid gland

During the initial period after the accident, the activity of ^{131}I in the body was evaluated with an assumption of the homogeneous distribution of radioiodine in the body (like for measurements of ^{137}Cs and ^{134}Cs on WBC) see Figure III.35(a). Such an approach leads to a significant systematic error. On the latter stages of the accident a more realistic calibration factor was introduced: all iodine in the body was assumed to be concentrated in the thyroid gland. Figure III.35(b) illustrates the updated measurement geometry. The ratio of the calibration factors obtained for two indicated above assumptions was 1.5. Therefore the ^{131}I activity in the "whole body" [III.6], was divided by a factor of 1.5 for purposes of this work. .

With such measurements from NPP Dukovany and NPP Jaslovske Bohunice (Slovakia, about 100 km from the border of the Czech Republic and about 350 km from Prague), it would be possible to evaluate the Prague measurements.

Table III.44. Daily production in dairies in 1986.

Dairy	Code	Daily production [thousands of L]		
		May 1986	Jun 1986	Dec 1986
Hostivice	D01		73.2	62.4
Praha - Kyje	D02	271.8	294	243.5
Praha – Radlice	D03	198.3	217	176.3
Praha – Troja	D04	185	122	98.5
Benešov	D05	235.6	195.3	218.7
Čáslav	D06	111.4	101.5	95.7
Kačice	D08		86.0	63.05
Slaný	D09	182.0		110.0
Kolín	D10	204.7	213.8	184.3
Čejetičky	D12	97.7	103.2	82.7
Poděbrady	D13	176.2	185.0	152.2
Příbram	D14	204.0		

(a) 

(b) 

Fig. III.35. Measurement of ^{131}I in the thyroid: (a) WBC; and (b) neck geometry.

ANNEX III. FORMULARIES

III-1. Calculation for model testing

Table III-1. Average ^{131}I concentration in milk for specified locations (Bq L^{-1} fresh weight).

Daily averages	PRAHA - KYJE dairy			PRAHA - TROJA dairy			BENEŠOV dairy		
	Arithmetic mean	95% Confidence interval Lower Bound	Upper Bound	Arithmetic mean	95% Confidence interval Lower Bound	Upper Bound	Arithmetic mean	95% Confidence interval Lower Bound	Upper Bound
28-04-86									
29-04-86									
30-04-86									
01-05-86									
02-05-86									
03-05-86									
04-05-86									
05-05-86									
06-05-86									
07-05-86									
08-05-86									
09-05-86									
10-05-86									
11-05-86									
12-05-86									
13-05-86									
14-05-86									
15-05-86									
16-05-86									
17-05-86									
18-05-86									
19-05-86									
20-05-86									
21-05-86									
22-05-86									
23-05-86									
24-05-86									
25-05-86									
26-05-86									
27-05-86									
28-05-86									
29-05-86									
30-05-86									
31-05-86									
01-06-86									
02-06-86									
03-06-86									
04-06-86									
05-06-86									
06-06-86									
07-06-86									
08-06-86									
09-06-86									
10-06-86									
Milk Integrals∗									

∗ For the period 27-04-06 - 16-06-86.

Table III-2. ^{131}I concentration in milk – redictions of ^{131}I thyroid burden for inhabitants of Prague – adults [Bq].

Daily averages	ADULTS		
	Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound
27-04-86			
28-04-86			
29-04-86			
30-04-86			
01-05-86			
02-05-86			
03-05-86			
04-05-86			
05-05-86			
06-05-86			
07-05-86			
08-05-86			
09-05-86			
10-05-86			
11-05-86			
12-05-86			
13-05-86			
14-05-86			
15-05-86			
16-05-86			
17-05-86			
18-05-86			
19-05-86			
20-05-86			
21-05-86			
22-05-86			
23-05-86			
24-05-86			
25-05-86			
26-05-86			
27-05-86			
28-05-86			
29-05-86			
30-05-86			
31-05-86			
01-06-86			
02-06-86			
03-06-86			
04-06-86			
05-06-86			
06-06-86			
07-06-86			
08-06-86			
09-06-86			
10-06-86			

III-2. Calculation for model comparison

Table III-3. The total integrated ^{131}I air concentration in ground level air and contribution of the radioiodine phases i.e. particulate. reactive gaseous and organic phases over Prague area [Bq m^{-3}d].

INTEGRATED $^{13}1$I AIR CONCENTRATION [Bq/ m^3 d]			**RADIOIODINE PHASES [%]**		
Arithmetic mean	**95% Confidence interval**				
	Lower Bound	**Upper Bound**	**particulate**	**reactive gaseous I_2**	**organic CH_3I**

Table III-4. Average ^{131}I concentration in grass for specified locations.

Daily averages	**PRAGUE**		
	Arithmetic mean	**95% Confidence interval**	
		Lower Bound	**Upper Bound**
27-04-86			
28-04-86			
29-04-86			
30-04-86			
01-05-86			
02-05-86			
03-05-86			
04-05-86			
05-05-86			
06-05-86			
07-05-86			
08-05-86			
09-05-86			
10-05-86			
11-05-86			
12-05-86			
13-05-86			
14-05-86			
15-05-86			
16-05-86			
17-05-86			
18-05-86			
19-05-86			
20-05-86			
21-05-86			
22-05-86			
23-05-86			
24-05-86			
25-05-86			
26-05-86			
27-05-86			
28-05-86			
29-05-86			
30-05-86			
31-05-86			

Table III-5. Average ^{131}I concentration in milk (hypothetical) for cows pastured in open grassland (Bq L^{-1} fresh weight).

Daily averages	PRAHA - KYJE dairy			PRAHA - TROJA dairy			BENEŠOV dairy		
	Arithmetic mean	95% Confidence Lower Bound	95% Confidence Upper Bound	Arithmetic mean	95% Confidence Lower Bound	95% Confidence Upper Bound	Arithmetic mean	95% Confidence Lower Bound	95% Confidence Upper Bound
29-04-86									
30-04-86									
01-05-86									
02-05-86									
03-05-86									
04-05-86									
05-05-86									
06-05-86									
07-05-86									
08-05-86									
09-05-86									
10-05-86									
11-05-86									
12-05-86									
13-05-86									
14-05-86									
15-05-86									
16-05-86									
17-05-86									
18-05-86									
19-05-86									
20-05-86									
21-05-86									
22-05-86									
23-05-86									
24-05-86									
25-05-86									
26-05-86									
27-05-86									
28-05-86									
29-05-86									
30-05-86									
31-05-86									
01-06-86									
02-06-86									
03-06-86									
04-06-86									
05-06-86									
06-06-86									
07-06-86									
08-06-86									
09-06-86									
10-06-86									
11-06-86									
12-06-86									
Milk Integrals∗									

∗ For the period 29-04-06 - 16-06-86

Table III-6. Mean doses to thyroid from inhalation for inhabitants of Prague (mSv).

Counter-measures	Age 1 in 1986			Age 5 in 1986			Age 10 in 1986			Adult (age 20 in 1986)		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
24 HOURS IN BUILDING												
16 HOURS IN BUILDING												
8 HOURS IN BUILDING												

Table III-7. Mean doses to thyroid from ingestion for inhabitants of Prague (mSv).

Assumptions	Age 1 in 1986			Age 5 in 1986			Age 10 in 1986			Adult (age 20 in 1986)		
	Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval		Arithmetic mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
Cows* on pasture on 27 April												
Cows kept in cows-shed and fed with uncontaminated fodder												
Based on milk data obtained in the validation study												

* Meaning that cows started grazing on 29 April 1986 and cows eat mostly grass from grassland open areas.

ANNEX IV. VALIDATION OF ENVIRONMENTAL MODELS USING DATA FROM CHERNOBYL I-131 AIR POLLUTION IN CENTRAL BOHEMIA AREA

IV-1. ^{131}I data from places outside of Central Bohemia region

IV-1.1. I-131 concentration in air

Table IV-1. Coordinates of sampling places for collection of aerosols samples.

Locality	Geographical coordinates	
	Latitude (°)	Longitude (°)
České Budějovice	48°58'28.09"	14°28'27.63"
Hradec Králové	50°12'30.74"	15°50'26.37"
Moravský Krumlov	49°02'56.15"	16°18'42.01"
Ústí nad Labem	50°39'38.54"	14°01'56.18"

Table IV-2. Aerosol fraction of ^{131}I, ^{134}Cs and ^{137}Cs measured on the station České Budějovice during the period 30 April – 26 June 1986.

Sampling		České Budějovice, activity [Bq/m^3]		
from	to	^{131}I	^{134}Cs	^{137}Cs
30-04-86	01-05-86	28.900	4.390	8.550
01-05-86	02-05-86	4.880	0.600	1.100
02-05-86	03-05-86	6.970	0.679	1.410
03-05-86	04-05-86	5.810	0.779	1.500
04-05-86	05-05-86	2.500	0.404	0.787
05-05-86	06-05-86	1.070	0.118	0.228
06-05-86	07-05-86	1.140	0.252	0.423
07-05-86	08-05-86	0.330	0.067	0.111
08-05-86	09-05-86	0.088	0.004	0.007
09-05-86	10-05-86	0.096	0.002	0.005
10-05-86	11-05-86	0.060	0.002	0.003
11-05-86	12-05-86	0.066	0.003	0.004
12-05-86		0.050		
13-05-86		0.050		
15-05-86		0.028		
16-05-86		0.033		
17-05-86		0.019		
18-05-86		0.012		
19-05-86		0.018		
20-05-86		<0.017		
21-05-86		< 0.017		
22-05-86		< 0.020		
23-05-86		0.008		
24-05-86		0.007		
25-05-86		0.007		
26-05-86		< 0.010		
27-05-86		0.006		
31-05-86	02-06-86	0.00048	0.00020	0.00032
03-06-86	05-06-86	0.00030	0.00030	0.00040
10-06-86	12-06-86	<0.00023	< 0.00036	0.00060
24-06-86	26-06-86	< 0.00020	< 0.00030	0.00039

Table IV-3. Aerosol fraction of ^{131}I, ^{134}Cs and ^{137}Cs measured on the station Hradec Králové during the period 30 April – 9 May 1986.

Sampling		**Hradec Králové, activity [Bq/m^3]**		
from	**to**	**^{131}I**	**^{134}Cs**	**^{137}Cs**
30-04-86 07:00	30-04-86 11:00	54.00	5.3	5.5
30-04-86 11:00	30-04-86 12:00	28.00	2.7	6.1
30-04-86 12:00	30-04-86 13:00	25.00	2	6
30-04-86 15:00	30-04-86 17:00	27.00		4.5
30-04-86 17:00	30-04-86 19:00	24.00		3.5
30-04-86 19:00	30-04-86 22:00	33.00	2.7	5.9
30-04-86 22:00	01-05-86 00:00	23.00	2.3	6.4
01-05-86 00:00	01-05-86 02:00	7.40	0.12	0.7
01-05-86 02:00	01-05-86 04:00	8.80	0.6	1.8
01-05-86 04:00	01-05-86 06:00	1.50	0.1	0.2
01-05-86 06:00	01-05-86 08:00	1.70	0.2	0.5
01-05-86 10:00	01-05-86 12:00	0.65	0.04	0.04
01-05-86 12:00	01-05-86 15:00	0.32		
01-05-86 15:00		0.30		0.02
02-05-86 18:00	02-05-86 21:00	0.63	0.07	0.11
02-05-86 21:00	03-05-86 00:00	0.52	0.1	0.19
03-05-86 00:00	03-05-86 03:00	0.46	0.05	0.08
03-05-86 03:00	03-05-86 06:00	0.50	<0.05	0.08
03-05-86 06:00	03-05-86 09:00	0.68	<0.05	0.07
03-05-86 09:00	03-05-86 17:00	0.26		
03-05-86 17:00	03-05-86 20:00	2.30		0.5
03-05-86 20:00	03-05-86 21:00	2.10	0.37	0.54
03-05-86 21:00	03-05-86 22:00	2.00	0.4	0.7
03-05-86 22:00	03-05-86 23:00	2.50	0.5	1.2
03-05-86 23:00	04-05-86 02:00	1.50	0.23	0.72
04-05-86 02:00	04-05-86 06:00	0.70	0.1	0.38
04-05-86 06:00	04-05-86 09:00	1.10		1.04
04-05-86 09:00	05-05-86 01:00	1.30	0.36	0.51
05-05-86 01:00	05-05-86 04:00	0.49	0.13	0.21
05-05-86 04:00	05-05-86 12:00	0.44	0.09	0.17
05-05-86 12:00	05-05-86 17:00	8.00		0.2
05-05-86 17:00	05-05-86 23:00	0.35	0.07	0.13
05-05-86 23:00	06-05-86 03:00	0.64	0.11	0.17
06-05-86 03:00	06-05-86 09:00	0.20	0.03	0.1
06-05-86 09:00	06-05-86 15:00	0.17	0.036	0.016
06-05-86 15:00	06-05-86 20:00	1.00	0.16	0.1
06-05-86 20:00	07-05-86 03:00	0.29	0.05	0.08
07-05-86 03:00	07-05-86 09:00	0.55	0.07	0.21
07-05-86 09:00	07-05-86 12:00	1.44	0.22	0.46
07-05-86 12:00	07-05-86 18:00	0.83	0.13	0.29
07-05-86 18:00	07-05-86 22:00	0.78	0.19	0.44
07-05-86 22:00	08-05-86 09:00	0.78	0.31	0.51
08-05-86 09:00	08-05-86 13:13	0.56	0.11	0.59
08-05-86 13:13	08-05-86 16:13	0.10	0.03	0.02
08-05-86 20:30	08-05-86 22:30	0.03	0.03	0.03
09-05-86 03:30	09-05-86 06:30	0.03	0.03	0.03
09-05-86 08:00	09-05-86 09:00	0.03	0.03	0.03

Table IV-4. Aerosol fraction of ^{131}I, ^{134}Cs and ^{137}Cs measured on the station Moravský Krumlov during the period 30 April – 12 May 1986.

End of sampling	**Moravský Krumlov, activity [Bq/m³]** ^{131}**I**	^{134}**Cs**	^{137}**Cs**
30-04-86	21.100	2.380	5.360
01-05-86	18.600	2.700	5.100
02-05-86	2.300	0.448	0.867
03-05-86	0.716	0.065	0.142
04-05-86	5.440	0.816	2.270
05-05-86	3.150	0.683	1.450
06-05-86	1.310	0.261	0.596
07-05-86	2.030	0.279	0.741
08-05-86	2.250	0.600	1.110
09-05-86	0.225	0.063	0.122
10-05-86	0.048	0.002	0.005
11-05-86	0.042	0.001	0.001
12-05-86	0.031	0.000	0.001

Sampling ended at 07:00 day in first column, started at 07:00 day before.

Table IV-5. Aerosol fraction of ^{131}I, ^{134}Cs and ^{137}Cs measured on the station Ústí Nad Labem during the period 30 April – 6 July 1986.

Sampling		**Ústí nad Labem, activity [Bq/m³]**		
from	**to**	^{131}**I**	^{134}**Cs**	^{137}**Cs**
30-04-86	01-05-86	5.24	1.44	2.6
01-05-86	02-05-86	4.81	1.43	2.6
02-05-86		0.196	0.013	0.019
03-05-86		1.3	0.502	0.931
04-05-86	05-05-86	1.32	0.56	1.04
05-05-86 10:00	06-05-86 10:00	0.25	0.07	0.24
06-05-86 18:00	07-05-86 16:00	0.18		0.11
07-05-86 17:00	08-05-86 17:00	0.38	0.24	0.22
08-05-86 21:30	09-05-86 15:30	0.015		
09-05-86 17:00	10-05-86 16:00	0.008		
10-05-86 17:12	11-05-86 16:00	0.0095		
11-05-86 17:30	12-05-86 16:00	0.0092		
13-05-86 15:00	14-05-86 16:00	0.0085		
14-05-86 18:00	15-05-86 16:00	0.006		
15-05-86 18:30	16-05-86 16:00	0.003		
16-05-86 18:00	17-05-86 16:00	0.0025		
20-05-86 14:30	21-05-86 14:00	0.0014		< 0.001
21-05-86 15:00	22-05-86 14:00	0.0009		< 0.001
22-05-86 14:30	23-05-86 14:00	< 0.0013		< 0.0012
23-05-86 15:00	24-05-86 14:00	0.0019		
24-05-86 15:30	25-05-86 14:00	0.0011		0.0017
25-05-86 18:30	26-05-86 14:00	0.0021		< 0.0015
27-05-86		0.0019		0.002
28-05-86 16:00	29-05-86 14:00	0.0011		
29-05-86 14:30	30-05-86 14:30	<0.0008		
30-05-86 15:00	31-05-86 14:10	<0.0008		
01-06-86 07:00	02-06-86 12:00	<0.0008		<0.0009
02-06-86 14:00	03-06-86 14:00	<0.0011		
03-06-86 14:30	04-06-86 14:10	<0.0011		
04-06-86 15:00	05-06-86 14:00	<0.0009		
05-06-86 14:30	06-06-86 14:00	<0.001		

Table IV-6. Contribution [%] of different physicochemical forms of iodine to the total ^{131}I concentration in air in Jaslovské Bohunice (Slovakia) during the period 1–13 May 1986.

Sampling from	Sampling to	I_{aer}	I_2	CH_3I	HIO
01-05-86 13:30	01-05-86 15:20	32.0	31.0	34.7	2.3
01-05-86 15:20	02-05-86 09:00	29.0	38.4	27.4	5.2
02-05-86 09:00	02-05-86 18:25	33.0	33.0	34.0	0
02-05-86 18:25	03-05-86 10:30	22.2	35.7	42.1	0
03-05-86 10:30	04-05-86 08:55	27.2	26.9	45.6	0
04-05-86 08:55	05-05-86 08:15	14.8	38.5	46.6	0
05-05-86 08:15	06-05-86 08:20	30.2	30.6	39.2	0
06-05-86 08:20	07-05-86 08:20	18.7	41.7	35.8	4.8
07-05-86 08:20	08-05-86 08:20	36.9	32.3	30.7	0
08-05-86 08:20	09-05-86 09:20	23.1	22.6	54.3	0
09-05-86 09:20	11-05-86 19:40	10.0	20.0	70.0	0
11-05-86 19:40	13-05-86 08:10	5.9	12.3	81.9	0

Table IV-7. ^{131}I and ^{137}Cs activity concentration in air, AMAD and GSD (cascade impactor). Station Moravský Krumlov, 3–4 May 1986.

Radionuclide	Activity concentration [$Bq.m^{-3}$] particle size [μm] > 7.2	3.0–7.2	1.5–3.0	0.95–1.5	0.49–0.95	< 0.49	AMAD	GSD
^{131}I	2.18E-01	6.20E-01	5.69E-01	8.79E-01	2.82E-01	3.56E+00	0.59	5.7
^{137}Cs	2.91E-02	1.67E-01	3.78E-01	7.25E-01	1.13E-01	2.09E+00	0.65	3.5

Table IV-8. ^{131}I and ^{137}Cs activity concentration in air, AMAD and GSD (cascade impactor). Station Ostrava, 6 May 1986.

Radionuclide	Activity concentration [$Bq\ m^{-3}$] particle size [μm] > 7.2	3.0–7.2	1.5–3.0	0.95–1.5	0.49–0.95	< 0.49	AMAD	GSD
^{131}I	2.53E-02	2.00E-02	1.58E-01	1.63E-01	3.15E-01	1.33E+00	0.33	4.4
^{137}Cs	6.14E-03	1.11E-02	5.79E-02	7.87E-02	1.07E-01	2.46E-01	0.67	3.3

Fig. IV-1. The location of the stations outside of Prague, where ^{131}I in air was measured.

IV-2. Fallout

Table IV-9. Coordinates of the stations collected and measured fallout.

Locality	State	geographical coordinates Latitude (°)	Longitude (°)	Deskription
Moravský Krumlov	Czechia	49°02'56.15"	16°18'42.01"	in the high 1.2 m above concrete surface
Hradec Králové	Czechia	50°12'30.74"	15°50'26.37"	the window of the 2nd floor
Bratislava	Slovakia	48°09'16.30"	17°08'37.34"	in the high 8 m above ground, 1.5 m from the house
Košice	Slovakia	48°41'41.35"	21°16'30.94"	roof of the house with 4 floors, 40 m southly was a 16 store building

Table IV-10. Daily fallout activities of ^{131}I, ^{137}Cs and ^{134}Cs in the station Moravský Krumlov.

Sampling date	Moravský Krumlov, daily fallout activity [Bq/m^2] ^{131}I	^{137}Cs	^{134}Cs
29-04-86	start	start	start
30-04-86	2900.0	23.0	16.0
01-05-86	W 8900.0	W 800.0	W 410.0
02-05-86	2600.0	170.0	100.0
03-05-86	500.0	52.0	26.0
04-05-86	3400.0	75.0	48.0
05-05-86	1100.0	58.0	37.0
06-05-86	680.0	52.0	38.0
07-05-86	690.0	23.0	14.0
08-05-86	1300.0	51.0	30.0
09-05-86	W 2000.0	W 390.0	W 240.0
10-05-86	W 160.0	W 57.8	W 29.9

W in the table means wet fallout.
0.0 means < MDA.

Table IV-11. Daily fallout activities of ^{131}I, ^{137}Cs and ^{134}Cs in the station Hradec Králové.

Sampling date	**Hradec Králové, daily fallout activity [Bq/m^2]**		
	^{131}I	**^{137}Cs**	**^{134}Cs**
30-04-86	start	start	start
01-05-86	W 50000.0	W 3100.0	W 1500.0
02-05-86	196.0	86.0	46.0
03-05-86	580.0	240.0	0.0
04-05-86	1880.0	250.0	170.0
05-05-86	3150.0	60.0	30.0
06-05-86	1340.0	0.0	0.0
07-05-86	73.0	16.6	6.4
08-05-86	140.0	12.0	9.0

W in the table means wet fallout.
0.0 means < MDA.

Table IV-12. Daily fallout activities of ^{131}I, ^{137}Cs and ^{134}Cs in the station Bratislava (Slovakia).

Sampling date	**Bratislava, daily fallout [Bq/m^2]**		
	^{131}I	**^{137}Cs**	**^{134}Cs**
29-04-86	start	start	start
30-04-86	169.0	116.0	65.0
01-05-86	W 567.0	W 348.0	W 183.0
02-05-86	192.0	156.0	81.0
03-05-86	64.0	25.0	17.0
04-05-86	126.0	90.0	40.0
05-05-86	53.0	64.0	32.0
06-05-86	15.0	31.0	11.0
07-05-86	35.0	78.0	59.0
08-05-86	36.0	45.0	18.0
09-05-86		W 116.0	W 47.0
10-05-86		4.0	6.0

W in the table means wet fallout.
0.0 means < MDA.

Table IV-13. Daily fallout activities of ^{131}I, ^{137}Cs and ^{134}Cs in the station Košice (Slovakia).

Sampling date	**Košice, daily fallout [Bq/m^2]**		
	^{131}I	**^{137}Cs**	**^{134}Cs**
30-04-86	start	start	start
01-05-86	W7660	W 404.0	W 199.0
02-05-86	1340.0	54.0	25.0
03-05-86	510.0	31.0	14.5
04-05-86	86.0	3.2	1.7
05-05-86	84.0	0.0	0.0
06-05-86	542.0	40.0	24.0
07-05-86	416.0	40.0	15.3
08-05-86	565.0	86.0	33.1
09-05-86	683.0	90.0	57.0
10-05-86	W8031	W 1000.0	W 497.0

W in the table means wet fallout.
0.0 means < MDA.

IV-3. ^{131}I concentration in fresh grass and in milk

Table IV-14. ^{131}I mass activity in fresh grass from Prague (ČR) and Bratislava (SR) during the period 1 May – 19 June 1986 (data from Bratislava are for information only).

Date of sampling	**Daily average ^{131}I [Bq/kg fresh mass]**	
	Prague	**Bratislava**
01-05-86		4300
04-05-86		14300
05-05-86		11600
06-05-86		9540
07-05-86		10300
08-05-86		7400
09-05-86		4700
10-05-86	4580	6700
11-05-86	2720	3900
12-05-86	3660	2700
13-05-86	2920	3800
14-05-86	1070	3900
15-05-86	1860	1700
16-05-86	1240	3200
18-05-86	1980	
20-05-86	1200	
21-05-86	1200	
22-05-86	660	
23-05-86	892	
24-05-86	966	
25-05-86	629	
26-05-86	619.5	
27-05-86	454	780
28-05-86	183.5	
29-05-86	176.5	
30-05-86	199	
31-05-86	162	
02-06-86	216	
03-06-86	165	
04-06-86	133	
05-06-86	98	
06-06-86	171	
09-06-86	108	
10-06-86	154	
11-06-86	105	
16-06-86	50	
17-06-86	38	
18-06-86	45	
19-06-86	0	

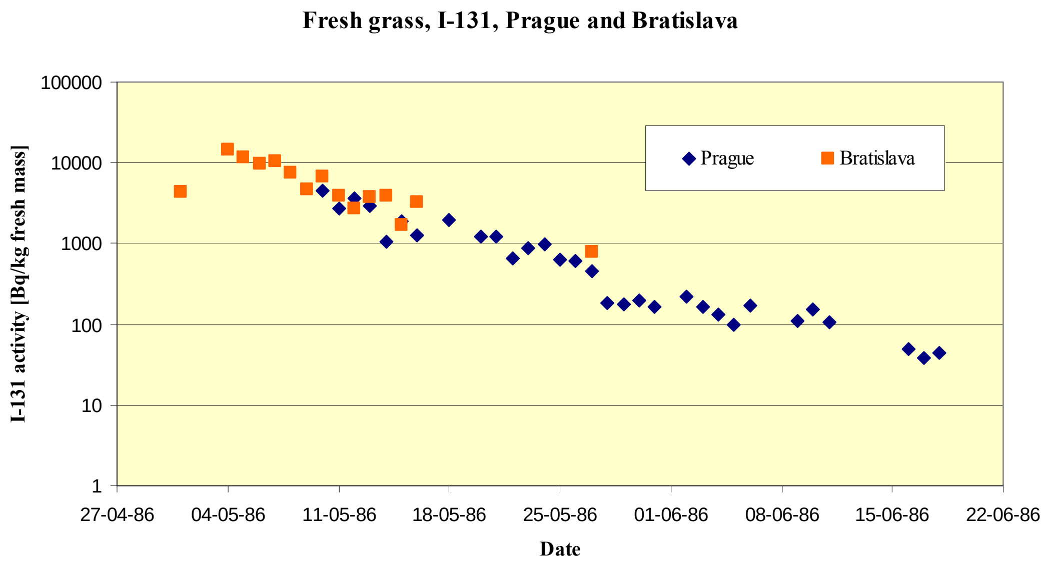


Fig. IV-2. ^{131}I mass activity in fresh grass from Prague and Bratislava during the period 1 May – 19 June 1986

Table IV-15. ^{131}I, ^{137}Cs and ^{134}Cs activity concentration in milk for Praha–Kyje dairy during the period 30 April – 15 June 1986.

Sampling date	**Activity concentration [Bq/L]**				**Ratio**	
	^{131}I	**^{131}I daily average**	**^{134}Cs**	**^{137}Cs**	**$^{131}I/^{137}Cs$**	**$^{137}Cs/^{134}Cs$**
30-04-86	103			4.5	22.9	
01-05-86	42			8	5.3	
01-05-86	170	301	8.2	9.6	17.7	1.2
01-05-86	690		15	23	30.0	1.5
02-05-86	135					
03-05-86	51					
03-05-86	88	116				
03-05-86	210		18	40	5.3	2.2
05-05-86	125	263				
05-05-86	400		4.6	6.2	64.5	1.3
06-05-86	45			6.2	7.3	
06-05-86	270	288	4.5	8.6	31.4	1.9
06-05-86	550		4.7	7.8	70.5	1.7
07-05-86	160			9.2	17.4	
09-05-86	105					
11-05-86	166		8	9.5	17.5	1.2
12-05-86	62		6	8.4	7.4	1.4
13-05-86	84		6.8	12.6	6.7	1.9
14-05-86	113		17	37.7	3.0	2.2
15-05-86	64	117	5	17	3.8	3.4
15-05-86	170		15	38	4.5	2.5
16-05-86	73			3	24.3	
17-05-86	124		15	34	3.6	2.3
18-05-86	170		10	33	5.2	3.3
19-05-86	81		8	12	6.8	1.5
20-05-86	69		11	20	3.5	1.8
21-05-86	123		14	31	4.0	2.2
22-05-86	124		18	34	3.6	1.9
23-05-86	108		25	41	2.6	1.6
24-05-86	103		16	29	3.6	1.8
25-05-86	29.7			12	2.5	
26-05-86	103			20	5.2	
27-05-86	96		17	33	2.9	1.9
28-05-86	63		11	22	2.9	2.0
29-05-86	32		23	46.2	0.7	2.0
30-05-86	44		10	24	1.8	2.4
31-05-86	33		13	32	1.0	2.5
03-06-86	22		6.5	21	1.0	3.2
04-06-86	27.4			20.3	1.3	
09-06-86	8			12	0.7	
11-06-86	9		8	21	0.4	2.6
15-06-86	22			23	1.0	

Table IV-16. ^{131}I, ^{137}Cs and ^{134}Cs activity concentration in milk for Praha–Troja dairy during the period 5 May – 16 June 1986.

Sampling date	Activity concentration [Bq/L]				Ratio	
	^{131}I	^{131}I daily average	^{134}Cs	^{137}Cs	$^{131}I/^{137}Cs$	$^{137}Cs/^{134}Cs$
05-05-86	200			3		
06-05-86	120			7		
07-05-86	3	94	3	6	0.5	2.0
07-05-86	185					
08-05-86	110					
09-05-86	140		8	19	7.4	2.4
11-05-86	75		4	6	11.9	1.6
12-05-86	65	67	7	13	5.1	1.8
12-05-86	69					
13-05-86	74		5	12	6.4	2.3
14-05-86	64		5	17	3.8	3.4
15-05-86	50	56	6	15	3.3	2.5
15-05-86	62		7	14	4.4	2.0
16-05-86	40	56				
16-05-86	71		6	17	4.2	3.1
17-05-86	71		8	16	4.4	2.0
18-05-86	52		5	15	3.5	3.0
19-05-86	40	54	4	11	3.6	2.8
19-05-86	67					
20-05-86	48		5	13	3.7	2.6
21-05-86	45			14	3.2	
22-05-86	43		5	13	3.3	2.6
23-05-86	55			16	3.4	
24-05-86	52		9	19	2.8	2.1
25-05-86	45		7	18	2.5	2.6
26-05-86	45		7	18	2.5	2.6
27-05-86	40		7	18	2.2	2.6
28-05-86	37		10	19	1.9	1.9
29-05-86	35		8	17	2.1	2.1
30-05-86	32		9	16	2.0	1.8
31-05-86	29		8	18	1.6	2.3
01-06-86	39		12	28	1.4	2.3
02-06-86	18		6	15	1.2	2.6
03-06-86	16			6	2.7	
04-06-86	19		7	12	1.6	1.7
05-06-86	15		6	14	1.1	2.3
09-06-86	11			19	0.6	
11-06-86	10					
16-06-86	6		3	7	0.9	2.3

Table IV-17. ^{131}I, ^{137}Cs and ^{134}Cs activity concentration in milk for the Benešov dairy during the period 7 May – 16 June 1986.

Sampling date	Activity concentration [Bq/L]				Ratio	
	^{131}I	^{131}I daily average	^{134}Cs	^{137}Cs	$^{131}I/^{137}Cs$	$^{137}Cs/^{134}Cs$
07-05-86	210	225		7.6	27.6	
07-05-86	240					
08-05-86	300		14	34.6	8.7	2.5
11-05-86	216		10	17.6	12.3	1.8
12-05-86	210		9	15.2	13.8	1.7
13-05-86	170		40	20	8.5	0.5
14-05-86	105		4.6	9.5	11.1	2.1
16-05-86	94		13	28	3.4	2.2
17-05-86	133		11	23	5.8	2.1
18-05-86	50			8	6.3	
19-05-86	94		11	24	3.9	2.2
20-05-86	160		10	23	7.0	2.3
21-05-86	76		10	23	3.3	2.3
22-05-86	60		9	21	2.9	2.3
23-05-86	20		5	9	2.2	1.8
24-05-86	48		12	20	2.4	1.7
25-05-86	53		11	22	2.4	2.0
26-05-86	51			30	1.7	
27-05-86	28		8	19	1.5	2.4
28-05-86	26		8	14	1.9	1.8
29-05-86	25		7	15	1.7	2.1
30-05-86	17		5	15	1.1	3.0
31-05-86	20		7	16	1.3	2.3
01-06-86	32		3	9	3.6	3.0
02-06-86	35.4		22.3	41.5	0.9	1.9
15-06-86	9			18	0.5	
16-06-86	10		31	56	0.2	1.8

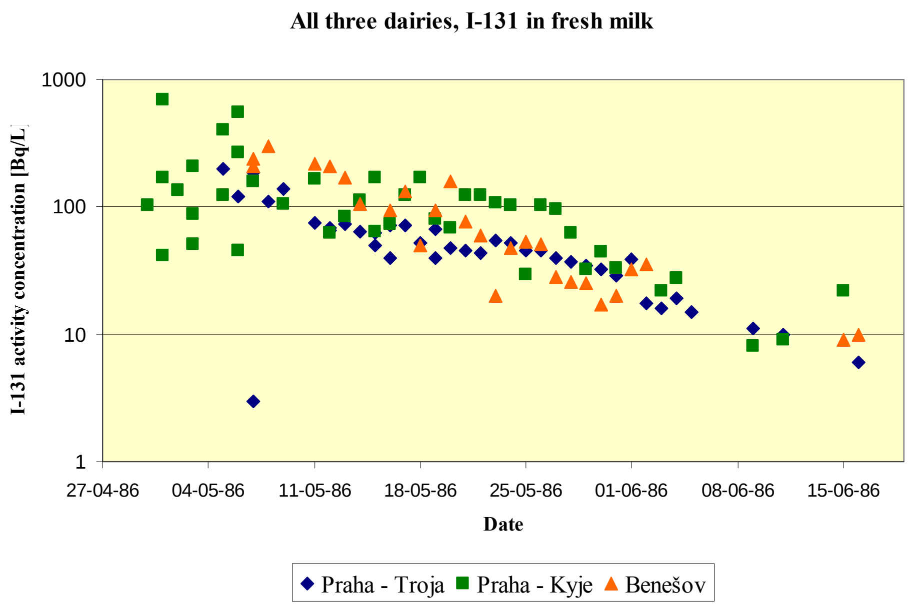


Fig. IV-3. ^{131}I activity concentrations in milk in the Praha–Kyje, Praha–troja and Benešov dairies during the period 30 May – 16 June 1986

IV-4. ^{131}I activities in thyroid

Table IV-18. ^{131}I activities in thyroid for the adult Prague inhabitants for the period 4 May – 20 June 1986.

Date	Personal code	Year of birth	Sex	I-131 activity in thyroid [Bq]
04-05-86	A002723	1943	f	1167
04-05-86	A002746	1940	f	1207
04-05-86	A002740	1956	m	1827
04-05-86	A001429	1966	f	2607
04-05-86	A000371	1947	f	2947
05-05-86	A002208	1925	m	733
05-05-86	A000908	1949	m	1000
05-05-86	A002364	1932	f	1027
05-05-86	A000604	1958	m	1033
05-05-86	A000746	1957	m	1207
05-05-86	A002251	1929	f	1887
05-05-86	A001494	1945	f	2200
05-05-86	A002127	1959	f	3180
05-05-86	A002707	1961	f	3593
06-05-86	A001644	1939	f	613
06-05-86	A001416	1945	f	913
06-05-86	A003106	1927	f	1220
06-05-86	A000052	1945	m	1253
06-05-86	A003107	1942	f	1747
06-05-86	A001463	1946	m	1767
06-05-86	A002726	1938	m	2700
06-05-86	A002769	1935	f	2720
07-05-86	A000360	1941	f	633
07-05-86	A002707	1961	f	633
07-05-86	A002103	1965	f	907
07-05-86	A000590	1950	m	1127
07-05-86	A001140	1945	f	1220
07-05-86	A001622	1948	m	1620
07-05-86	A002282	1936	m	1720
08-05-86	A002720	1943	f	447
08-05-86	A001640	1944	m	1160
08-05-86	A001877	1942	m	1240
08-05-86	A001850	1946	f	1513
08-05-86	A000730	1962	f	1573
08-05-86	A002726	1938	m	1800
08-05-86	A000371	1947	f	2400
08-05-86	A002702	1945	f	3000
08-05-86	A000475	1964	m	3127
09-05-86	A002740	1956	m	413
09-05-86	A001775	1935	m	680
09-05-86	A002498	1952	f	873
09-05-86	A002707	1961	f	1073
09-05-86	A001637	1900	m	1127
09-05-86	A002718	1954	m	3053
11-05-86	A002734	1944	f	320
11-05-86	A000904	1956	m	687
11-05-86	A002701	1925	m	807
11-05-86	A002730	1943	m	840
11-05-86	A002726	1938	m	993
11-05-86	A002718	1954	m	1160
11-05-86	A000371	1947	f	2247

F in the table means female.
M means male.

Table IV-18. (Continued)

Date	Personal code	Year of birth	Sex	I-131 activity in thyroid [Bq]
12-05-86	A001429	1966	f	333
12-05-86	A002746	1940	f	447
12-05-86	A001680	1939	f	473
12-05-86	A001801	1946	m	507
12-05-86	A000610	1965	f	507
13-05-86	A000717	1955	m	300
13-05-86	A000933	1927	m	327
13-05-86	A000437	1954	f	413
13-05-86	A000299	1953	f	647
13-05-86	A000737	1969	f	720
14-05-86	A003110	1900	f	127
14-05-86	A002498	1952	f	307
14-05-86	A002724	1936	f	540
14-05-86	A000371	1947	f	833
14-05-86	A002741	1941	m	1140
15-05-86	A000457	1952	f	160
15-05-86	A001663	1955	f	273
15-05-86	A002507	1946	f	860
16-05-86	A000176	1940	m	360
16-05-86	A000333	1974	f	473
17-05-86	A000163	1928	m	413
19-05-86	A001429	1966	f	113
19-05-86	A002740	1956	m	207
22-05-86	A001825	1958	f	213
22-05-86	A001429	1966	f	220
22-05-86	A000894	1960	f	267
22-05-86	A000371	1947	f	420
22-05-86	A000536	1936	m	540
24-05-86	A001170	1930	m	407
26-05-86	A000334	1948	m	753
27-05-86	A002747	1931	m	73
27-05-86	A002701	1925	m	200
27-05-86	A002730	1943	m	260
27-05-86	A002741	1941	m	307
28-05-86	A001252	1943	m	107
28-05-86	A002718	1954	m	147
28-05-86	A002718	1954	m	193
28-05-86	A002726	1938	m	627
29-05-86	A002498	1952	f	107
29-05-86	A001644	1939	f	233
02-06-86	A001132	1949	m	67
03-06-86	A000180	1951	f	193
04-06-86	A003129	1954	m	87
06-06-86	A003144	1952	f	127
11-06-86	A002720	1943	f	107
17-06-86	A002730	1943	m	80
17-06-86	A002701	1925	m	100
20-06-86	A002717	1949	f	60

F in the table means female.
M means male.

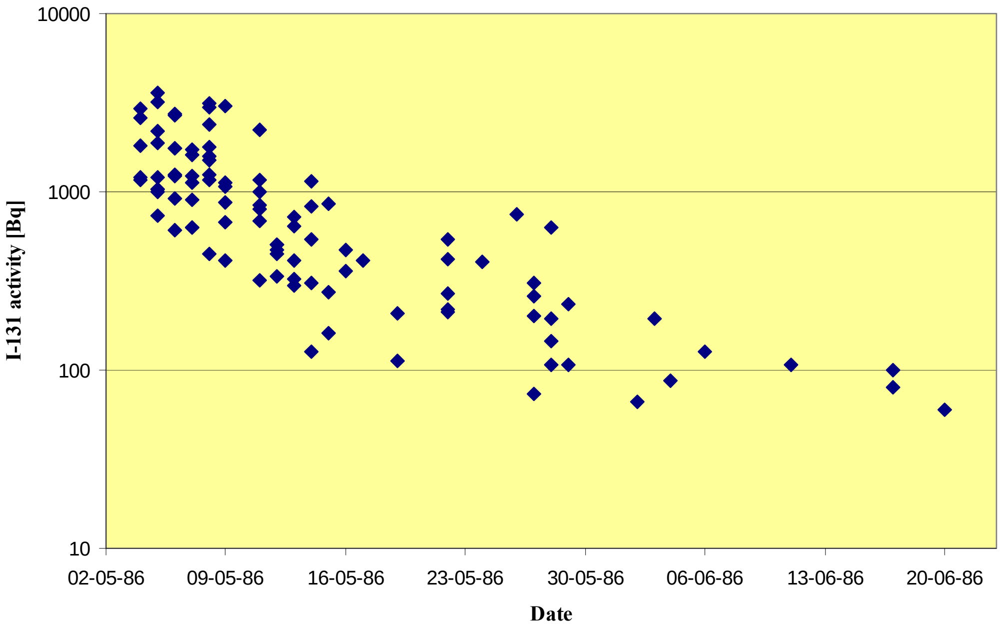


Fig. IV-4. ^{131}*I Activity in the thyroid for the adult Prague inhabitants.*

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APPENDIX IV. MODEL DESCRIPTIONS AND PERSONAL EVALUATION OF MODELS PERFORMANCE

IV.1. LIETDOS-IODINE Model Description

T. Nedveckaite, V. Filistovic, Institute of Physics, Lithuania

IV.1.1. Generic model description and assumptions

The LIETDOS computer code has been developed to calculate hourly radioiodine air activity concentrations, deposition, grass and milk activities over the entire study region. The part of the LIETDOS code system, the LIETDOS-IODINE module used in Plavsk, Warsaw or Prague scenarios, has been developed in connection with the investigation of the Chernobyl accident consequences, namely the assessments of doses to the thyroid gland.

IV.1.2. Modelling Approaches (conceptual and mathematical)

IV.1.2.1. Total integrated ^{131}I air concentration in air

The integrated ^{131}I air concentration in air:

$$C_{int,air}(t) = \int_0^t C_{air}(\tau)\cdot d\tau \qquad \text{(IV.1.1)}$$

The contribution of the radioiodine forms i.e. particulate, reactive gaseous and organic forms, to the integrated air concentration in air was estimated as:

$$f_{p,total} = \frac{1}{C_{int,air}}\int_0^t f_p(\tau)\cdot C_{air}(\tau)\cdot d\tau \qquad \text{(IV.1.2)}$$

where:

$p = a$ for particulate;
$p = u$ for reactive gaseous; and
$p = o$ for organic gaseous radioiodine.

Were used ^{131}I dry and wet deposition velocities as follows:

$$v_{dry} = v_{d,p}\cdot f_p + v_{d,r}\cdot f_r + v_{d,o}\cdot f_o \qquad \text{(IV.1.3)}$$

$$v_{wet} = I_0\cdot\left(w_p\cdot f_p + w_r\cdot f_r + w_o\cdot f_o\right) \qquad \text{(IV.1.4)}$$

where:

f_p, f_r, f_o is the particulate, reactive and organic parts of all ^{131}I activity, respectively;
$v_{d,p}$, $v_{d,r}$, $v_{d,o}$ is the dry deposition of ^{131}I particulate, reactive and organic fractions respectively, m s^{-1};
I_0 is the precipitation rate, m s^{-1};
w_p, w_r, w_o is the washing factors of ^{131}I particulate, reactive and organic fractions respectively.

IV.1.2.2. Total deposition density D_{total}, dry deposition velocity v_d

The total (dry and wet) deposition rate at time *t* to plants is given by:

$$\dot{D}_{dry\&wet,grass}(t) = \dot{D}_{grass}(t) + f_{w,grass}\dot{D}_{w,grass}(t) \qquad \text{(IV.1.5)}$$

where:

$\dot{D}_{total,gras}(t)$ is the total dry deposition rate (Bq m^{-2} d^{-1}) onto grass or another plant;
$\dot{D}_{gras}(t)$ si the dry deposition rate onto grass (Bq·m^{-2}·d^{-1});
$f_{w,grass}$ is the wet interception fraction for grass; and
$\dot{D}_{w,gras}(t)$ is the wet deposition rate (Bq·m^{-2}·d^{-1}).

The dry deposition rate to different plant species is calculated from the time-dependent air concentration using a deposition velocity rate which depends on the plant type:

$$\dot{D}_{gras}(t) = v_{d,grass}(t) \cdot C_{air}(t) \tag{IV.1.6}$$

$$\dot{D}_{soil}(t) = v_{d,soil} \cdot C_{air}(t) \tag{IV.1.7}$$

where:

$\dot{D}_{gras}(t)$ is the dry activity deposition rate onto plant type *i* (Bq·m^{-2}·d^{-1});
$v_{d,grass}(t)$ is the deposition velocity for pasture grass (m·s^{-1}); and
$C_{air}(t)$ is the time-dependent activity concentration in air (Bq·m^{-3}).

$$D_{dry,total} = \int_0^{\infty} \left[v_{d,eff,gras}(\tau) + v_{d,eff,soil}(\tau)\right] \cdot C_{air}(\tau) \cdot d\tau \tag{IV.1.8}$$

One way to consider the two parts of the dry deposition process such as the atmospheric and the surface part is the so-called resistance approach [IV.1].

The deposition velocity $v_{d,i}$ to plant canopy is defined as the inverse of R_{tc}, and the total deposition velocity to both surfaces as the sum of the inverse of R_{tc} and R_{ts}:

$$v_{d,i} = 1 / R_{tc};\ v_{total} = 1 / R_{tc} + 1 / R_{ts}\ v_{d,i} = 1 / R_{tc};\ v_{total} = 1 / R_{tc} + 1 / R_{ts} \tag{IV.1.9}$$
$$R_{tc} = R_a + R_c;\ R_{ts} = R_a + R_s$$

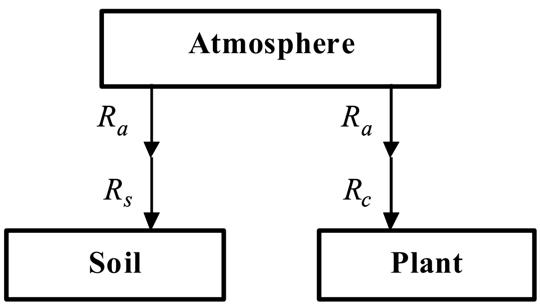


Fig. IV.1.1. Deposition process in the resistance approach.

The atmospheric resistance R_a can be estimated as:

$$R_a = \frac{U}{u_*^{\ 2}};\ u_* = 0.4\frac{U}{\log(z_U / z_0)} \tag{IV.1.9}$$

where:

u_* is the friction velocity;
U is the mean wind speed at reference height (used value U=5 m/s); and
z_U (z_U =10 m) and z_0 is the roughness height (for grassland z_0 =0.05 m, for agricultural surface type - z_0 = 0.1 m).

The canopy resistance R_c is assumed to depend on the stage of development of the plant canopy. This causes a pronounced seasonality of the deposition to the plant. The plants' stage of development can be characterized by the actual leaf area index (LAI; unit: $m^2 \cdot m^{-2}$) which is defined as the area of leaves present on a unit area of ground. The canopy resistance is assumed to be inverse proportional to the LAI:

$$\frac{1}{R_c} = v_{d,\max} \cdot \frac{LAI_i}{LAI_{\max,i}} \tag{IV.1.10}$$

where:

$v_{d,\max}$ is the maximum dry deposition velocity(m s^{-1}) for plant type i (i.e. for fully developed foliage - this corresponds to the maximum deposition velocity $v_{d,max}$);
$LAI_i$is the leaf area index of plant type i at time of deposition; and
$LAI_{max,i}$ is the leaf area index of plant type i at time of fully developed foliage (for pasture grass $LAI_{max,grass}$ = 7 m^2/m^2).

The canopy resistance depends on the chemical form of the radionuclides. It is assumed that iodine radionuclides are bound to aerosol particles, elemental and organic forms, where f_a, f_u and f_o denote the relative amount of these fractions respectively ($f_a + f_u + f_o = 1.0$). The effective dry deposition velocity can be evaluated by:

$$v_{d,eff,grass} = \left(f_a \cdot v_{d,a} + f_u \cdot v_{d,u} + f_o \cdot v_{d,o}\right) \tag{IV.1.11}$$

In this calculations it was used value $LAI_{grass}/LAI_{max,grass}$ = 0.3 .

The default values of $v_{g,i,max}$ – the maximum deposition velocity for plants with fully developed foliage - used in [IV.1] are given in Table IV.1.1.

Table IV.1.1. Deposition velocities $v_{d,max}$ used in [IV.1] for soil, other surfaces and fully developed plant canopies.

Surface type	**Deposition velocity (mm s^{-1})**		
	Aerosol bound radionuclides	**Elemental iodine**	**Organic bound iodine**
Soil	0.5	3	0.05
Pasture (grassland)	1.5	15	0.15

IV.1.2.3. Contamination of grass and soil

Time dependent grass $C_{grass}(t)$, kBq kg^{-1}, and soil $C_{soil}(t)$, kBq kg^{-1}, contamination by ^{131}I, based on ^{137}Cs ground deposition density and ^{131}I/^{137}Cs ratio scenario data, are given by:

$$C_{grass}(t) = D_{ground}\left(^{131}I\right)\cdot \frac{f}{Y}\cdot \exp\left[-(\lambda_{wd} + \lambda_r)\cdot t\right] \tag{IV.1.13}$$

$$C_{soil}(t) = D_{ground}\left(^{131}I\right)\cdot \frac{(1-f)}{H_S \cdot \rho_S}\cdot \exp(-\lambda_r \cdot t) \tag{IV.1.14}$$

where:

f is the initial interception factor of ^{131}I by vegetation, relative units;
Y is the yield of vegetation at the time of deposition, kg·m^{-2};
$\boldsymbol{H_S}$ is the depth of upper soil layer where initial deposited activity was distributed, m;
ρ_S is the upper soil layer density, kg·m^{-3}; and
λ_{wd} is the rate of the radionuclide remove from grass due to weathering and growth dilution, d^{-1}.

Time-dependent concentration in grass C_{grass}, Bq kg^{-1} and soil contamination C_{soil}, Bq kg^{-1} for specified location in Warsaw and Prague Scenario has been calculated as:

$$C_{grass}(t) = \int_0^t \frac{1}{Y_{grass}} v_{deff,grass}(\tau)\cdot C_{air}(\tau)\cdot \exp\left[-(\lambda_{wd} + \lambda_r)\cdot(t-\tau)\right]d\tau \tag{IV.1.15}$$

$$C_{soil}(t) = \int_0^t \frac{1}{H_S \cdot \rho_S} v_{deff,soil}(\tau)\cdot C_{air}(\tau)\cdot \exp\left[-\lambda_r \cdot(t-\tau)\right]d\tau \tag{IV.1.16}$$

where:

$$v_{deff,grass}(\tau) = f_a(\tau)\cdot v_{d,a,grass} + f_u(\tau)\cdot v_{d,u,grass} + f_o(\tau)\cdot v_{d,o,grass} \tag{IV.1.17}$$

$$v_{deff,soil}(\tau) = f_a(\tau)\cdot v_{d,a,soil} + f_u(\tau)\cdot v_{d,u,soil} + f_o(\tau)\cdot v_{d,o,soil} \tag{IV.1.18}$$

where:

f_a, f_u, f_o is the time-dependent particulate, reactive gaseous and organic gaseous radioiodine phases fractions respectively, relative units;
Y is the yield of vegetation at the time of deposition, kg·m^{-2};
H_S is the depth of upper soil layer where initial deposited activity was distributed, m;
ρ_S is the upper soil layer density, kg·m^{-3};
λ_{wd} is the rate of the radionuclide remove from grass due to weathering and growth dilution, d^{-1}; and
λ_r is the is the radioactive decay constant of ^{131}I, d^{-1}.

For the Prague Scenario:

$v_{d,eff,soil}$ – estimated effective dry deposition velocity on soil (=0.10 cm/s); and
$v_{d,eff,grass}$ – effective dry deposition velocity on grass (=0.14 cm/s).

IV.1.2.4. Food (milk and leafy vegetables) contamination for thyroid dose assessment due to ingestion

For all (Plavsk & Warsaw & Prague) scenarios the transfer of radionuclides from the grass and soil intake to the milk is described by the equilibrium transfer factor F_m and one exponentials using biological excretion rate λ_b, thus the time dependent milk contamination by ^{131}I $C_{milk}(t)$, kBq L^{-1}, has been calculated as:

$$C_{milk}(t) = F_m \cdot \int_{\Delta t_{pd}}^{t} \left[C_{grass}(\tau) \cdot I_g + C_{soil}(\tau) \cdot I_s \right] \cdot \lambda_b \cdot \exp\left[-(\lambda_b + \lambda_r) \cdot (t + \Delta t_{pd} - \tau) \right] d\tau \quad \text{(IV.1.19)}$$

where:

F_m is the cow's intake-to-milk transfer factor, d L^{-1};
I_g, I_s is the daily intake of grass and soil by cow, correspondently, kg·d^{-1};
Δt_{pd} is the period from deposition till starting of pasture period, d; and
λ_b is the biological transfer rate of iodine, d^{-1}.

Using grass and soil specific activity's time dependence as in (IV.1.2) and (IV.1.3) the last integral can be calculated analytically and the concentration of ^{131}I in milk may be expressed as:

$$C_{milk}(t) = F_m \cdot \left\{ \begin{aligned} & \frac{\lambda_b}{\lambda_b - \lambda_{wd}} \cdot C_{grass}(t) \cdot \exp\left(-\lambda_{wd} \cdot \Delta t_{pd} \right) \cdot \left[1 - \exp\left(-\left(\lambda_b - \lambda_{wd} \right) \cdot t \right) \right] \\ & \qquad + C_{soil}(t) \cdot \left[1 - \exp\left(-\lambda_b \cdot t \right) \right] \end{aligned} \right\} \quad \text{(IV.1.20)}$$

IV.1.2.5. Intake rate

The time-dependent intake rate $Q_i(t)$, kBq d^{-1} of a ^{131}I radionuclide by members of *i*-th age group has been calculated as:

$$\begin{aligned} Q_i(t) = {} & C_{milk}\left(t - \Delta t_m \right) \cdot \exp\left(-\lambda_r \cdot \Delta t_m \right) \cdot P_m \cdot I_{m,i} \\ & + C_g\left(t - \Delta t_{lv} \right) \cdot \exp(-\lambda_r \cdot \Delta t_{lv}) \cdot P_{lv} \cdot I_{lv,i} \end{aligned} \quad \text{(IV.1.21)}$$

where:

$C_g(t)$, $C_{milk}(t)$ is the ^{131}I concentration in leafy vegetables, kBq·kg^{-1}, and in milk, kBq·L^{-1}, correspondingly;
Δt_{ld} is the period from deposition till starting of leafy vegetable consumption, d;
Δt_m, Δt_{lv} is the storage time period for milk and leafy vegetable, d;
P_m, P_{lv} is the processing factors for milk and leafy vegetable, relative units; and
$I_{m,i}$, $I_{lv,i}$ is the daily intake of milk and leafy vegetable by members of *i*-th age group correspondingly, kg·d^{-1}.

It was suggested, that the same laws governed the contamination of leafy vegetables and grass.

IV.1.2.6. Thyroid dose due to inhalation and ingestion

The equivalent dose to the thyroid gland for the *i*-th age group from inhalation of ^{131}I has been estimated as:

$$D_{inh,i} = r \cdot IR_i \cdot DF_{inh,i} \cdot \int_{t_1}^{t_2} C_{air}(\tau) \cdot d\tau \qquad \text{(IV.1.22)}$$

where:

$D_{inh,i}$ is the thyroid dose for *i*-th age group due to inhalation of ^{131}I, mSv;
C_{air} is the activity concentration of ^{131}I in air, kBq·m^{-3};
IR_i is the age-dependent inhalation rate, m^3·d^{-1};
$DF_{inh,i}$ is the thyroid dose per unit of ^{131}I inhalation [IV.2], mSv·kBq^{-1}; and
$r = 0.7$, dose reduction factor for staying indoors.

The Average equivalent dose to the thyroid for *i*-th age group from ingestion of ^{131}I during time period $t_1 - t_2$ has been estimated as:

$$D_{ing,i} = \int_{t_1}^{t_2} Q_i(t) \cdot DF_{ing,i} dt \qquad \text{(IV.1.23)}$$

where:

$D_{ing,i}$ is the thyroid dose for *i*-th age group from ingestion of ^{131}I, mSv;
$Q_i(t)$is the ^{131}I intake function for *i*-th age group, kBq·d^{-1}; and
$DF_{ing,i}$ is the thyroid dose per unit of ^{131}I ingestion [IV.3], mSv·kBq^{-1}.

IV.1.2.7. Calculation of the thyroid burden

$$Q(t) = \frac{f_2 \cdot U_0}{(\lambda_m - \lambda_{eff})} \cdot \left[e^{-\lambda_{eff} \cdot t} - e^{-\lambda_m \cdot t}\right] \qquad \text{(IV.1.25)}$$

where:

$Q(t)$ is the ^{131}I content in thyroid, Bq;
U_0 is the initial ^{131I} intake rate by ingestion, Bq d^{-1};
λ_m is the clearance rate for iodine in the thyroid, d^{-1};
f_2 is the thyroid ^{131}I uptake parameter;
λ_{eff} is the effective transfer rate (decrease) of iodine from thyroid, d^{-1}; and

Another way to calculate the thyroid equivalent dose HT (Sv) was based on biokinetic model for iodine. A three-compartmental biokinetic model for iodine, data for reference man, and the computer program LIETDOS, which was tested during the BIOMASS Hanford exercise, have been used to evaluate the radiation dose to the thyroid gland, depending on the age at exposure and stable iodine deficiency. The following equations were used for stable iodine ($Y_{S,i}$ = the content of stable iodine, μg):

$$\frac{dY_{S,1}}{dt} = I_{S,0}(t) - \lambda_{12} Y_{S,1};$$
$$\frac{dY_{S,2}}{dt} = \lambda_{12} Y_{S,1} + f_1 I'_{S,0}(t) + \lambda_{42} Y_{S,4} - \alpha_S - \lambda_2 Y_{S,2};$$
$$\frac{dY_{S,3}}{dt} = \alpha_S - \lambda_{34} Y_{S,3}; \quad \frac{dY_{S,4}}{dt} = \lambda_{34} Y_{S,3} - (\lambda_{42} + \lambda_4) Y_{S,4} \tag{IV.1.26}$$

where:

$I_{S,0}$, $I'_{S,0}$ is the daily stable iodine intake by ingestion and inhalation respectively, µg d^{-1};
α_S is the uptake rate of stable iodine to the thyroid gland, µg d^{-1};
f_1 is the fraction of inhalation intake that is cleared directly from the lung to the blood;
λ_{12} is the constant for ingested iodine intake to the blood, d^{-1};
λ_{34} is the constant for iodine cellular uptake from thyroid pool, d^{-1};
λ_{42} is the constant for deiodination of thyroid hormone, d^{-1}; and
λ_2, λ_4 is the constant for iodine urinary and faecal excretion, respectively, d^{-1}.

The activity balance for radioactive iodine ($Y_{R,i}$ = the activity of radioiodine, Bq) can be represented as follows:

$$\frac{dY_{R,1}}{dt} = I_{R,0}(t) - (\lambda_{12} + \lambda_r) Y_{R,1}$$
$$\frac{dY_{R,2}}{dt} = \lambda_{12} Y_{R,1} + f_1 I'_{R,0}(t) + \lambda_{42} Y_{R,4} - \alpha_S \frac{Y_{R,2}}{Y_{S,2}} - (\lambda_2 + \lambda_r) Y_{R,2} \tag{IV.1.27}$$
$$\frac{dY_{R,3}}{dt} = \alpha_S \frac{Y_{R,2}}{Y_{S,2}} - (\lambda_{34} + \lambda_r) Y_{R,3}; \quad \frac{dY_{R,4}}{dt} = \lambda_{34} Y_{R,3} - (\lambda_{42} + \lambda_4 + \lambda_r) Y_{R,4}$$

where:

$I_{R,0}$, $I'_{R,0}$ is the radioiodine intake rate by ingestion and inhalation respectively, Bq d^{-1}; and
λ_r is the radioiodine decay constant, d^{-1}.

The thyroid equivalent dose H_T (Sv) is:

$$H_T = \frac{E_{eff,\beta\gamma}}{m_T} \cdot \int_0^\infty Y_{R,3}(t) dt = SEE \cdot \int_0^\infty Y_{R,3}(t) dt \tag{IV.1.28}$$

where:

$E_{eff,\beta\gamma}$ is the effective energy absorbed in thyroid per transformation of iodine radionuclide, J (Bq d)$^{-1}$;
m_T is the thyroid mass, kg; and
SEE is the specific effective energy, Sv (Bq d)$^{-1}$.

IV.1.3. Parameter Values

Used parameter distribution functions, their mean and standard deviation values in the Plavsk scenario are given in Table IV.1.2. For other (Warsaw and Prague) scenarios some parameters were changed, according the scenario description.

IV.1.4. Uncertainties

The uncertainties and accuracy used in model results, due to uncertainties in scenario description and model parameter values has been determined by Cristal Ball sampling from prescribed distributions of model parameters.

The validity and limitation of developed software are demonstrated through comparison of results using LIETDOS-IODINE program scenario measurements and other publications [IV.5]. The uncertainty used in the model results due to uncertainties in model parameter values, has been determined by Monte Carlo sampling from prescribe distributions of model parameters. In specific cases the uncertainty estimates were derived by personal judgement of model parameters uncertainty range, considering experience after the Chernobyl accident. Basically the model employs a deterministic approach. This deterministic code was run repeatedly to generate a distribution of predictions in order to obtain 95% confidence interval. 1000 series of runs were required to obtain all results.

TableIV.1.2. Parameter values and distributions used in the Plavsk scenario study: parameter values according [IV.4–IV.6].

Parameter	Description	Distribution	Mean	S.D. (min, max)	Units
$Date_{Start}$	Started district contamination	–	29 04 1986 09:00	–	–
$Date_{End}$	Depart district date	–	30 12 1986 09:00	–	–
R	Ratio $^{131}I/^{137}Cs$	lognormal	3.34	0.33	–
$T_{1/2}$	Half-life of ^{131}I	–	8.05	–	d
μ	Mass interception factor for grass (FW)	–	1	–	$m^2\ kg^{-1}$
f	Initial interception factor for grass	lognormal	0.36	0.09	-
Y	Yield of pasture (FW)	uniform	0.45	0.2	$kg\ m^{-2}$
λ_{wd}	Weathering and dilution constant	normal	0.08	0.016	d^{-1}
F_m	Milk transfer factor	lognormal	0.003	0.0026	$d\ L^{-1}$
I_g	Daily intake of grass by cow (FW)	uniform	45	6.75	$kg\ d^{-1}$
I_s	Daily intake of soil by cow	uniform	0.25	0.075	$kg\ d^{-1}$
H_S	Depth of upper soil layer, where initial deposition was distributed	uniform	0.005	0.001	m
ρ_S	Upper soil layer density	uniform	1200	115	$kg\ m^{-3}$
λ_b	Biological transfer rate of iodine to milk	triangle	0.81	0.1	d^{-1}
Δt_m	Storage time period for milk	uniform	0.5	0.29	d
Δt_{lv}	Storage time period for leafy vegetable	uniform	2	1.15	d
P_{lv}	Processing factor of leafy vegetable	normal	0.7	0.3	–
I_{lv}	Daily intake of leafy vegetable (FW)	normal	0.030	0.005	$kg\ d^{-1}$
f_p	Particulate fraction in the air	–	0.4	–	–
f_r	Reactive fraction in the air	–	0.3	–	–
f_o	Organic fraction in the air	–	0.3	–	–
$v_{d,p}$	Dry deposition of particulate ^{131}I	loguniform	0.158	(0.05–0.5)	$cm\ s^{-1}$
$v_{d,r}$	Dry deposition of reactive ^{131}I	loguniform	0.950	(0.3–3.0)	$cm\ s^{-1}$
$v_{d,o}$	Dry deposition of organic ^{131}I	loguniform	0.007	(0.001–0.050)	$cm\ s^{-1}$
w_p	Wet deposition coefficient of particulate ^{131}I	logtriangular	2.50×10^6	$(1.0–5.4)\times10^6$	–
w_r	Wet deposition coefficient of reactive ^{131}I	logtriangular	5.00×10^6	$(2.1–10.7)\times10^6$	–
w_o	Wet deposition coefficient of organic ^{131}I	logtriangular	8.00×10^3	$(4.0–18.0)\times10^3$	–
p	Ratio of wet deposition time to total deposition time	–	0.375	–	–
r	Dose reduction factor for staying indoors	uniform	0.7	0.05	–
I_0	Precipitations, mm	–	6.3	–	mm

IV.1.5. Application of the model to the all (Plavsk & Warsaw & Prague) scenarios

IV.1.5.1. Application of the model to the Plavsk scenario

Ground deposition

In areas with the predominantly mixed (wet and dry) deposition, the determination of the hypothetical deposition value leads to large uncertainty. In relation to this the effective (dry and wet) deposition velocity v_{eff} has been put in use and time-integrated activity concentration of ^{131}I in air was estimated according the ground deposition (Plavsk Scenario) as follows:

$$\int_{t_1}^{t_2} C_{air}(\tau)\cdot d\tau = \frac{D_{ground}}{v_{eff}} = p\cdot\frac{D_{wet}}{v_{wet}} + (1-p)\cdot\frac{D_{ground}-D_{wet}}{v_{dry}} \qquad \text{(IV.1.29)}$$

where:

D_{ground} is the total (dry and wet) deposition, Bq m^{-2};
D_{wet} is the part of wet deposition, Bq m^{-2} ;
p is the ratio of wet deposition time to total deposition time;
v_{wet} is the wet deposition velocity, m s^{-1};
v_{dry} is the dry deposition velocity, m s^{-1}; and
v_{eff} *is* the effective (dry and wet) deposition velocity of ^{131}I, m·s^{-1}.

The deposition velocity of iodine varies with the physiochemical speciation of the iodine. For instance, the deposition velocity of elemental iodine is up to 10^4 times higher than that of organic iodides and about five times higher than that of iodine attached to particulate matter [IV.6]. Knowledge of the physiochemical form of ^{131}I in the atmosphere as well as their dry and wet deposition velocities is therefore important in order to evaluate atmospheric radioiodine species and inhalation dose assessment based on ^{137}Cs ground deposition density and ^{131}I/^{137}Cs ratio scenario data.

Finally the effective deposition velocity was estimated as:

$$v_{eff} = \left[\frac{p}{I_0\cdot\left(w_p\cdot f_p + w_r\cdot f_r + w_o\cdot f_o\right)}\cdot\frac{D_{wet}}{D_{ground}} + \frac{(1-p)}{v_{d,p}\cdot f_p + v_{d,r}\cdot f_r + v_{d,o}\cdot f_o}\cdot\left(1-\frac{D_{wet}}{D_{ground}}\right)\right]^{-1} \qquad \text{(IV.1.30)}$$

In Figure IV.1.2 the dependence of particulate, gaseous reactive and gaseous organic fraction effective deposition velocities in the case of different contribution of wet deposition are presented.

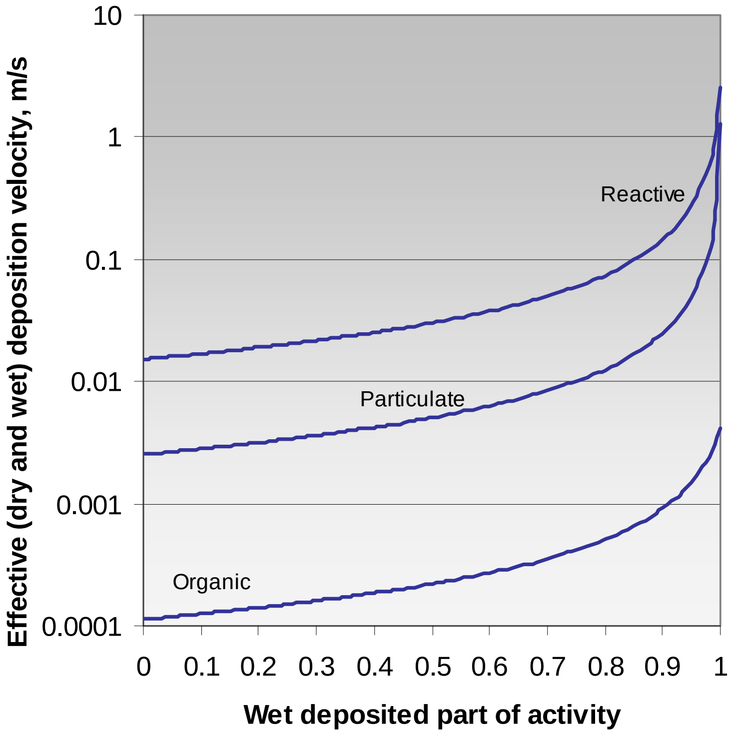


Fig. IV.1.2. The dependence of effective deposition velocities on the part of reactive, particulate and organic ^{131}I wet deposited activity.

These evaluations are based on ^{137}Cs ground deposition density and ^{131}I/^{137}Cs ratio in the ground depositions at the time of deposition started. The ^{131}I ground deposition density D_{ground}(^{131}I), kBq·m^{-2}, in the settlements at the time of deposition started was estimated as:

$$D_{ground}\left({}^{131}\mathrm{I}\right) = R\left({}^{131}\mathrm{I}/{}^{137}\mathrm{Cs}\right)\cdot D_{ground}\left({}^{137}\mathrm{Cs}\right)\cdot \exp\left(\lambda_r \cdot \Delta t_0\right) \qquad \text{(IV.1.31)}$$

where:

D_{ground}(^{131}I) is the ground deposition density of ^{131}I, kBq·m^{-2};
D_{ground}(^{137}Cs) is the ground deposition density of ^{137}Cs, kBq·m^{-2};
R(^{131}I/^{137}Cs) is the ratio of ^{131}I and ^{137}Cs activities in the ground depositions (R(^{131}I/^{137}Cs) = 3.34; standard error 19.5%; corresponds to 10 May 1986);
λ_r is the radioactive decay constant of ^{131}I, d^{-1};
Δt_0 is the period from deposition starting time (by Scenario Description it was 4.3 days after accident) till deposition measurement time (10 May 1986), d.

The value of R(^{131}I/^{137}Cs) is corrected according to radioactive decay and corresponds to 10 May 1986.

The ground deposition density of ^{137}Cs and ^{131}I/^{137}Cs ratio is given as the sum of dry and wet deposition. The dry or wet deposition velocity depends on the physical-chemical speciation of these radionuclides (aerosol bound, elemental iodine and organically bound iodine are distinguished). It would therefore be necessary to determine whether fallout was dry or wet in the settlements under study. Semi-empirical and ecological methods were applied for these studies to reduce the uncertainty. Based on data presented in [IV.1] first of all for wet deposition it was assumed that the contribution of wet deposition increases with increasing precipitation. As a default, it was assumed that per mm of rainfall, 10% of the total deposit has been deposited during precipitation and for rainfalls of more than 9 mm, a maximal contribution of 90% wet deposition has been assumed. However, the information about rainfalls, which could be obtained from the scenario meteorological station data, is not sufficient. In areas with predominantly mixed (wet and dry) deposition, the determination of a hypothetical value of the dry deposition is extremely highly subjective, and leads to large uncertainty. Thus, our totally independent assessment of the virtual dry soil contamination density with ^{137}Cs in the Plavsk region has been based on the ground deposition density in the Southern part of Plavsk region (collective farm Udarnik, Ol'hi, Skorodnoje and Novo-Nikol'skij). In this part of the Plavsk region the ^{137}Cs ground deposition density as well as its upper bound was less than 100 kBq m^{-2} and the median value was 40 kBq.m^{-2}. This assumption (40 kBq m^{-2} dry deposition density and the rest - wet deposition) has been used for further calculations.

^{131}I Transfer factors from grass to milk

In our model the transport of radioiodine from feed to milk are presented in terms of equilibrium transfer factors (*TF*) i.e. the quotient of the activity concentration in the milk expressed in terms of Bq L^{-1} and the daily intake of the radionuclide expressed as Bq d^{-1}. For radioactive iodine the transfer factor value was selected on the basis of stable iodine isotope *TF* values F_m^{St}, d/L and biological half time T_b, d of iodine passage through cows organism (iodine elimination):

$$F_m = F_m^{St} \frac{T_{1/2}}{T_b + T_{1/2}} \qquad \text{(IV.1.31)}$$

The value of the transfer factor F_m^{St} was 0.02 d/L. The average value for ^{131}I F_m= 0.0028 d L^{-1} was taken to represent the transfer to milk.

It must be noted, that the scenario data on the dates of the beginning of the grazing period for collective and private herds in 1986 (Figure IV.1.3) are assessed with the high uncertainty.

Thyroid burden

The determination of the thyroid burden for each individual group was based on the biokinetic model for iodine using time-dependent intake rate $Q_i(t)$, kBq d^{-1} of a ^{131}I radionuclide by ingestion and inhalation. In Figure IV.1.2 presents examples of the age dependent thyroid burden in the Plavsk district.

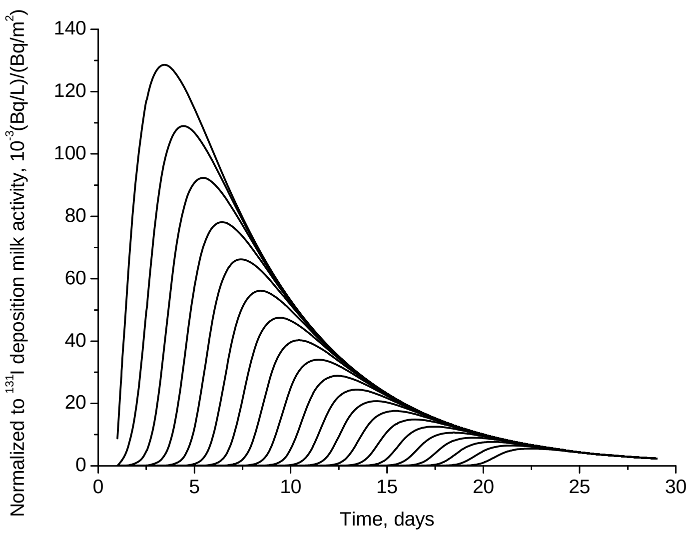


Fig. IV.1.3 ^{131}I activity in milk (normalized to ground deposition density) vs. the started time of the pasture season .

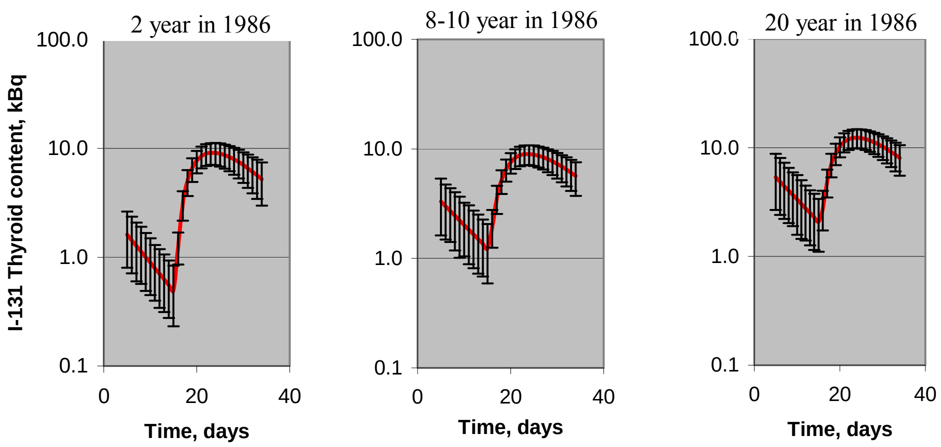


Fig. IV.1.4. An example of age dependent thyroid burden in Plavsk district.

Table IV.1.3. The relationship between aerosol-associated f_p, gaseous reactive f_r and gaseous organic f_o radioiodine measured after the Chernobyl accident (%).

Aerosol-associated	Gaseous				Area	References
	Reactive	HOI	Organic	Total		
29	32	-	39	71	Czech Rep., Prague	[IV.7]
35	14	-	51	65	Lithuania, Vilnius	[IV.8]
47	40		13	53	Poland, Warszawa	[IV.9]

IV.1.5.2. Application of the model to the Warsaw scenario

Integrated air concentration in air

Thyroid dose for *i*-th age group from the inhalation of ^{131}I has been estimated as:

$$D_{inh,i} = r \cdot IR_i \cdot \left(f_r \cdot DF^r_{inh,i} + f_p \cdot DF^p_{inh,i} + f_o \cdot DF^o_{inh,i} \right) \cdot \int_{t_1}^{t_2} C_{air}(\tau) \cdot d\tau \qquad \text{(IV.1.33)}$$

where:

$D_{inh,i}$ is the thyroid dose for *i*-th age group due to inhalation of ^{131}I, mSv;
C_{air} is the activity concentration of ^{131}I in air, Bq·d·m^{-3};
IR_i is the age-dependent inhalation rate, m^3·d^{-1};
$DF^r_{inh,i}$, $DF^p_{inh,i}$, $DF^o_{inh,i}$ is the inhalation dose coefficients, committed equivalent thyroid dose per unit of intake for reactive (elemental iodine), particulate (aerosols) and organic (methyl iodine) ^{131}I (ICRP, 1989), mSv·Bq^{-1};
r = 0.7 is the dose reduction factor for staying indoors, relative units;
f_p, f_r, f_o is the aerosol-associated (particulate), gaseous reactive and organic fractions of ^{131}I in air.

In the Warsaw Scenario the time period from 27-04-1986 to 31-05-1986 was used for the calculation of integrated air concentration (35 days period). The integrated ^{131}I air concentration value was 390 Bq·d·m^{-3}. The contribution of the radioiodine phases i.e. particulate, reactive gaseous and organic to the total integrated air concentration in air was f_p : f_r : f_o = 59 : 37 : 04 .

Ground deposition

The deposition of the ^{131}I to the grass or soil strongly depends from the foliage development state. Figure IV.1.1 presents the dependence of the dry deposition velocity from the foliage development state (LAI/LAI_{max}). The dependence of the dry ^{131}I activity interception factors by grass f on the foliage development state is presented in Figure IV.1.2.

For Warsaw scenario the estimated effective dry deposition velocity $v_{d,eff,soil}$ on Soil is 0.139 cm/s, the effective dry deposition velocity $v_{d,eff,grass}$ on grass is 0.188 cm/s and the total effective dry deposition velocity $v_{d,eff,total}$ is 0.327 cm/s. The dry activity interception factor by grass f = 0.58.

Lettuce contribution to the intake rate

The contribution of lettuce to the intake rate of ^{131}I for various individual age groups of the Warsaw and Ostroleka district was presented in Figure IV.1.7.

Thyroid doses calculation

The thyroid doses determination for each individual group was based on the biokinetic model for iodine using time-dependent intake rate $Q_i(t)$, kBq d^{-1} of a ^{131}I radionuclide by ingestion. In Figures IV.1.8 and IV.1.9 it was presented age dependent thyroid doses in Warsaw and Ostroleka district respectively.

The Influence of pasture date on the thyroid dose for various age groups of Warsaw and Ostroleka district is presented in Figure IV.1.10.

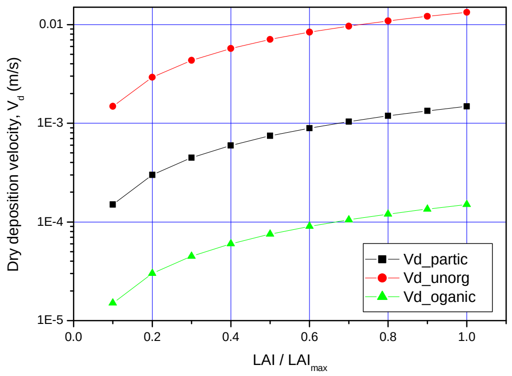


Fig.IV.1.5. Dependence of the dry deposition velocity $v_{d,grass}$ from the foliage development state LAI/LAI_{max}.

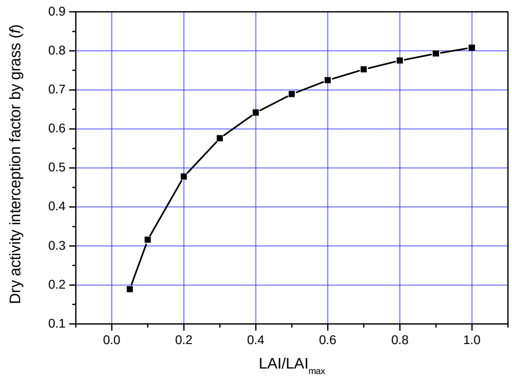


Fig. IV.1.6. Dependence of the dry ^{131}I activity interception factor by grass f from the foliage development state LAI/LAI_{max}.

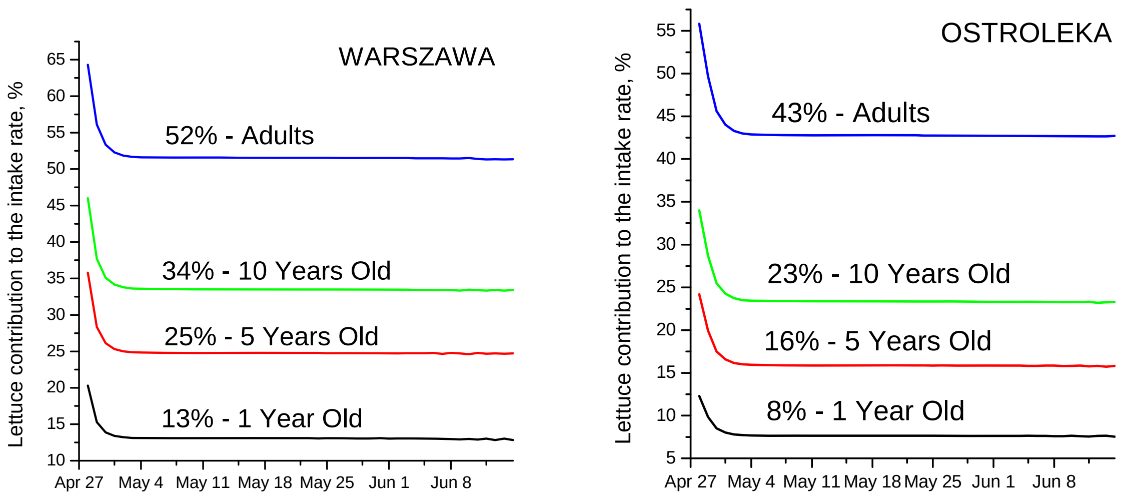


Fig. IV.1.7. Contribution of lettuce to the intake of ^{131}I for various age groups of Warsaw and Ostroleka district.

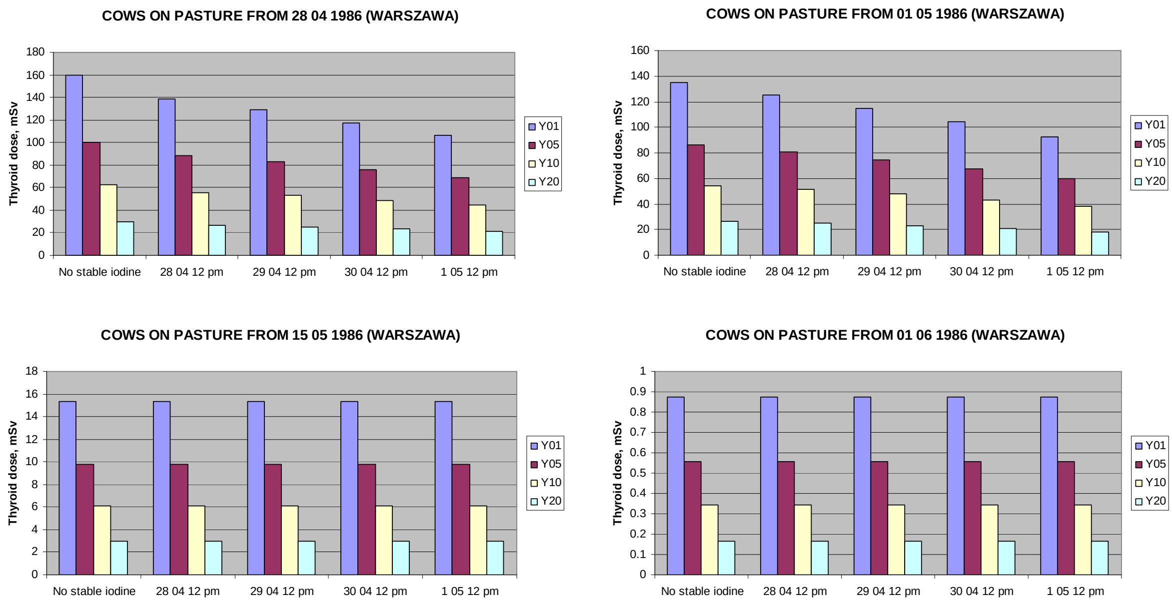


Fig. IV.1.8. Predicted age dependent thyroid doses in Warsaw district.

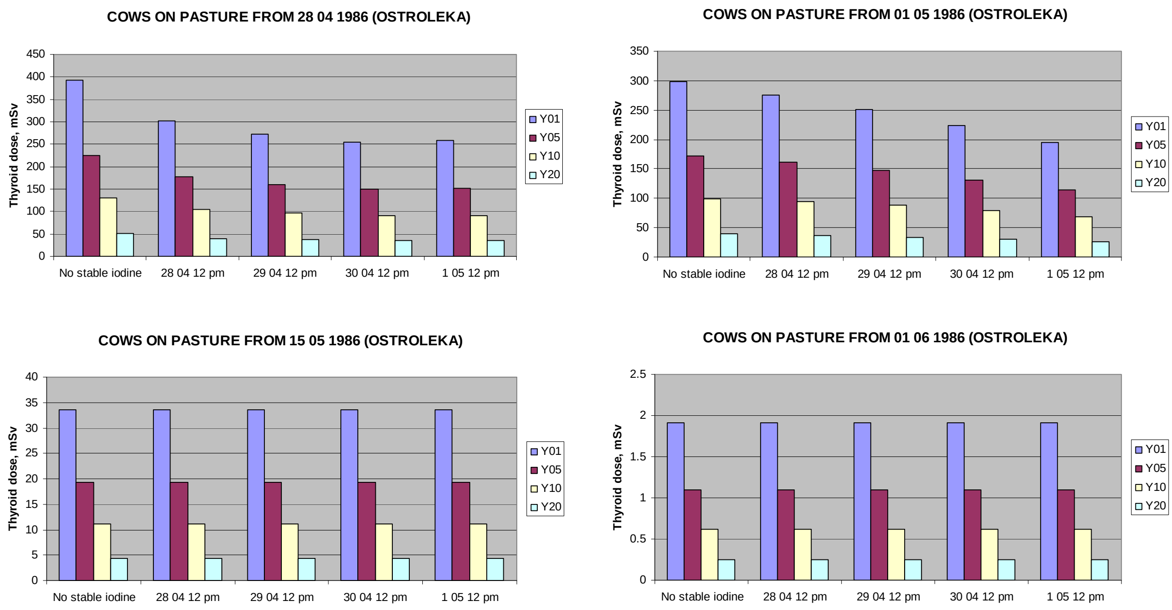
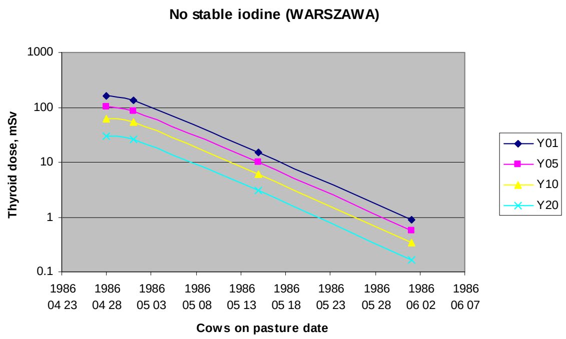


Fig.IV.1.9. Predicted age dependent thyroid doses in Ostroleka district.



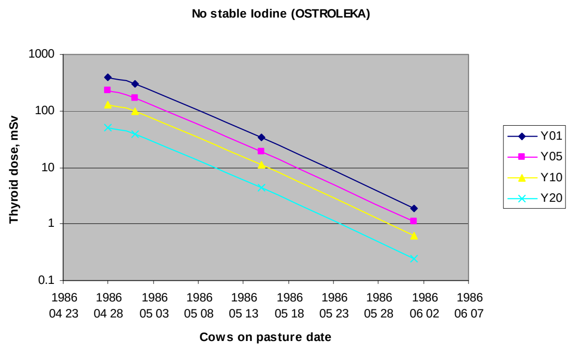


Fig.IV.1.10. Influence of the "cows on pasture date" on the thyroid dose for various age groups of Warsaw and Ostroleka district.

IV.1.6. Application of the model to the Prague scenario

IV.1.6.1. Integrated air concentration and inhalation doses

For the integration in the Prague Scenario the value t = 35 days was used (from 27-04-1986 to 31-05-1986) . The value of the integrated ^{131}I air concentration was about 162 Bq·d·m^{-3}. The contribution of the radioiodine forms (i.e. particulate, reactive gaseous and organic iodine) to the total integrated air concentration was estimated as $f_p : f_r : f_o = 28 : 32 : 40$.

The equivalent dose to the thyroid gland for i-th age group from inhalation of ^{131}I may be estimated using Jonson Model and the following intake of activity function:

$$I_{0,i}(\tau) = r \cdot IR_i \cdot C_{air}(\tau) \qquad \text{(IV.1.34)}$$

The thyroid burden and doses to the thyroid was estimated with the program Thyroid v. 2.2, which is available for download from the EMRAS I-131 webpage:
http://www-ns.iaea.org/projects/emras/emras-iodine-131-wg.asp?s=8

Age-dependent parameter values for the assessment of inhalation dose, using Jensen iodine biokinetic model for various iodine compounds [IV.2] in the Prague Scenario are presented in Table IV.1.5.

IV.1.6.2. Ingestion doses

The effect of countermeasures on the milk and leafy vegetables intake to the ingestion dose of 1 year children and adult person is presented in Figures IV.1.11 and IV.1.12.

Table IV.1.4. Inhalation doses (dose reduction factor for staying indoors r = 0.7 was assumed).

Parameter	**Units**	**Age group, years**					
		0.25	**1**	**5**	**10**	**15**	**20**
Breathing rate	m^3 d^{-1}	2.9	5.2	8.8	13.3	17.9	20
Effective dose	mSv	1.71	3.01	2.88	2.19	1.86	1.35

Table IV.1.5. Age-dependent values of model parameters and effective doses due to inhalation .

Age group, years	Inhalation rate, $m^3 d^{-1}$	Organic (methyl iodine) DF, $mSv\ Bq^{-1}$	Reactive (elemental iodine) DF, $mSv\ Bq^{-1}$	Particulate (aerosols) DF, $mSv\ Bq^{-1}$	Mean DF, $mSv\ Bq^{-1}$	Dose (using ICRP DF), mSv	Dose (using Jensen model), mSv
3 mo	2.9	2.60E-03	3.30E-03	1.40E-03	2.49E-03	1.17	1.78
1	5.2	2.50E-03	3.20E-03	1.40E-03	2.42E-03	2.04	2.33
5	8.8	1.50E-03	1.90E-03	7.30E-04	1.41E-03	2.02	1.96
10	13.3	7.40E-04	9.50E-04	3.70E-04	7.04E-04	1.52	1.75
15	17.9	4.80E-04	6.20E-04	2.20E-04	4.52E-04	1.31	-
20	20.0	3.10E-04	3.90E-04	1.50E-04	2.91E-04	0.94	1.33

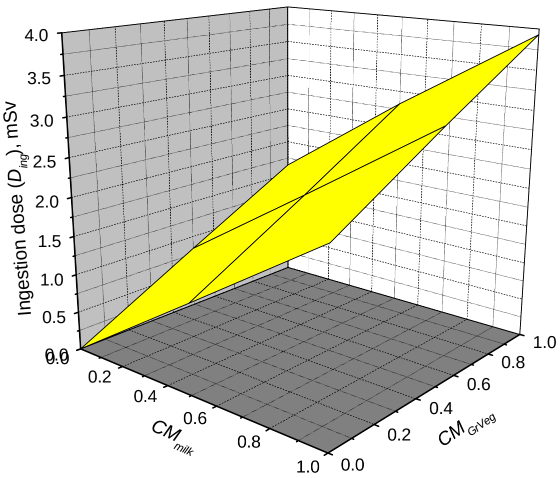


Fig. IV.1.11. Effective dose to 1 year old child (ingestion) , mSv.

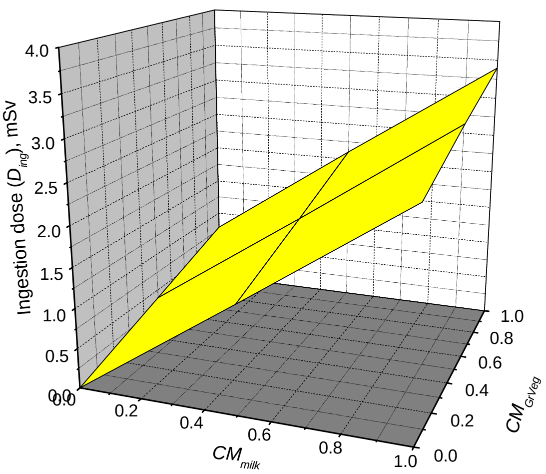


Fig. IV.1.12. Effective dose to adult (ingestion), mSv.

IV.2. MRRC – A radioecological model for assessing transferring of ^{131}I on food chains after radiation accident

O. Vlasov, Medical Radiological Research Center (MRRC RAMS), Obninsk, Russian Federation

IV.2.1. Introduction (brief model description)

Modelling of the ^{131}I environment transfer was carried out with the modified model CLIMRAD, which is a set of linear differential equations, describing the ^{131}I transport in the human foodchain.

Basis of the model, further model CLIMRAD2, make models PATHWAY [IV.10], RADFOOD [IV.11], ECOSYS-87 [IV.12] and CLIMRAD [IV.13].

The models consider the following major factors and processes, influencing the formation of ^{131}I thyroid doses:

(1) ^{131}I specific activity dynamics in the radioactive cloud;
(2) forms ^{131}I in the radioactive cloud;
(3) rain intensity during and after fallout;
(4) ^{131}I wet and dry depositions;
(5) weathering factors;
(6) biomass growth and its correlation with the weather conditions;
(7) beginning dates for pasturing of dairy cows and consumption of leave vegetables by human;
(8) gradual transition from indoor to pasture modes for feeding cows;
(9) three pathways of intake ^{131}I to the human thyroid: inhalation, milk and consumption of leave vegetables;
(10) origin of the food products: public versus private production;
(11) milk and green vegetables diet of rural and urban population, diet structure can be time dependent; and
(12) relocation, iodine prophylactic and questionnaires data, concerning food consumption habits.

It is supposed in model:

(i) the private dairy cows is grazed on natural pastures with low efficiency, public - on cultural pastures with higher efficiency; and
(ii) city dwellers consume perennial green vegetables and commercial milk of public dairy, rural - green vegetables and milk of private cows.

The model uses:

(i) vegetation growth model [IV.14] accounting an air daily temperatures annual course;
(ii) the multi-compartmental model of the dairy “European” and “Russian cows [ÏV.15] adjusted on experimental data about the biokinetics of ^{131}I in their organs for “European” cow [IV.16] and ”Russian" cow [IV.17] by taking into consideration cow’s milk productivity;
(iii) the single-compartmental model of the dairy cow with milk-transfer factor equals 0.01 (kBk/l)/(kBq/day) is used as the software work test; and
(iv) the standard multi-compartmental ICRP model of ^{131}I migration in the human body [IV.18], the single-compartmental models of the man [IV.19] are used as the work test of the software.

Model used next the following data:

(i) time pattern of the ^{131}I specific volumetric activity in the radioactive cloud;
(ii) time pattern of the ^{131}I forms in the radioactive cloud;
(iii) time pattern of rains during and after fallout;
(iv) daily average temperatures of the air annual course in year accident;
(v) ^{131}I and ^{137}Cs fallout densities (if there are no data on time pattern of fallouts);
(vi) dates and time of beginning and ending fallout (if there are no data on fallout time pattern);
(vii) diet of the rural and urban populations;
(viii) forage ration and milk productivities of private and collective cows; and
(ix) green vegetables and natural and cultural pastures yield in the accident year.

IV.2.1.1. Grows vegetation dynamic agro-climatic model

The ^{131}I pasture grass and green vegetables specific contamination is strongly dependent on the biomass vegetation.

The time pattern of the biomass growth is a time dependent function of the mean daily temperature and rain. The average daily temperatures and rains meteorological data was obtain from meteorological stations located in the European part of the former USSR. Using the GIS system the measurements results were interpolated to the regular grid nodes for the contamination territories.

Using the mean daily temperatures data T_i for the contaminated areas we estimated the sum of effective biological temperatures $\sum_i T^b(t_i)$ {Tb(t$_i$)=$T(t_i)$-5°C } by the methodology presented in work [IV.14]. The threshold of average daily temperature equal to 5°C was used to determine the spring vegetation period beginning. According to work [IV.14] the $\sum_i T^b(t_i)$ value determines the dates for the development plant development phases, namely, seeding and germination of the green vegetables, the sorrel and pasture grass spring growth start and the crop maturation dates.

The following parameters are calculated at the first stage:

(i) the development plants basic phases dates,
(ii) the wet vegetation biomass density growth dynamics,
(iii) the date of the start of pasturing,
(iv) the date of the start of the consumption green vegetables
(v) the date of the start of the milk consumption.

Taken into account plants phases are given in Table IV.2.1.

At the second stage we calculated the dates when the grass have been used for cows and when green vegetables could have been started to be consumed by the population.

Table IV.2.1. The development plant phases taken into consideration.

N#	Duration	Development plant phases
1	t_{g0}	the planting
2	t_{g1}	the germination for one year's plant, revive of vegetation for perennial plants
3	$t_{g1}^{1}-t_{g2}^{1}$	the biomass growth
4	$t_{g2}^{1}-t_{g3}^{1}$	the 1st harvest maturation
5	$t_{g3}^{1}-t_{h}^{1}$	the 1st harvesting
6	$t_{g1}^{2}-t_{g2}^{2}$	the 2nd harvest growth
7	$t_{g2}^{2}-t_{g3}^{2}$	the 2nd harvest maturation
8	$t_{g3}^{2}-t_{h}^{2}$	the 2nd harvesting

The calculation of the time course of the biomass growth s are carried out in the assumption, that biomass plants growth are proportional to the accumulated effective temperatures sum [IV.14]. In this approximation plants biomass density is represented as:

$$\rho_{f,gr}(t)=\begin{cases}\rho^{0}_{f,gr}, & t<t_{g1}\\ \rho^{\max}_{f,gr}\cdot\left(2\cdot\overline{\Sigma T^{b}}(t)\left(1-\dfrac{\overline{\Sigma T^{b}}(t)}{2}\right)\right)^{n}\cdot\left(1-\dfrac{\rho^{0}_{f,gr}}{\rho^{\max}_{f,gr}}\right)+\rho^{0}_{f,gr}, & t_{g1}\le t\le t_{g2}\\ \rho^{\max}_{f,gr}, & t_{g2}<t<t_{h}\end{cases} \tag{IV.2.1}$$

$$\overline{\Sigma T^{b}}=\begin{cases}0, & t<t_{g1}\\ \dfrac{\Sigma T^{b}(t)-\Sigma T^{b}(t_{g1})}{\Sigma T^{b}(t_{g2})-\Sigma T^{b}(t_{g1})}, & t_{g1}\le t\le t_{g2}\\ 1, & t_{g2}<t\end{cases} \tag{IV.2.2}$$

where:

t is the time after the accident, day;

$\rho^{0}_{f,gr}, \rho^{\max}_{f,gr}$ correspondingly, wet plant biomass ($_{f}$- food, $_{gr}$- green vegetables) at the beginning and at the end of plant growth phases, kg m^{-2};

for annual green vegetables - $\rho^{0}_{f,gr}=0$ kg*m^{-2}, for sorrel and pasture grass - $\rho^{0}_{f,gr}=0.05\rho^{\max}_{f,gr}$;

$\rho^{\max}_{f,gr}=\dfrac{Y_{f,gr}}{N_{Y}}$

here:

$Y_{f,gr}$ is the annual yield, kg m^{-2};

N_{Y} is the harvest number;

$\overline{\sum T^{b}}$ is the relative effective temperatures sum, rel. units;

n = 1.0-1.2.

The starting date of the consumption of meadow sorrel and green vegetables was estimated with use of the following condition: the vegetation biomass should be sufficient for the consumption and should constitute 20% of its maximum value.

The starting date of pasturing was estimated with use of following conditions::

(a) should be sufficient for the consumption and should constitute 20% of its maximum value;
(b) the daily average temperature of air should exceed 10°C.

The results of assessments of starting dates for Plavsk area in 1986 are given in Figures IV.2.1 and IV.2.2.

The biomass of the pastures grass was doubled during the period between the start of fallouts and the start of pasturing (see Figure IV.2.2). The same doubling also has taken place during the period between the start of pasturing and 1 June, 1986. The growth of biomass led to the substantial decrease of the contamination of forage and milk.

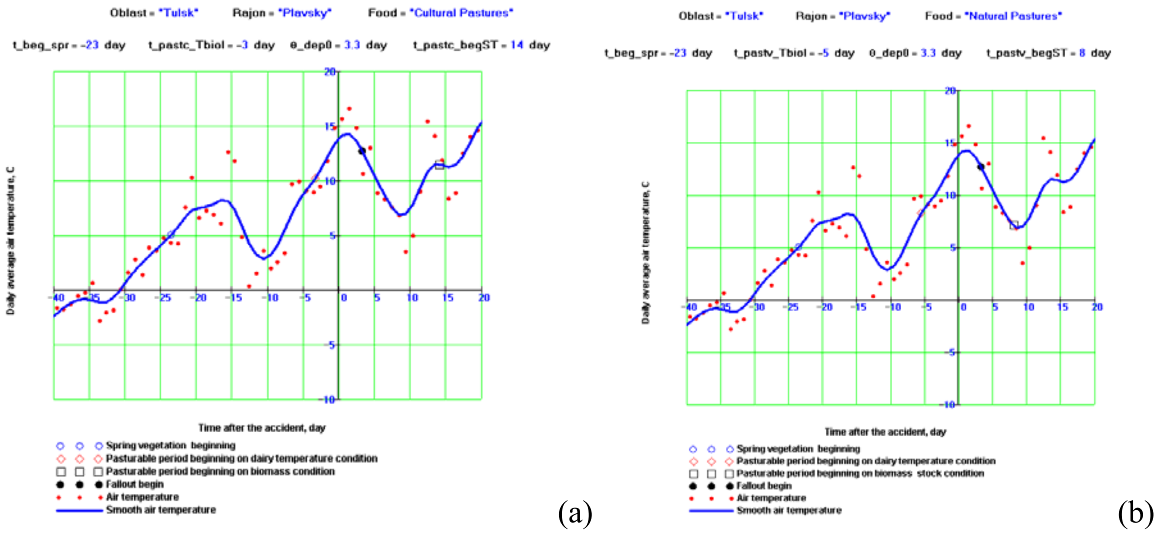


Fig. IV.2.1. Daily average air temperature and the start of pasturing on cultural (a) and natural (b) pastures in Plavsk area during the spring 1986.

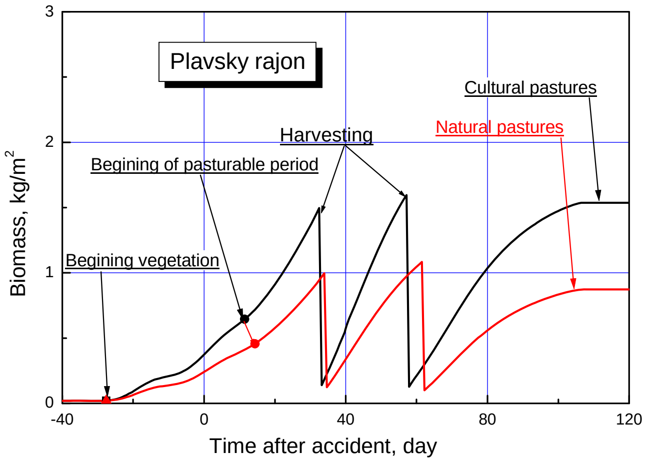


Fig. IV.2.2. Vegetation biomass growth dynamics for cultural and natural pastures in 1986 for Plavsk area.

IV.2.1.2. Iodine biokinetic models of dairy cow and human

Man models

The ^{131}I age dependent exchange rates k_{ij} between compartments are used from ICRP Publication 56 [IV.18].The model is represented by a set of linear differential equations (IV.2.3):

$$\frac{dQ_i(t)}{dt} = \sum_{j=1}^{J} k_{ij} \cdot Q_j(t)\,,\ I,j=1,\ldots,J\ (i \neq j), \qquad \text{(IV.2.3)}$$

where:

$Q_i(t)$ is ^{131}I activity in the i-th compartment at the time moment t; and
k_{ij} coefficients are on Figure IV.2.4.

The carried out calculations results of the contents ^{131}I in the reference adult person on model [IV.18] and monocompartmental model [IV.19], given in Figure IV.2.3, testify that the single-compartmental model gives faster removing ^{131}I from thyroid. It is caused by that the single-compartmental model does not take into account additional receipt of iodine in thyroid for the account it's removing from a body.

Model ICRP-56 [IV.18] was used also for calculations of ^{131}I activity dynamics in newborn during feeding by milk mother. The factor of transition ^{131}I from blood to mother milk was assumed to be equal 0.2 [IV.20]. The coupled mathematical model consisting of two blocks was used. First block was the feeding mother with the additional channel of removing ^{131}I from her body. Second block was the newborn with ^{131}I intake due to inhalation and consumption of breast milk. The consumption of cow's milk by was 2 litres/days. The breast milk consumption value of 0.8 litres/day was assumed.

Model ICRP-56 [IV.18] and the coupled feeding mother and newborn models were used for Plavsk scenario only. Model Johnson [IV.21] was used for ^{131}I thyroid activity dynamics and thyroid doses calculations after iodine prophylactic for Mazovia and Prague scenarios. The modified Johnson model [IV.21] was used also for calculations of ^{131}I content in the thyroid of new born and feeding mother and for assessment of doses after stable iodine prophylactics.

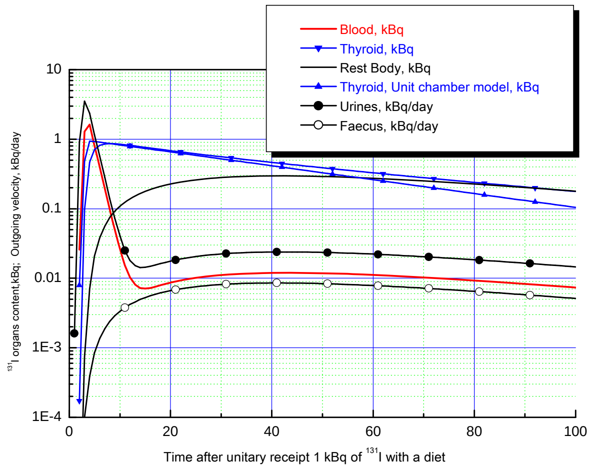


Fig. IV.2.3. Dynamics of a ^{131}I biokinetics in an adult organ after unitary receipt 1 kBq ^{131}I with a diet on model ICRP-56 [IV.18] and monocompartmental model [IV.19].

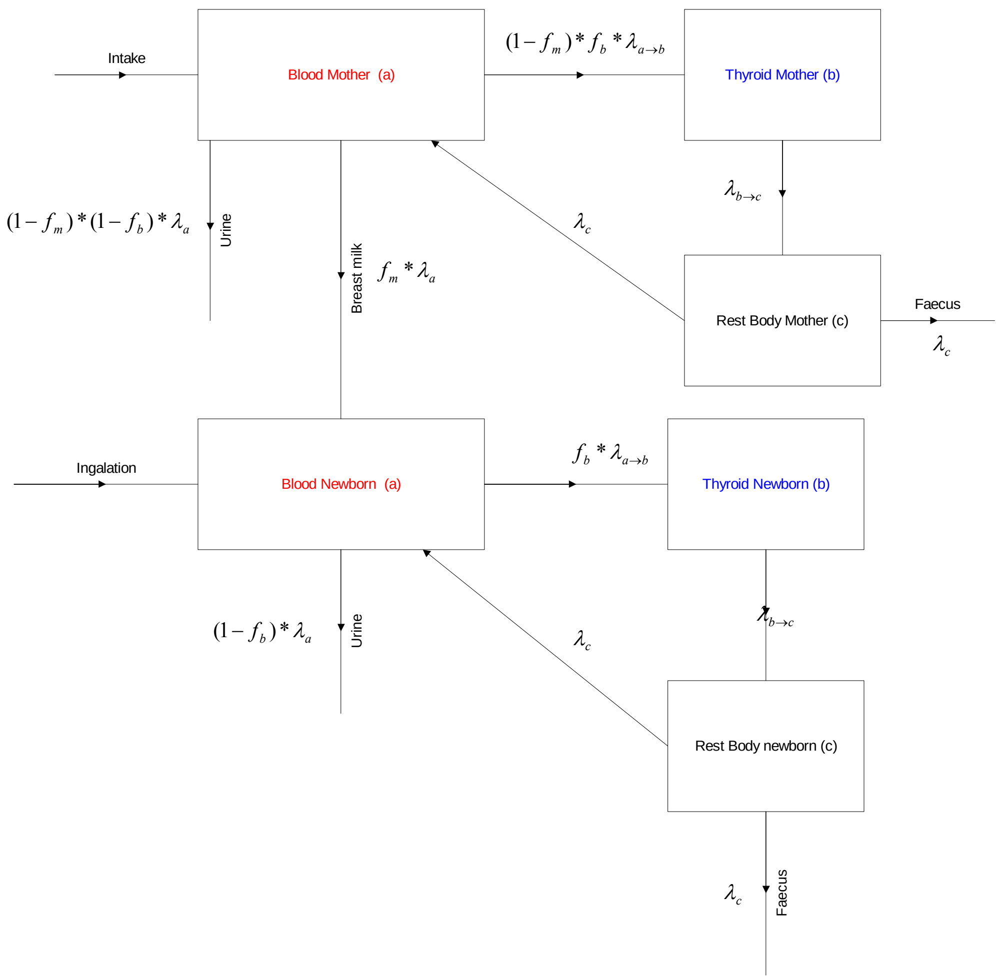


Fig. IV.2.4. Coupled feeding mother and newborn model based on ICRP Publication No. 56 [IV.18].

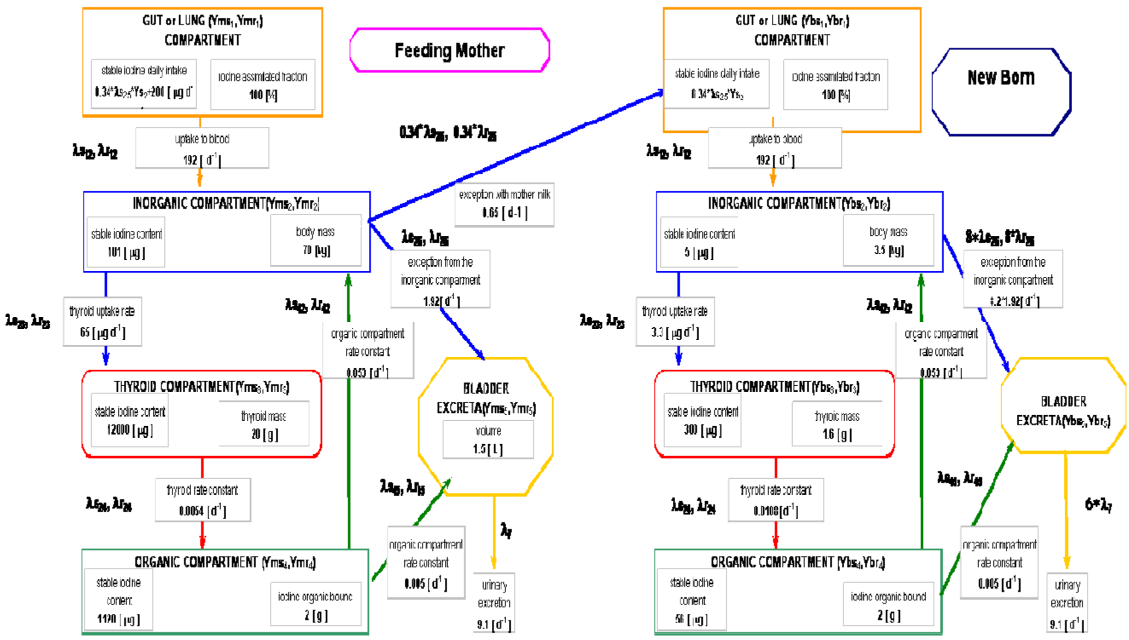


Fig. IV.2.5. Coupled feeding mother and newborn model based on Johnson model [IV.21].

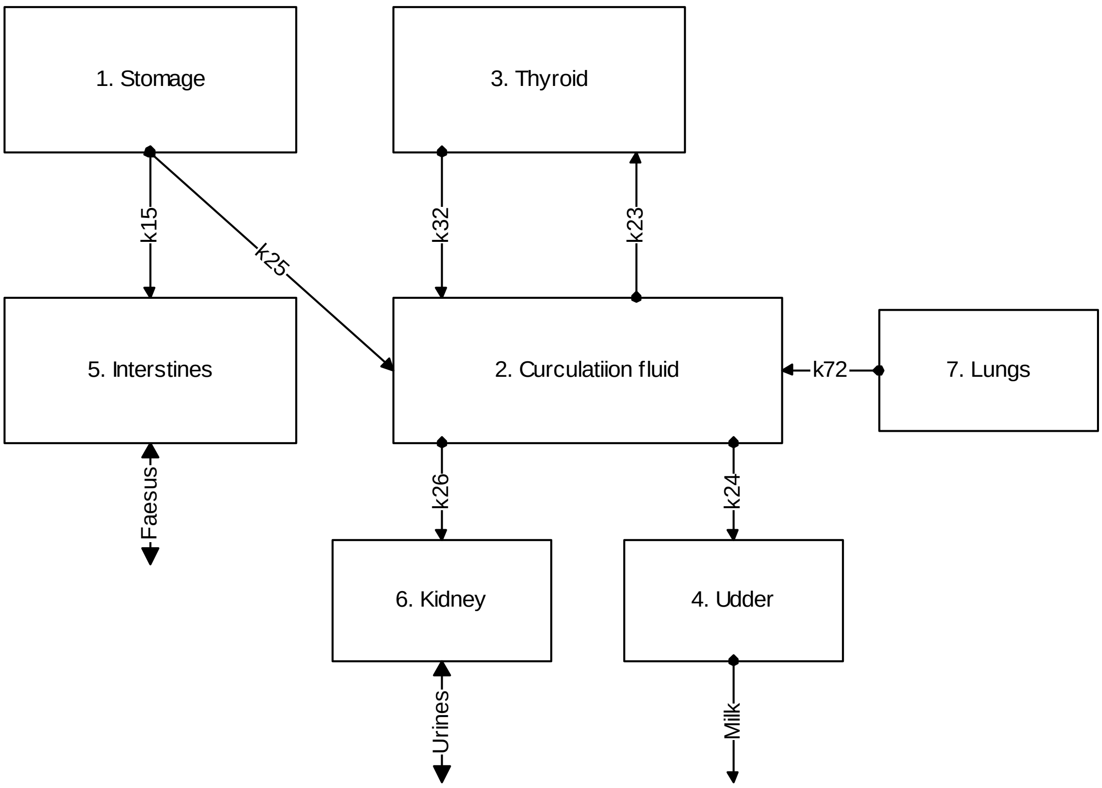


Fig. IV.2.6. Iodine dairy cows block diagrams.

Cow model

Block diagrams of iodine dairy cows models are given on Figure IV.2.6.

It is rather difficult to use the multi-compartmental cow model of ^{131}I biokinetics work [IV.15] for describing milk contamination, as it does not contain the rates of iodine exchange between the compartments. The above work contains only a flow-chart of the model and calculation formulae relating the constants of the three exponential time dependence of iodine content in milk $a_s(k_{ij})$ and $b_s(k_{ij})$ in relation Equation (IV.2.4):

$$Q_m(t) = \sum_{s=1}^{3} a_s(k_{ij}) \cdot e^{-b_s(k_{ij}) \cdot t} , \qquad \text{(IV.2.4)}$$

where:

k_{ij} is the rate of compartment-to-compartment ^{131}I exchange in Equation (IV.2.3) after acute intake of the radionuclide by cow with fodder. Work [IV.16] includes the values of coefficients a_s and b_s for an “European” cow with milk yield of 18 l/day.

The carried out comparison of dependences for the dynamics of ^{131}I milk contamination after one-time intake with fodder and the values of “fodder-milk” transfer factors, given for chronic ^{131}I intake with fodder, differ significantly from the experimental data of Russian researchers [IV.17]. Therefore, we determine the constants k_{ij} of the multi-compartment model of ^{131}I biokinetics in the “Russian” cow body using the work [IV.17] experimental data. In this connection, the determination of constants kij three-compartmental model of a biokinetics ^{131}I in a body of the Russian cow was executed.

For this purpose a_k and b_k coefficients values from work [IV.16] were used for determination “European” cow model coefficients k_{ij} by the solution of a set of six nonlinear algebraic equations. These factors values are given in a column “European” cow of Table IV.2.2.

Then the differential “European” cow model was adjusted on experimental data from [IV.17] for the “Russian” cow by milk productivity 5 l/days. The k_{ij} constants for the “European” cow were used as an intitial approximation for the adjustment of the Russian cow model. The adjustment was made in such a way that for all data of [IV.17] the best fit was achieved.

Results of the adjustment of k_{ij} parameter values for the Russian conditions together with the parameter values of the “European” cow are given in Table IV.2.2.

Table IV.2.2. Iodine biokinetic parameters of the “European” and “Russian” cow.

Organ$_i$ - organ$_j$	Compartment-to-compartment exchange rate, 1/day	
	“European” cow	“Russian” cow
Stomach - Plasma, k_{12}	3.2	2.3
Stomach - IGT, k_{15}	3.7	5.7
Plasma - Thyroid, k_{23}	0.27	0.27
Thyroid - Plasma, k_{32}	0.046	0.06
Plasma - Kidney, k_{26}	0.46	0.7
Plasma - Milk, k_{24}	0.19	0.24

Table IV.2.3. Integrated excretion rate ^{131}I and stables I from an organism the “European” and “Russian” cows for single momentary ^{131}I consumption with diet.

Organs	Integrated ^{131}I excretion rate			Integrated stable iodine excretion rate	
	Experimental data [IV.17]	**“Russian” cow**	**“European” cow**	**“Russian” cow**	**“European” cow**
Urine	0.15	0.15	0.23	0.19	0.25
Faeces	0.77	0.74	0.53	0.74	0.67
Milk	0.04	0.05	0.1	0.07	0.08
All	0.96	0.94	0.86	1.00	1.00

Table IV.2.4. “European” and “Russian” cows conversion factors ^{131}I “diet-milk” for acute and chronic ^{131}I intake.

Parameter	Experimental data [IV.17]	“Russian” cow	“European” cow
Single receipt - 1 kBq, (kBq/kg)/kBq, maximum value	0.008-0.013	0.008	0.003
chronic receipt ^{131}I - 1 kBq*day^{-1}, (kbq*kg^{-1})/kBq*day)$^{-1}$	0.01	0.01	0.005

This suggests a lower inflow of iodine from stomach to plasma and correspondingly higher inflow to IGT and faster removal of ^{131}I from the “Russian” cow body through IGT. This is obviously associated with specific features of the “Russian” cow whose milk productivity is almost three times lower the “European” cow at most equal fodder consumption.

^{131}I biokinetics were calculated with use of the received constants of “Russian” cow differential models at various modes of its receipt together with forage. Calculated and experimental data are given in Tables IV.2.3 and IV.2.4 and on Figure IV.2.7.

The main features of ^{131}I biokinetics in a cow body on various models are following:

(1) milk contamination dynamics, calculated with multi-compartmental differential models and on mono-exponential [IV.19] and two-exponential [IV.16] models, are substantially different;
(2) the maximal distinctions in values of transition ^{131}I in milk of the “European” and “Russian” cows after ^{131}I unitary introduction an cow organs reach 2 times;
(3) appreciable distinctions in dynamics of milk contamination testify to an incorrectness of direct carry of parameters of "iodine" cow models the received by foreign researchers, on the Russian conditions.

Thus, results of the studies give a basis for the use of a dairy cow multi-compartmental model.

The model can be simplified to the set of equations with an analytical solution. The human and cow single-compartmental models consider the growth of biomass, gradual increase of the contribution of 1886 forage and the transition from indoor feed to pasturing [IV.19].

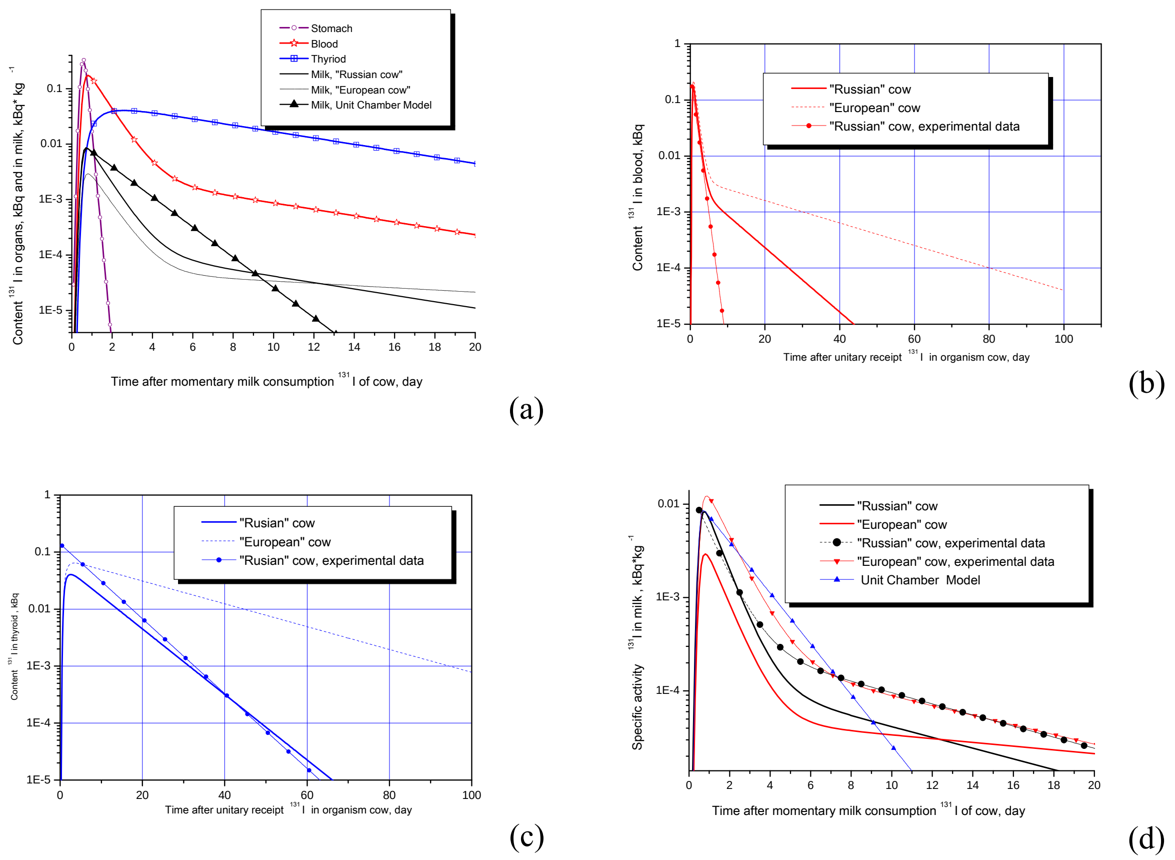


Fig. IV.2.7. ^{131}I biokinetics in dairy cow organs after unitary introduction 1 kBq with a diet.

Table IV.2.5. Effective dry and wet sedimentation of iodine.

Radionuclide forms	v^k_{dg} **mm/s**	v^k_{ds} **mm/s**
gaseous	10	2
aerosol	1	0.2
organic	0.1	0.02

Table IV.2.6. Volumetric washout factor.

Radionuclide forms	W^k
gaseous	$2*10^5$
aerosol	$1*10^5$
organic	$0.1*10^5$

IV.2.1.3. Transport of radionuclide in food chains

Vegetative chain

A set of differential equations, which describes the transport of radioiodine in vegetation and soil, is following:

$$\frac{dq_p}{dt} = [K^{dry}_{f,gr} * \sum_{k=1}^{3}(v^k_{dg} * \delta^k_I) + K^{wet}_{f,gr} * \dot{R}_{dep} * \sum_{k=1}^{3}(Rwash^k * \delta^k_I)] \cdot \frac{C_a}{\rho^{wet}_{f,gr}} - (\lambda_n + \lambda_p + \lambda_{wind} + \lambda_{wet} + \frac{d\ln(B_p)}{dt}) \cdot q_p;$$

$$\frac{d\sigma_{gs}}{dt} = [(1 - K^{dry}_{f,gr}) * \sum_{k=1}^{3}(v^k_{ds} * \delta^k_I) + (1 - K^{wet}_{f,gr}) * \dot{R}_{dep} * \sum_{k=1}^{3}(Rwash^k * \delta^k_I)] \cdot C_a + (\lambda_p + \lambda_{wind} + \lambda_{wet}) \cdot q_p - \lambda_n \cdot \sigma_{gs}, \quad \text{(IV.2.5)}$$

where:

q_p is the specific activity of the vegetation, kBq/kg;
σ_{gs} is the specific surface activity of the soil, kBq/m^2;
C_a is the ^{131}I air volumetric specific activity in an atmosphere ground level, kBq/m^3;
B_p is the plant wet biomass, kg/m^2;
δ^k_I is the relative fractions of gaseous, aerosol and organic iodine forms in air, *:* κ=1 – elementary,*,* κ=2 - aerosol*,* κ=3 – organic;
v^k_{dg} and v^k_{wg} are the effective dry and wet sedimentation of iodine on plant (Table IV.2.5), m/day;
v^k_{ds} и v^k_{ws} are the effective dry sedimentation of iodine on the soil under the vegetation (Table IV.2.5), m/day;
$Rwash^k$ is the volumetric washout factor (the rato of volumetric specific activity in rain water and air), Table IV.2.6.
$K^{dry}_{f,gr}(t)$, $K^{wet}_{f,gr}(t)$ - *dry* and *wet* retention coefficients for grass (gr) and pasture vegetation (f), respectively*,* dimensionless:

$$K^{dry}_{f,gr}(t) = 1 - \exp(-\alpha_0 \times \eta \times \rho_{f,gr}(t)) \quad \text{(IV.2.6)}$$

$$K^{wet}_{f,gr}(t) = L_{ai} \times (1 - \exp(-\frac{0.693}{3} \times \frac{\overline{R_{dep}(t,\theta_0)}}{S_{wl}}) \quad \text{(IV.2.7)}$$

$$L_{ai}(t) = L^{\max}_{ai} \times (1 - \exp(-\alpha_1 \times \rho_{f,gr}(t)))$$

where:

α_0 is the constant, 1.75 (m^2/kg);
$\rho^{wet}_{f,gr}(t)$ are the specific densities of the vegetable wet biomass at the accident time estimated according to (1) under actual temperature conditions, kg/m^2;
η is the dry substance part in wet vegetation biomass, 0.2;
$\overline{R_{dep}(t,\theta_0)}$ is the accumulated rains from the start of fallouts, mm;
S_{wl} is the maximal thickness of the rain water layer retained by the vegetation, 0.1 mm, [IV.12];
$L^{\max}_{ai}$ is the maximal superficial area of the vegetation leaf surface, (7 m^2/m^2) [IV.12];

α_1 is the constant, 1 (m^2/kg)
$\dot{R}_{dep}$ is the rain intensity during the fallout, mm/day;
θ_0 and θ_1 are the time of the start and end of fallouts, day,
λ_n is the ^{131}I radionuclide decay rate, day^{-1},
λ_p is the plant self-cleaning rate, λ_p=0.02 day^{-1} [IV.16];
$\lambda_{wind} = k_w \bar{u}$, is the plant cleaning rate under wing influence, day^{-1}, value k_w equals 7 10^{-9} $s \cdot m^{-2}$ [IV.16];

where:

$\bar{u}$ is the wind daily average speed is accepted equal 3 m*s^{-1};
$\lambda_{wet} = k \cdot \dot{R}(t, \theta_1)$ is the plant cleaning rate under rain influence, day^{-1};

where:

k is the constant = (0.02-0.09)*10^3 m^{-1} [IV.16]; and
$\dot{R}(t, \theta_1)$ is the rain intensity after fallout, m/day.

Milk chain

A time course of the ^{131}I activity in the stomach of the dairy cow is described by equation:

$$\frac{dq^I_{mk}}{dt} = FV \cdot q^I_3 \cdot \eta(t - \theta_{past}) + FS \cdot \left(\frac{\sigma^I_{qs}}{\rho_l \cdot x_l} \right) * \left[1 - \eta(t - \theta_{past}) * 0.9 + 0.1 \right], \qquad \text{(IV.2.8)}$$

where:

$$\eta(t - \theta_{past}) = \begin{cases} \dfrac{t - \theta_{past}}{\tau_0}, & if \quad \theta_{past} < t < \theta_{past} + \tau_0 \\ 0 & otherwise \end{cases},$$

τ_0 is the duration of the transition from the indoor feeding to pasturing of dairy cows, 10 day;
θ_{past} is the beginning time of pasturing, day;
FV, FS are the daily intake of the grass and soil, accordingly; for the collective cow FV=50 kg/day and FV=40 kg/day for private cattle, FS=1 kg/day;
x_l is the depth of the contaminated layer of the soil, 1 mm; and
ρ_l is the soil density, 1kg/m^2.

The set of the linear differential equations is used for the description of a ^{131}I biokinetics in the cow (see Figure IV.2.6) and calculation of the specific activity of milk:

$$\frac{dQ^I_i}{dt} = \sum_{j=1...J, j \neq i} k_{ij} Q^I_j \qquad \text{(IV.2.9)}$$

$$Q^I_{milk}(t) = \frac{\frac{d}{dt} Q^I_{udder}(t)}{Y_{milk}} \qquad \text{(IV.2.10)}$$

where:

Q_i^I is the ^{131}I cow organs activities, kBq;
Q_{udder}^I is the ^{131}I content in udder, kBq;
Q_{milk}^I is the specific milk activity, kBq/kg; and
Y_{milk} is the cow milk productivity, l/day.

^{131}I biokinetics in human bodies

The ^{131}I or ^{137}Cs biokinetics in the human stomach and lung during passage of the radioactive cloud is described by the following equations:

$$\frac{dQ_{st\to bl}(t)}{dt} = Q_{mc}(t-\tau_{mc})\cdot R_{mc}(t) + Q_{mp}(t-\tau_{mp})\cdot R_{mp}(t) + (Q_{gv}(t)\cdot R_{gv}(t) + \cdot Q_s(t)\cdot R_s(t))\cdot K_{pr}, \qquad \text{(IV.2.11)}$$
$$\frac{dQ_{\ln\to bl}}{dt} = q_a \cdot V_a \cdot K_{\ln\to bl},$$

where:

Q_{st}, Q_{ln} is the ^{131}I or ^{137}Cs receipt speeds in the human stomach, kBq/day;
τ_{mc}, τ_{mp} is the time interval between milk production and its consumption, they equal 2 day for urban population and 1day for rural population; and
V_a is the air inhalation speed, m^3/day, (see Figure IV.2.8);
$K_{ln\to bl}$ is the ^{131}I, ^{137}Cs share acting from lung in blood, 0.63 [IV.19]; and
R_{mc}, R_{mp}, R_{gr} и R_s are the daily consumption of collective cow's milk (urban area), of private cow's milk (rural area), (see Figure 9(a)), leafy vegetable (urban and rural areas), respectively, kg/day, (see Figure 9(b)).

The set of linear differential equations (IV.2.3) is used for the description of ^{131}I biokinetics in the human body (see Figure 3(b)).

Thyroid dose

The absorbed dose and absorbed dose rate in the thyroid gland is:

$$P_{th}(t, age) = q_{th}(t, age) * Kp(age), \text{ mGy/day} \qquad \text{(IV.2.12)}$$
$$D = \int_{t_0}^{\infty} P_{th}(\tau, age)d\tau, \text{ Gy.}$$

where:

$Kp(age)$ is the dose coefficient, mGy/(kBq*day).

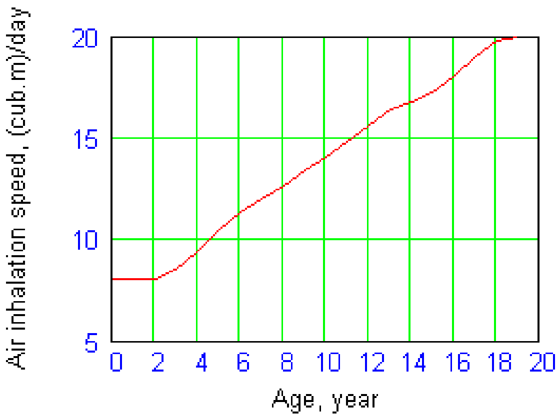
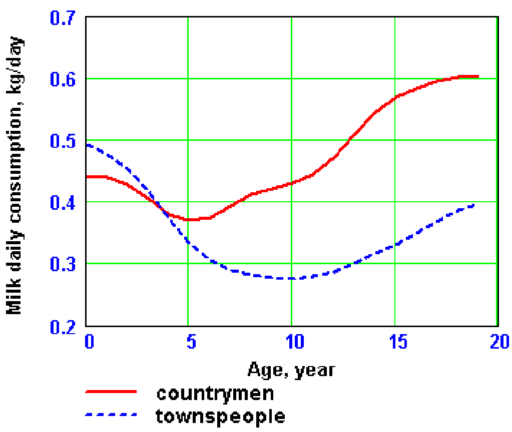
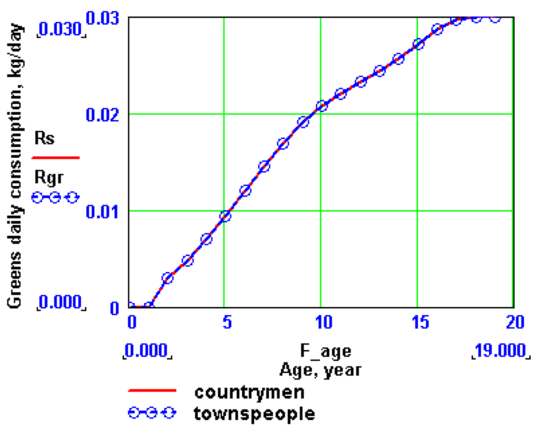


Fig. IV.2.8. The age-dependence of the lung ventilation rate.



(a)



(b)

Fig. IV.2.9. Dependence of milk daily consumption (a) and green vegetables (b) from person age [IV.22].

^{131}I in food chains

The data on weather conditions in 1986 on all meteorological stations of former USSR network were given in IIGMI WCD. Each of four considered regions of the Russian Federation was divided on 3–5 homogeneous on weather conditions sub-regions.

An example of obtained results is given in Figure IV.2.10 for cultural and natural pastures of the strongly contaminated regions of Bryansk and Kaluga areas. Here are given the data on fallout begin, the consumption beginnings of the contaminated green forage by public and private dairy cows on cultural and natural pastures.

The dates of pasturing of private dairy cow are given in Figure IV.2.11 for forth contaminated Russia oblasts.

The calculations of the ^{131}I and ^{137}Cs content in vegetables were carried out without taking into account precipitations during fallouts (as an initial approximation). It was supposed, that ^{131}I was present only in the aerosol forms only. The mean specific volumetric activity ^{131}I and ^{137}Cs in cloud were reconstructed:

$$C_i^{Cs,I} = \frac{\sigma_i^{Cs,I}}{v_{eff} \times (\theta_1^{dep} - \theta_0^{dep})}, \qquad \text{(IV.2.13)}$$

where:

C_i^{Cs} is the mean specific volumetric activity ^{137}Cs in cloud above i-locality, kBq/m^3;

C_i^{I} is the mean specific volumetric activity ^{131}I in cloud above i-locality, given in accident time, kBq/m^3;

v_{eff} is the effective ^{131}I and ^{137}Cs sedimentation speeds from a cloud on ground and vegetation, 1 sm/сек;

$\theta_0^{dep}, \theta_1^{dep}$ is the data of work /16/ about the fallout beginning and the ending times for contamination territories Russia areas;

σ_i^{Cs} is the ^{137}Cs fallout density in i-locality, kBq/m^2; and

σ_i^{I} is the ^{131}I fallout density in i-locality, kBq/m^2.

$$\sigma_i^{I} = \sigma_i^{Cs} \times K_\sigma^{I/Cs}, \qquad \text{(IV.2.14)}$$

where:

$K_\sigma^{I/Cs}$ is the $^{131}I/^{137}Cs$ activities ratio in fallouts on Russia areas [I.22].

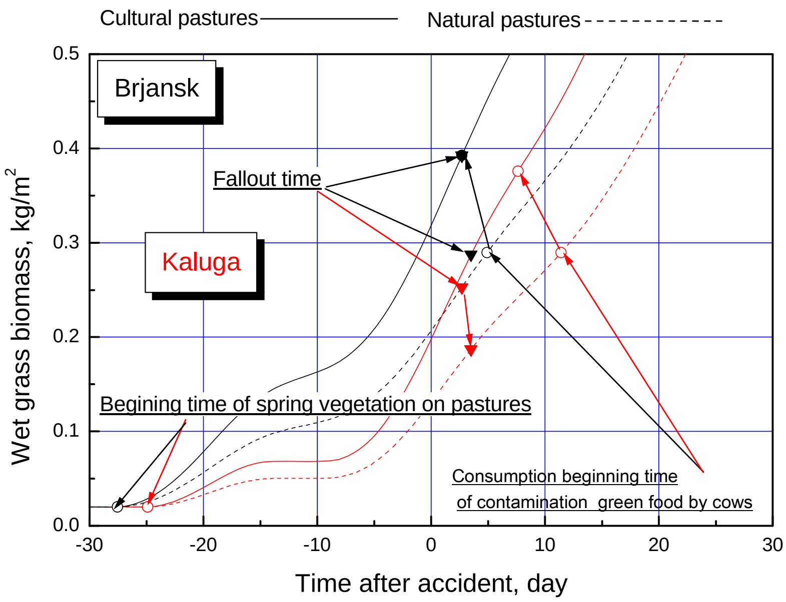


Fig. IV.2.10. Dynamics of vegetable biomass growth on pastures of southern regions of Bryansk and Kaluga areas.

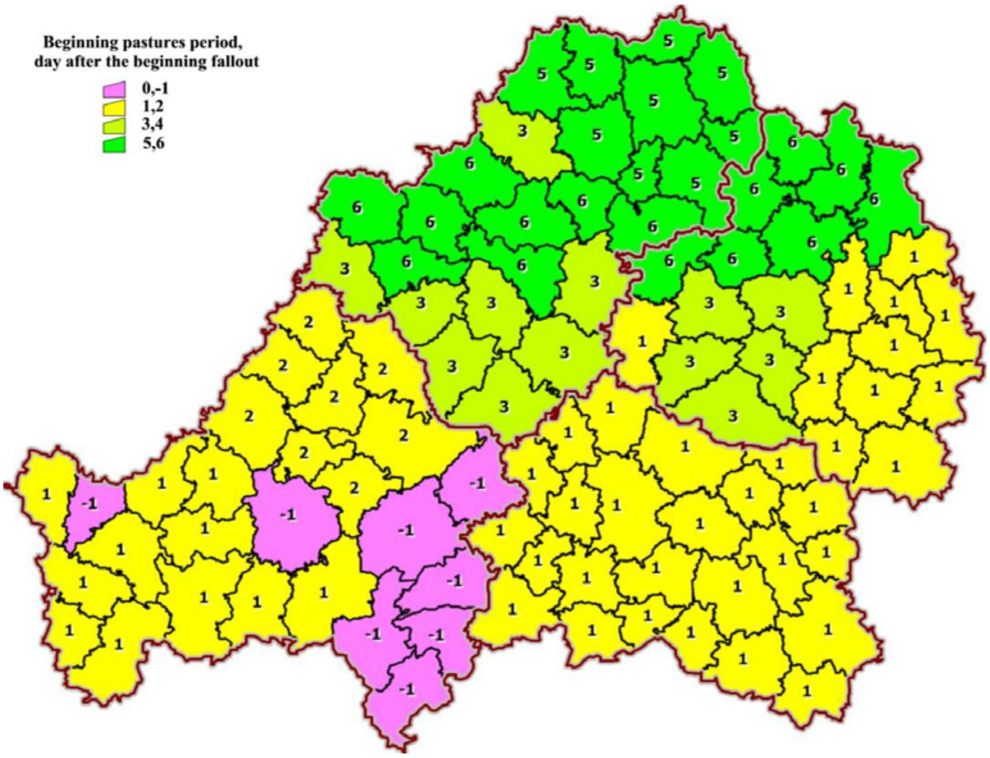


Fig. IV.2.11. The map of starting dates of pasturing of private dairy cows, days after the start of fallouts.

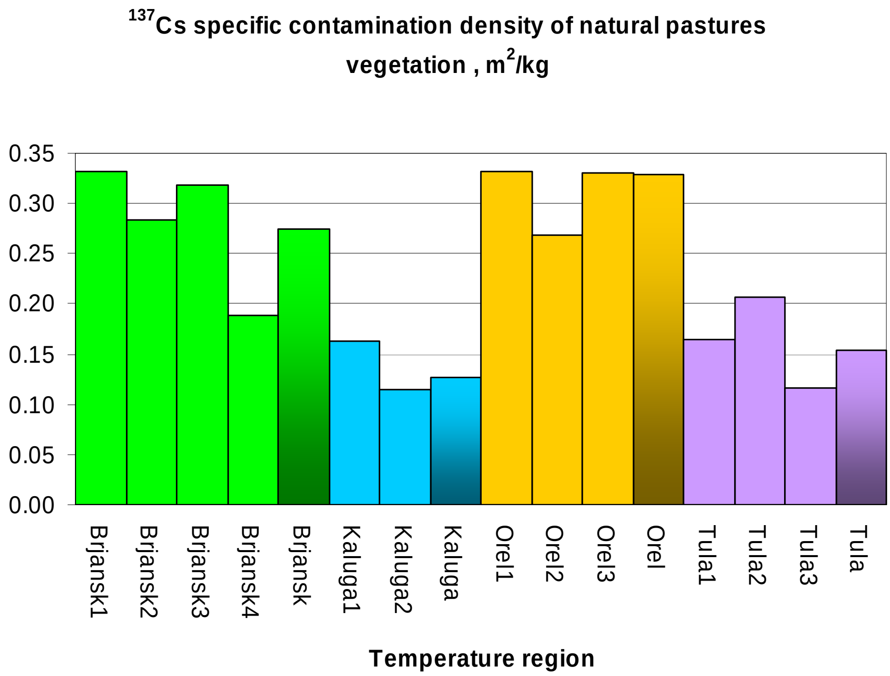


Fig.IV.2.12. ^{137}Cs specific activity of grass on natural pastures (at the start of pasturing) normalized by the deposition density (kBq/kg)/(kBq/m^2).

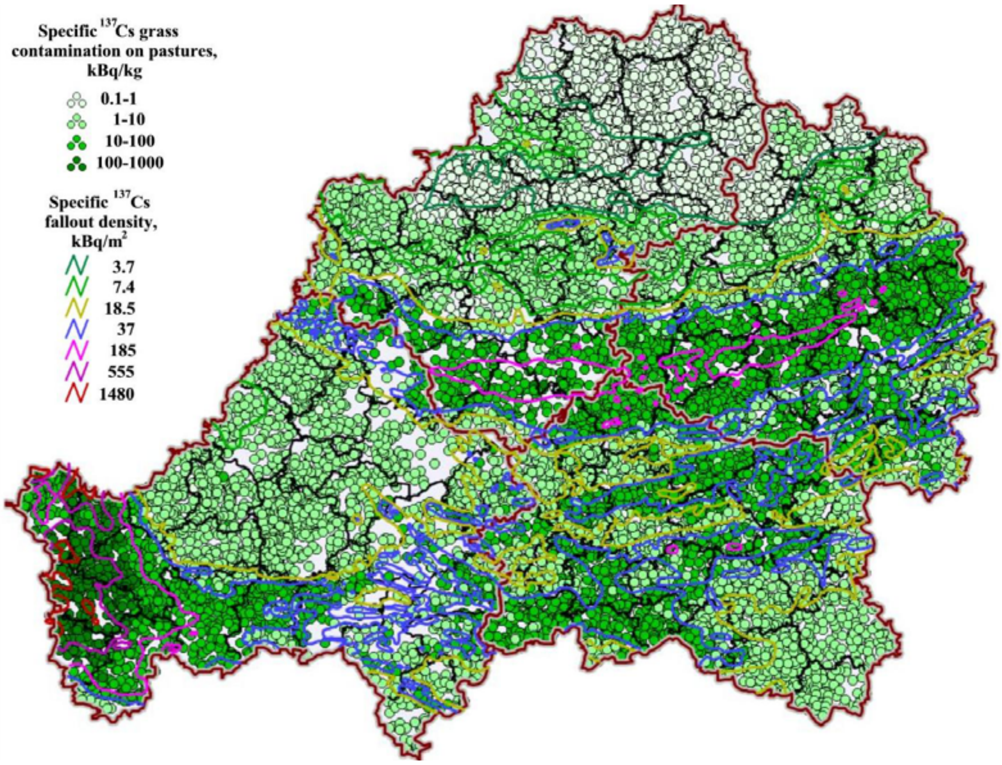
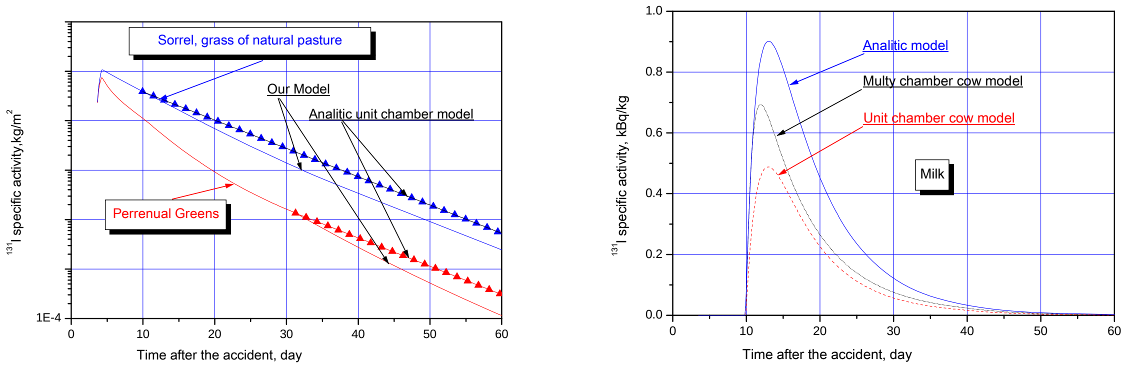


Fig. IV.2.13. The map of ^{137}Cs green food specific activities on natural pastures on ending fallout time, kBq/kg.



(a) (b)

Fig. IV.2.14. . ^{131}I specific activities green vegetables (a) and milk (b) dynamic in contamination Kaluga area on unit ^{131}I fallout density, (1 kBq/m^2 at the accident time).

Table IV.2.7. Mean radio ecological parameters for four Russian areas.

Model parameter	**Area**			
	Brjansk	**Kaluga**	**Orel**	**Tula**
Timing parameters, day after the accident				
Fallout time, begin/end	2.8/3.8	3.5/4.3	3.3/4.2	3.5/4.3
The consumption beginning of contaminated (annual /perinnial) green vegetables by population	4/26	4/31	4/27	4/31
The consumption beginning of contaminated green food (private /common) dairy cows	4/3	11/8	3/3	11/8
The beginning of consumption contaminated milk by (rural/city) population	5/5	12/10	4/5	12/10
Contamination for the beginning consumption period, kBq/kg at ^{131}I fallout density for accident time equals 1 kBq/m^2				
(annual /perennial) green vegetables	0.19/0.0014	0.046/0.0001	0.25/0.0015	0.06/0.0004
Grass of (cultural/natural) pastures	0.17/0.19	0.043/0.047	0.22/0.25	0.006/0.006
(private /common) milk	0.09/0.07	0.023/0.019	0.012/0.01	0.03/0.025

The specific activity of grass on natural pastures at pasturable beginning time, are given in Figure IV.2.12. From the data shown in Figure IV.2.12 follows that the ^{137}Cs biggest green forage specific activity for the beginning of its consumption by dairy cows, given to unit ^{137}Cs density fallout, was in the Oryol area, then in Bryansk, then in Tula and the least in the Kaluga area.

The green forage ^{137}Cs specific activities on natural pastures on ending fallout time are given in Figure IV.2.13.

Dynamic calculations results of green vegetables, sorrel, vegetation of natural pastures and private milk contaminations are given in Figure IV.2.14 for Kalug area. The milk contamination calculation on our model and on single-compartmental model [IV.19] are executed with biomass grows account.

As one would expect, monoexponential model [IV.18] which is not taking into account a vegetation biomass grows , gives higher values of vegetation contamination (see Fig.ure IV.2.14(a)). Accordingly, these distinctions, collecting on a chain "forage - milk", and also due to the greater value of factor of transition in model [IV.18], result and in the big values of the maximal milk contamination - 0.9 m^2/kg in model [IV.18] in comparison with 0.68 m^2/kg in our model.

The relation of the maximal milk contamination values in calculations on multi compartmental to single-compartmental cow models the equally 1.42 (see Figure IV.2.14(b)), while relations of the maximal values of ^{131}I milk transition factors at its unitary receipt in cow stomach the equally 1.3 (see Table IV.2.4). It is obvious, that other part of this excess is caused by additional charging of milk contamination due to receipt ^{131}I in blood and then in milk from other bodies.

The radio ecological parameters calculations results are given in Table IV.2.7 for 4th Russia areas.

From given Table IV.2.6 it is visible, that rank of areas on specific green vegetables and milk contamination at the beginning of their consumption looked as follows: the Oryol, Bryansk, Tula and Kaluga areas at identical ^{131}I fallout density on district

^{131}I body contents dynamics in the adult countryman of the contaminated Tula areas due to inhalation, and the use in food of the contamination green vegetables and sorrel (100 g/day) on unit ^{131}I fallout density on district(for the accident time - 1kBq/m^2), calculated on ICRP models [IV.20], differential unit exponential models and analytical model [IV.19] are given in Figure IV.2.15.

It is well visible from the data of the diagram for an inhalation (see Figure IV.2.15(a)), that the ^{131}I thyroid activity on both models coincides only within 10 days after accident, on later times ICRP model [IV.19] gives more higher ^{131}I thyroid activity values.

In the even greater degree this excess is appreciable as a result of calculations for sorrel consumption (see Figure IV.2.15(c)). ICRP model [IV.19] gives in 1.3 times the greater ^{131} I thyroid activity, than unit mono-compartmental person model. Significant (in 3.6 times) distinction in the ^{131} I thyroid activity is received between calculations on our model and analytical model [IV.18]. A principal cause - in not the model [IV.18] account of green vegetables biomass growth for a time interval from accident time (3-4 day after failure) prior to the beginning of its consumption by population (31 day after accident).

Thus, the received results testify for the benefit of use of full agro-ecological models at thyroid dose estimations of the contamination Russia areas population. This conclusion confirms calculation results of ^{131} I thyroid activity and thyroid doze accumulation dynamics due to the contaminated milk consumption, appreciated on various models and given in Figure IV.2.16. At these calculations were used the contaminated milk dynamics data, estimated on dairy cow multi-compartmental model (by a Figure IV.2.4).

The calculations data on various models essentially differ from each other, as on a time course of the ^{131}I thyroid activity, and on an end result - the saved up thyroid doze. So, the dose value at calculation on multi-compartmental models of human and the cow (Man3_Milk6) makes 4.2 мГр, while at calculation with use of single-compartmental models of cow and the human (Man_Milk1) - 2.7 мГр. Calculations with use of single-compartmental human model – multi – compartmental cow model (Man1_Milk6) and multi-compartmental model of human – single-compartmental cow model (Man3_Milk1) yield intermediate results, accordingly, 3.2 мГр and 3.0 мГр. For all calculated variants distinction between calculations on full model (multi-compartmental human and the cow models) and other variants exceeds 30%.

(i) Man3 – multi - compartmental ICRP model of radioiodine biokinetics in human body [IV.19];
(ii) Milk6 – multi-compartmental model of radioiodine biokinetics in cow;
(iii) Man1 – multi-compartmental model of radioiodine biokinetics in human body; and
(iv) Milk1 – single-compartmental model of radioiodine biokinetics in cow.

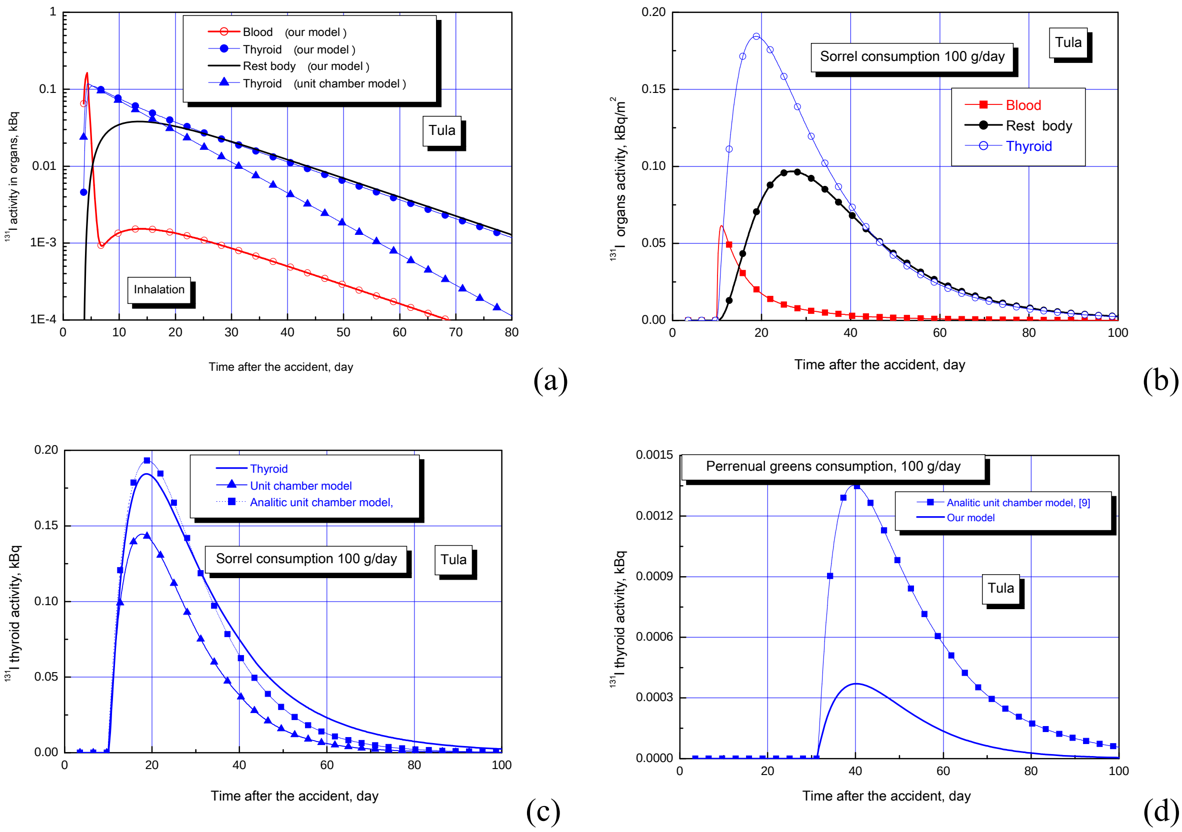


Fig. IV.2.15. ^{131}I body contents dynamics in the adult countryman of the contaminated Tula areas due to inhalation, and the use in food of the contamination green vegetables and sorrel (100 g/day) on unit ^{131}I fallout density (for the accident time - 1kBq/m^2) on district.

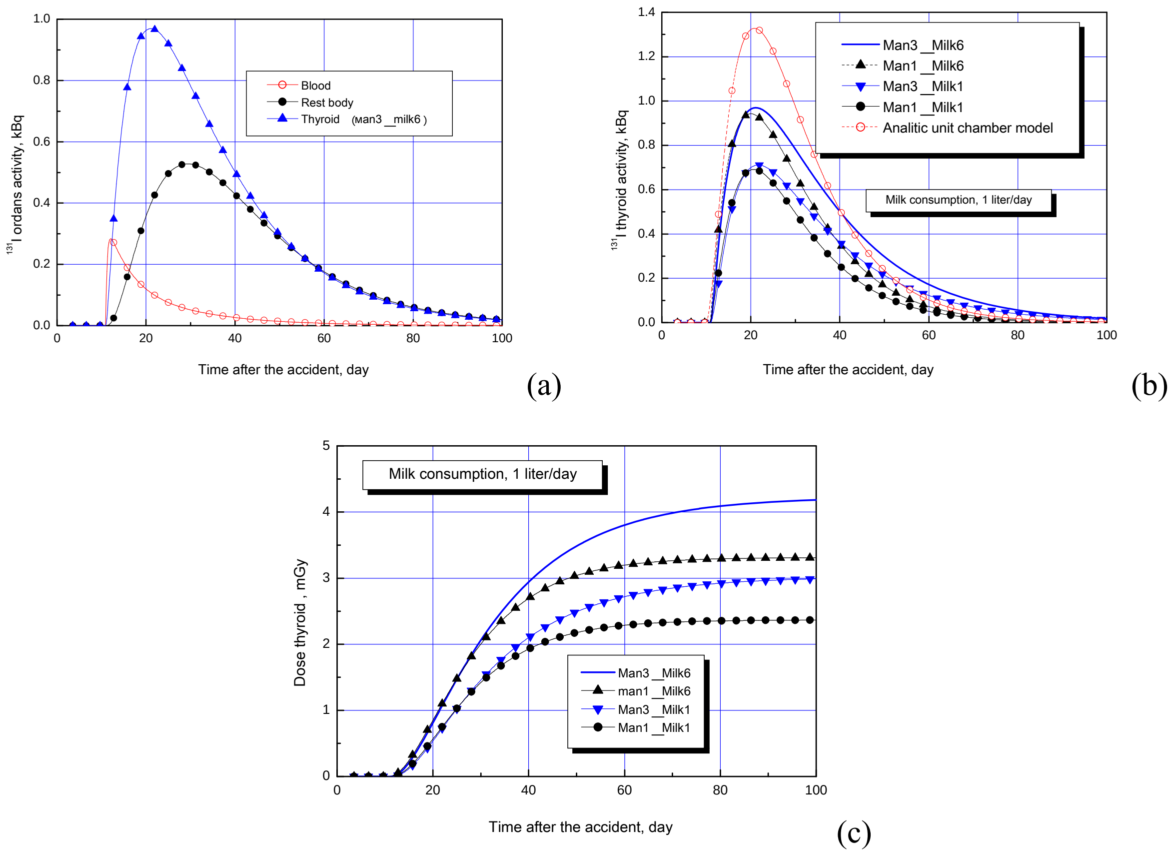


Fig. IV.2.16. ^{131} I thyroid activity and thyroid doze accumulation dynamics due to the contaminated milk consumption, appreciated on various models for countryman adult of Tula area due to the consumption contaminated milk (1kg/day) on unit ^{131}1fallout density (for the accident time - 1 kBq/m^2) on district.

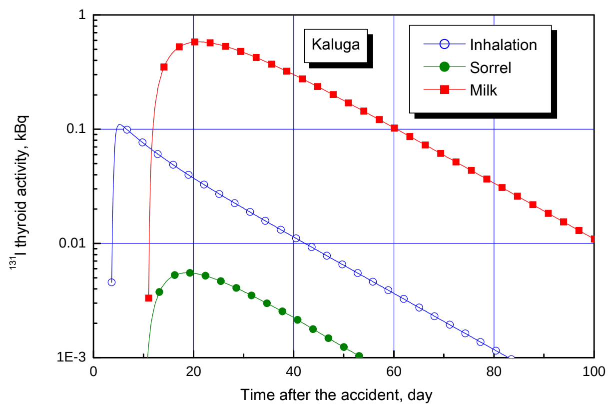


Fig. IV.2.17. Dynamics of ^{131}I thyroid activity the adult countryman of the contaminated Kaluga areas due to inhalation, the use in milk and sorrel food at unit ^{131}I fallout density (for the accident time - 1 kBq/m^2) on district.

The contribution of various ways of ^{131}I intake for an adult rural person is described by the data given in Figure IV.2.17 for conditions of the Kaluga area. As one would expect, the milk consumption gives the greatest contribution. So, the maximal $^{131}1$ thyroid activity is 0.97 kBq and it is reached on 21st day after the accident. I a case of the consumption of the sorrel the maximal activity is 0.18 kBq and it is reached on 19th day after the accident. The least contribution is given by the inhalation: the maximal $^{131}1$ thyroid activity is 0.11 kBq and it is reached on the day of fallouts.

Accordingly, thyroid doses of internal ^{131}I exposure due to inhalation, consumption of green vegetables, milk and a full dose are following 1.7, 0.2, 17.8 and 19.6 mGy(kBq/m^2), respectively. Their contributions to the total dose are 8.7%, 1.0% , and 90.3%, respectively.

IV.2.2. Conclusion

(1) The carried out calculations results testify that the single-compartmental human model gives faster removing ^{131}I from thyroid. It is caused by that the single-compartmental model does not take into account additional receipt of iodine in thyroid for the account it's removing from a muscular fabric,

(2) The time courses of the milk contamination assessed by the multi-compartmental, mono-exponential [IV.18] and two-exponential [IV.16] models are substantially different;

(3) the maximal discrepancy in values of transition ^{131}I in milk of the "European" and "Russian" cows after an acute intake reach 2 times;

(4) appreciable distinctions in the time course of the milk contamination testify to an incorrectness of direct carry of parameters of "iodic" cow models the received by foreign researchers, on the Russian conditions,

(5) Discrepancies in weather conditions have resulted a substantial variation in doses to the thyroid gland at identical ^{131}I deposition density.

IV.3. Thyroid dose estimations for Plavsk District inhabitants basing on direct measurements of ^{131}I in thyroid

Zvonova, I., Institute of Radiation Hygiene of the Ministry of Public Health, St. Petersburg, Russian Federation

For the purposes of reconstruction of thyroid doses, two main sources of ^{131}I intake were taken into account: the inhalation of the radionuclide during the passage of the radioactive cloud and the consumption of contaminated milk. Additionally other sources of ^{131}I intake were considered: the consumption of leafy vegetables and other contaminated food. The value of radioiodine intake was strongly influenced by the date of the beginning of pasturing of dairy caw and the date of local milk consumption cessation. We developed the model of ^{131}I intake in a human body taking into account these main factors and basing on the analysis of the radiation monitoring data [IV.23].

Figure IV.3.1 shows the general form of the ^{131}I intake function in the body of inhabitants of age u with inhaled air i_{inh} and with food products i_{ing}.

Equations (IV.3.1) and (IV.3.2) give its mathematical description:

$$i_{inh}(t, u, \sigma_{137}) = i_0 \cdot f_1(u) \cdot f_2(\sigma_{137}), \quad 0<t<t_1; \qquad \text{(IV.3.1)}$$

$$i_{ing}(t) = \begin{cases} i_0 \cdot f_3 \cdot e^{-\ln 2 \cdot t/T_{ec}}, \quad 0<t \le t_2; \\ i_0 \cdot (f_3 \cdot e^{-\ln 2 \cdot t/T_{ec}} + (1-f_3)\cdot(e^{-\ln 2\cdot(t-t_2)/T_{tc}} - e^{-\ln 2\cdot(t-t_2)/T_1})), \quad t_2 < t \le t_3; \\ i_0 \cdot f_4 \cdot (f_3 \cdot e^{-\ln 2 \cdot t/T_{ec}} + (1-f_3)\cdot(e^{-\ln 2\cdot(t-t_2)/T_{ec}} - e^{-\ln 2\cdot(t-t_2)/T_1})), \quad t_3 < t; \end{cases} \qquad \text{(IV.3.2)}$$

where:

i_0 , kBq/day is the constant is accepted to be equal to the ^{131}I intake with milk at "zero" time;
t , days is time after the beginning of radioactive depositions in the region;
t_1, days is the duration of inhalation from the radioactive cloud; it is assumed equal to 1 day;
t_2 , days is the time of beginning of pasturing cows in private farms;
$f_1(u)$ is the factor that describes the relationship between daily consumption of milk and the volume of air inhaled during a day by children and teenagers of age u, as compared with adults, see Table IV.3.1; and
$f_2(\sigma_{137})$ is the factor that takes into account the relation between inhalation and "milk" ways of ^{131}I intake in formation of the thyroid dose in dependence on the density of soil contamination with ^{137}Cs. The following considerations were taken into account for estimation its value.

Table IV.3.1. Values of factor $f_1(u)$, rel. un., in Equation (IV.3.7) for persons of different age groups.

Age, years	**< 1**	**1–2**	**3–7**	**7–12**	**12–17**	**> 17**
$f_1(u)$, rel. un., (villages)	0.1	0.2	0.4	0.6	0.9	1.0
$f_1(u)$, rel. un., (towns)	0.1	0.2	0.4	0.8	1.5	1.8

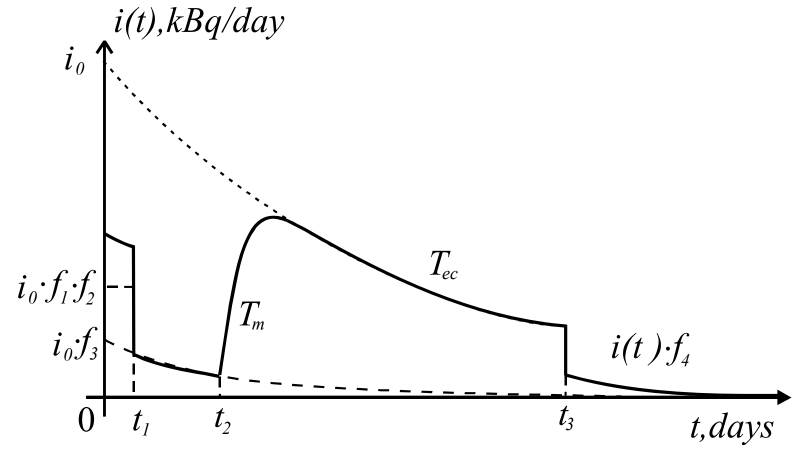


Fig. IV.3.1. Model of ^{131}I intake after the Chernobyl accident (members of the public).

At dry fallout of radionuclides their deposition on soil is proportional to the time of the passage of the radioactive cloud across the given area and to the velocity of the radionuclides deposition. The average ^{131}I deposition velocity was 0.8 cm/s [IV.24, IV.25]. Using this value for the rate of dry deposition and the average value of ^{131}I retention by grass (0.25), we calculated the relation between intake of the iodine radionuclides to a human body with the air and with food products at dry deposition when duration of the radioactive cloud passage through a settlement was equal to 1 day. For adult rural inhabitants it was estimated as $f_2(\sigma_{137}) = 0.15$. For children at the age u this ratio differed by $f_1(u)$ times.

In the areas, where contamination took place by wet washing out, the relative role of inhalation decreases with the increase of the level of soil contamination by $f_2(\sigma_{137})$ times. We assumed that the inhalation component stays approximately the same for the whole area of the passage of the radioactive cloud. The basic soil contamination and the interception of radioiodine by vegetation depended on the amount of precipitations [IV.26]. The level of soil contamination, at which wet depositions began to influence, was assessed on the basis of the data of measurements of ^{131}I concentration in milk. At the level of about 50 kBq, the point of inflection was observed in the curve of dependence of ^{131}I concentration in milk on the soil contamination density with ^{137}Cs. We assume this value as the upper limit of the contamination, which was attributed only to dry depositions. Taking into account the non-linear character of the dependence of radioiodine interception by vegetation [IV.26], the ratio between the inhalation and ingestion ways of ^{131}I intake in the body of adult inhabitants in dependence on the soil contamination density with ^{137}Cs is described by the expression:

$f_2(\sigma_{137}) = 0.15$ at $\sigma_{137} \leq 100$ kBq/sq.m;

$$f_2(\sigma_{137}) = 2.0 \cdot \sigma_{137}^{-0.56} \text{ at } \sigma_{137} > 100 \text{ kBq/sq.m;} \qquad \text{(IV.3.3)}$$

where:

f_3 , rel. un., is the factor that assesses ^{131}I intake in the body of inhabitants with leaf vegetables, other surface contaminated food products, and with milk during the time of cattle stabling. The total contribution of these processes in the thyroid dose formation was determined as $f_3 = 0.15$;

f_4, rel. un., is the factor of decrease of ^{131}I intake in the body due to cessation of consumption of local milk and other local food products in May, 1986. For persons, with respect to whom the fact of cessation of milk consumption was determined, the f_4 value was assumed equal to 0.15 rel. un., and for the rest persons – 1.0 rel. un.

For the inhabitants of a settlement, for which there were no individual data on cessation of milk consumption, we assumed: $f_4 = 1 - 0.85 \cdot f_5$,

where:

f_5, rel. un., is the part of inhabitants in the settlement, who stopped to consume milk, according to the data of the polls in 1986 and 1987.

Population in the Plavsk district of Tula region did not stop milk consumption in May1986.

T_1 = 1.5 days is the half-period of milk decontamination after single intake of iodine-131 in the body of a cow (17);

T_{ec}, days, is the period of decrease of ^{131}I concentration in milk of cows pastured on the contaminated area. It was assumed equal to 4.2 days on the basis of data of monitoring in Russia after the Chernobyl accident.

The data about the dates of beginning of pasturing cows were obtained as a result of individual polls of inhabitants in 1987 and collection of data in collective farms in 1995–1997. Dates of beginning pasture period in private farms were used for dose calculation in thyroids of rural residents. For those districts, where no polls were performed, the dates of the beginning of pasturing were assessed on the basis of the analysis of meteorological data on daily average temperatures, the amount of precipitations and the mass of growing grass in April-May, 1986.

The unknown parameter i_0 in the intake function (see Equations (IV.3.1) and (IV.3.2)) was determined from the equation:

$$G(t_M) = \int_0^{t_M} (i_{inh}(\tau) \cdot 0.66 \cdot R_{th}(t_M - \tau; u) + i_{ing}(\tau) \cdot R_{th}(t_M - \tau; u)) d\tau, \text{ kBq,} \qquad \text{(IV.3.4)}$$

where:

$G(t_M)$, kBq, is the ^{131}I activity in thyroid at the moment of the measurement t_M;

$i_{inh}(t)$, $i_{ing}(t)$ – inhalation and ingestion intake functions, they are determined by Equations (IV.3.1) and (IV.3.2), respectively;

$R_{th}(t;u) = 0{,}3 \cdot e^{-\frac{\ln 2 \cdot t}{T_{th}(u)}}$, rel. un., is the ^{131}I retention function in thyroid after its intake with food. The values of the iodine excretion half-life from thyroid $T_{th}(u)$ for persons of different ages were taken from the ICRP Publication 56 [IV.18], see Table IV.3.2;

$0.66 \cdot R_{th}(t; u)$, rel. un., is the ^{131}I retention function in thyroid after intake with inhaled air of the mixture of equal concentrations in the air of ^{131}I in the forms of elementary iodine, methyliodide and aerosol fraction with AMAD equal to 1 μm, and fast absorption in the inhalational tract.

Table IV.3.2. Effective half-life of ^{131}I excretion from thyroid, $T_{th}(u)$, dose factors $d_{inh}(u)$ and $d_{ing}(u)$, mGy/kBq, for ^{131}I intake at the age u with inhalation and contaminated food consumption, respectively [IV.18].

Age *u*, full years	T_{th}, **days**	$d_{inh}(u)$ ***, mGy/kBq**	$d_{ing}(u)$, **mGy/kBq**	**Age *u*, full years**	T_{th}, **сут**	$d_{inh}(u)$***, mGy/kBq**	$d_{ing}(u)$, **mGy/kBq**
0	5.4	2.40	3.70	10	6.9	0.69	1.0
1	5.5	2.40	3.60	11	7.0	0.61	0.93
2	5.7	2.13	3.22	12	7.0	0.57	0.87
3	5.9	1.88	2.85	13	7.1	0.54	0.81
4	6.1	1.63	2.47	14	7.1	0.49	0.74
5	6.3	1.40	2.10	15	7.2	0.44	0.68
6	6.5	1.24	1.88	16	7.2	0.39	0.59
7	6.6	1.10	1.66	17	7.3	0.34	0.51
8	6.7	0.95	1.44	>17	7.4	0.28	0.43
9	6.8	0.81	1.22				

* For the mixture of gas, organic and aerosol forms of ^{131} in the air in equal concentrations with AMAD equal to 1 μm, and fast absorption in the inhalation trac].

After determination of the parameter i_0, kBq/day of the intake function, Equation (IV.3.4) is used for calculation of the total intake in the body of an individual with inhaled air, I_{inh}, and food, I_{ing}, kBq, as the integral over time of the corresponding function of intake $i(t)$, kBq/day:

$$I_{inh} = \int_0^\infty i_{inh}(\tau) \cdot d\tau \qquad \text{(IV.3.5)}$$

$$I_{ing} = \int_0^\infty i_{ing}(\tau) \cdot d\tau \qquad \text{(IV..3.6)}$$

The expected individual absorbed dose in thyroid $D_{th}(u)$ for a person of age u is calculated according to the formula:

$$D_{th}(u) = I_{inh} \cdot d_{inh}(u) + I_{ing} \cdot d_{ing}(u) \text{, mGy} \qquad \text{(IV.3.7)}$$

where:

$d_{inh}(u)$, $d_{ing}(u)$, mGy/kBq, are the dose factors for ^{131}I intake in the body of persons of age u by inhalation and ingestion ways, respectively, (see Table IV.3.2)

Figure IV.3.2 shows the dependences of the average absorbed doses in thyroid on age for villages and urban settlements obtained with results of direct measurements in thyroid of inhabitants in the Bryansk, Kaluga, Tula and Oryol regions [IV.27, IV.28]. Average thyroid dose in adults was taken as unit in each settlement. Ratios of average thyroid dose in other age groups to the value for adults were calculated; all data for the same age groups were averaged and used for graphing. At least five and more measurements in an age group in a settlement were used for this analysis. The mean thyroid dose in an age group without direct measurements can be estimated using these age dependences by mean thyroid dose in other age group with measurements in the same settlement.

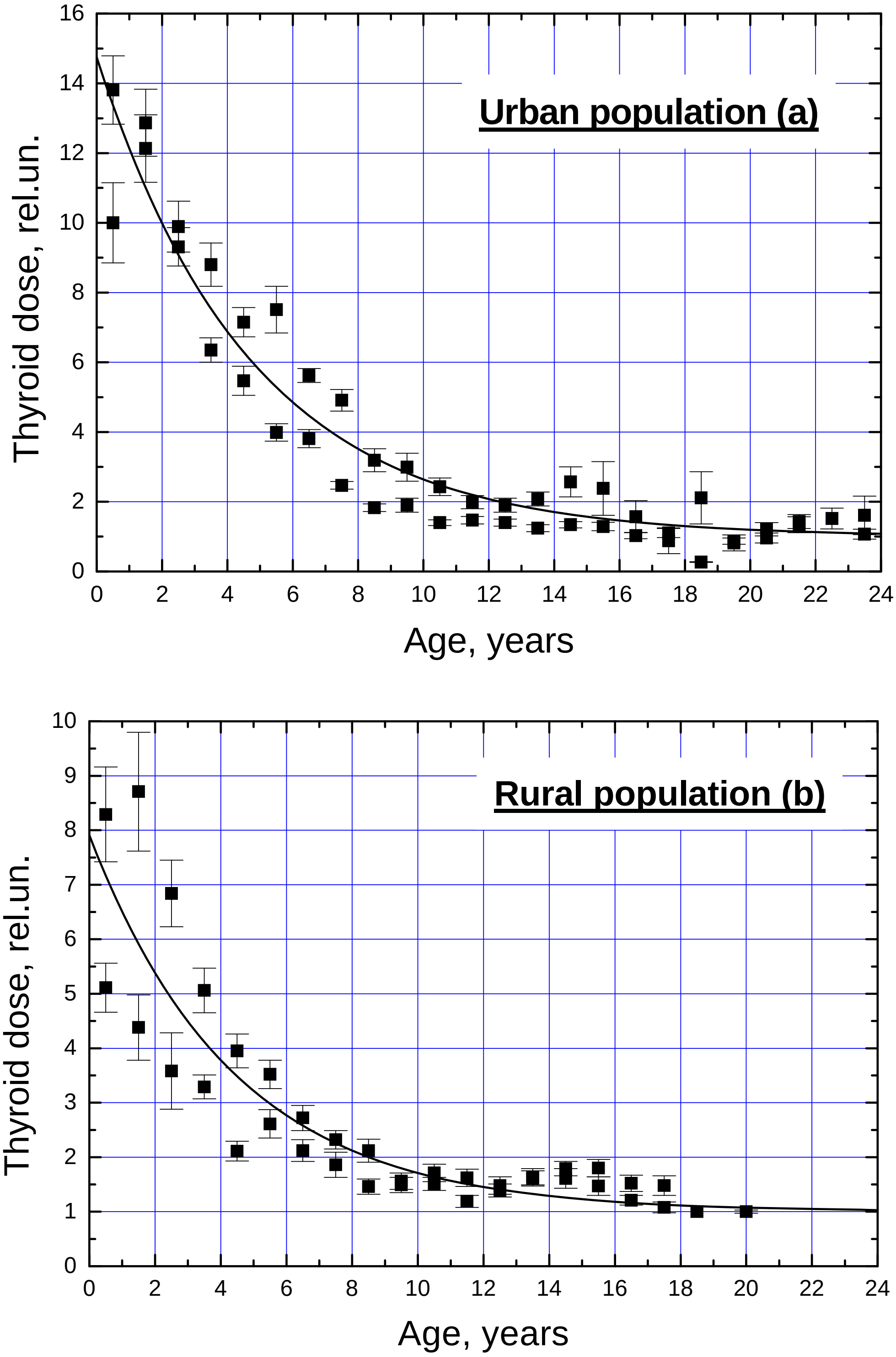


Fig.IV.3.2. Age dependence for average thyroid dose in urban (a) and rural (b) population in contaminated regions of Russia.

Tables IV.3.3 and IV.3.4 present the values $p(u_i)$ and p_j for the j-th age group assessed on the basis of individual radiometry of thyroid in inhabitants of settlements in the four regions of Russia in dependence on the age separately for the rural and urban population. We assumed the age of three years as the reference age, because the maximum number of ^{131}I measurements in thyroid was done in the four regions of Russia in May and June, 1986, in children of this age.

The absorbed dose in thyroid depended on the dynamic of ^{131}I concentration in milk, on milk consumption rate, on age and performed countermeasures. To find out regularities of the thyroid dose connection with other parameters of radioactive contamination, the dose values were standardised with respect to the time of beginning of pasturing dairy cattle, to age, and to countermeasures. For this, the standard dose, D_{th}^{st}, was introduced. It was calculated as the arithmetic mean of all individual doses recalculated to one "reference" age - 3 year, with the use of the dependencies of the average dose on age for urban and rural inhabitants, in the assumption that dairy cattle was pastured by the moment of radioactive depositions (t_2=0), and that countermeasures were not applied ($t_3 = \infty$).

Empirical dependence of the standard dose on reference ^{131}I concentration in milk was obtained on the basis of ^{131}I measurements in milk and in human thyroids in May-June 1986 in four most contaminated regions of Russia. For this purpose all results of measurements in milk in May, 1986, were recalculated to one reference date, 08.05.86 using effective half-time of the ^{131}I concentration decreasing in milk according to results of measurements – 4.2 d. The dependence of the standard dose on reference ^{131}I concentration in milk is show at Figure IV.3.3.

This dependence was used for reconstruction of the standard thyroid dose in settlements, where direct measurements in thyroid were not done in 1986. The average standard thyroid dose in inhabitants of a settlement D_{th}^{st} was connected with the reference ^{131}I concentration in milk C^r_m, kBq/l by the linear regression equation:

$$D_{th}^{st} = b \cdot C_m^r \text{, mGy} \qquad \text{(IV.3.8)}$$

where:

b = (10.5 ±0.7) mGy·L/kBq for villages, towns and cities.

Then mean thyroid dose in a separate age group was calculated from the standard dose using the age dependencies of the dose for villages and towns and a correction factor RR on real conditions of dose formation. The last parameter was defined as:

$$\text{RR} \equiv D_{1j}/D_{1j}^{st}, \qquad \text{(IV.3.9)}$$

where:

D_{1j}, mGy, is the dose in persons of the j-th age group calculated with Equation (IV.3.7) for the intake rate i_0=1 kBq/day and actual conditions of the given settlement;

D_{1j}^{st}, mGy, is the dose in persons of the j-th age group calculated with Equation (IV.3.7) for the intake rate i_0=1 kBq/day and standard conditions: dairy cattle was at pasture by the time of the radioactive fallout ($t_2 = 0$) and countermeasures were not used in a settlement ($t_3 = \infty$).

Table IV.3.3. Average ratios *p(u)* thyroid dose in persons of the referent age (3 years) to that in persons of age *u*, rel.un..*.

Age *u*, full years	Towns	Villages	Age *u*, full years	Towns	Villages
0	0.60±0.05	0.6±0.1	10	3.0±0.4	2.5±0.8
1	0.70±0.07	0.7±0.2	11	3.4±0.4	2.7±0.9
2	0.80±0.08	0.8±0.2	12	3.8±0.5	2.9±0.9
3	1.0±0.1	1.0±0.3	13	4.2±0.5	3.1±0.9
4	1.2±0.1	1.2±0.4	14	4.6±0.6	3.3±0.9
5	1.4±0.2	1.4±0.5	15	5.0±0.6	3.4±0.9
6	1.7±0.2	1.6±0.5	16	5.3±0.6	3.5±0.9
7	2.0±0.3	1.9±0.6	17	5.7±0.6	3.6±0.9
8	2.3±0.3	2.1±0.7	> 17	7.4±0.4	4.1±0.6
9	2.7±0.4	2.3±0.7			

* Average values and its errors are presented.

Table IV.3.4. Average ratios p_j thyroid dose in persons of the referent age (3 years) to that for persons of *j*-age group, rel.un.*.

Age group *j*,	Age interval, years	Towns	Villages
1	<1	0.6±0.05	0.6±0.1
2	1--2	0.8±0.1	0.8±0.21
3	3--7	1.5±0.4	1.4±0.5
4	8--12	3.1±0.6	2.5±0.8
5	13--17	5.0±0.6	3.4±0.9
6	>17	7.4±0.4	4.1±0.6

* Average values and its errors are presented.

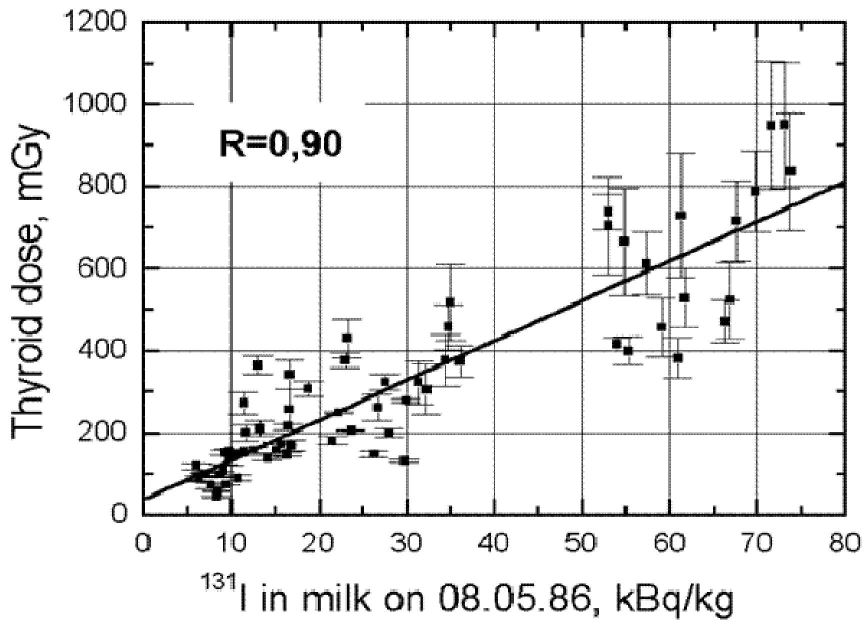


Fig.IV.3.3. Dependence of standard thyroid dose in rural settlements on reference ^{131}I concentration in milk on 08.05.1986 according to data from Bryansk, Kaluga and Tula regions.

IV.4. Overview of the Astral Code

Duffa, c., Institut de Radioprotection et de Sûreté Nucléaire (IRSN)[12], France

IV.4.1. Introduction

The ASTRAL code was developed as part of a project co-funded by IRSN (French Institute for Radioprotection and Nuclear Safety) and EDF, the French national electric utility. ASTRAL is a French acronym for "technical assistance for post-accident radiological protection". If a large quantity of radionuclides were to be released to the environment, several measures would have to be rapidly taken: estimating the concentration of radionuclides in various environmental compartments and food products, deducing from this the potential exposure of the surrounding population to radiation, predicting future developments in the situation, and proposing scenarios for managing contaminated areas. With this situation in mind, a software program was created for use by a relatively large group of personnel involved in the management of emergency response centres or conducting radioecological assessments. Estimations begin with the deposition of radionuclides on the ground.

This code does not process the atmospheric dispersion phase and exposure to the plume. Calculations are performed to determine how concentrations of radionuclides in various elements of the food chain (agricultural and forest ecosystems) change over time and to assess doses due to external and internal exposure. These variables are compared with admissible limits and intervention levels. Various simulations of contaminated zone management can be conducted by implementing counter-measures to reduce the impact of the accident on the environment and population. The second version of ASTRAL released at the end of 2001 can be used as a decision-making aid.

IV.4.2. General operation

Following radioactive release to the atmosphere, the composition of deposits on the soil varies with the distance from the point of release of the concerned facility, atmospheric conditions, and the type of soil cover. A series of deposition zones can be defined in which each zone consists of a geographical entity, theoretically with an indeterminate surface area, but over which deposits and meteorological conditions (rainfall in particular) are considered to be identical and uniform. These are referred to as "iso-deposition" zones. The map given in Figure IV.4.1 shows an example of deposition zones. The map was made by a Geographical Information System (GIS) during a crisis drill called "Becquerel", carried out in October 1996, and dealing with a hypothetical accident on the Saclay nuclear site. A number of management strategies representing specific methods of situation management can be developed on each of these zones. The first management strategy adopted is always the one where no countermeasure is implemented. For the other strategies, users can simulate the application of countermeasures to define alternatives to the initial study. In this way, they can compare the benefits expected from the various measures taken and propose the best solution for managing contaminated zones. By default, calculations are not saved, although they can all be stored in the ASTRAL database so that they can be exported and used at a later stage by another tool (e.g. representation of results by a GIS).

[12] This section was compiled based on https://www.irsn-astral.org/astralV200Fichier/.../PresentationAstral_EN.pdf.

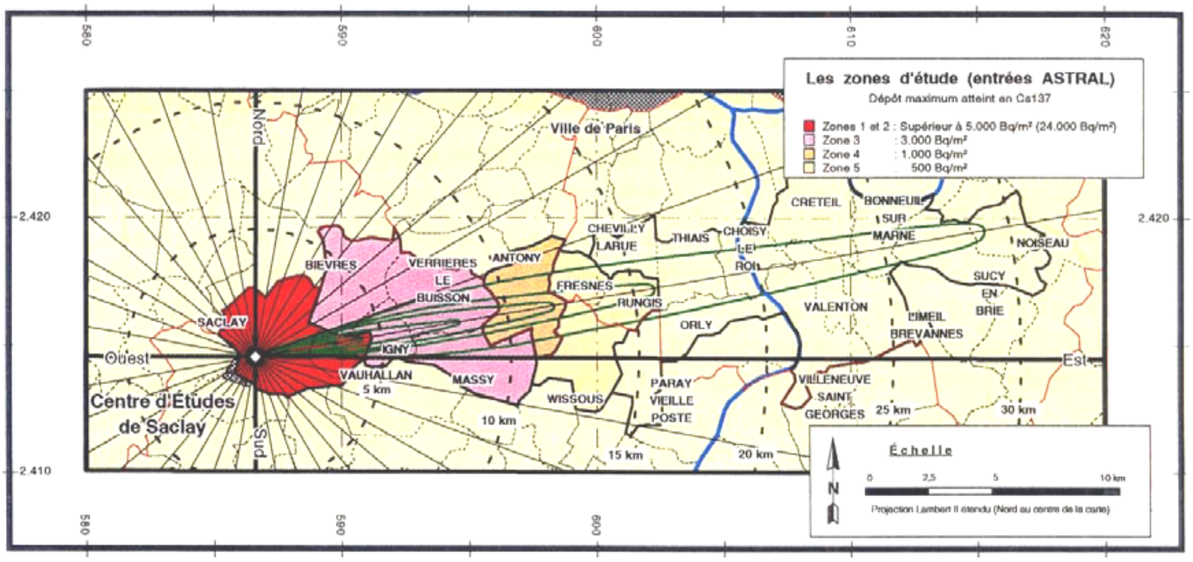


Fig.IV.4.1. Definition of study zones – Example taken from the "Becquerel" drill

IV.4.3. Calculation module

IV.4.3.1. Main functions

ASTRAL is designed to meet the objectives of crisis situations and radioecological studies. Two user profiles ("user" and "expert") and two management strategies ("normal" or "crisis") have been defined to allow a single tool to meet both types of objectives. The main difference between the two profiles lies in the type of calculation option available to users. The "user" profile, particularly practical for crisis situations, is designed with the non-specialist in mind: the operations required to obtain initial results and the options for modifying parameters unrelated to the accident have been deliberately limited. Although some assessment options can be modified, they are given by default and automatically taken into consideration (deposition condition, agricultural and feeding calendars). The difference between the two types of management strategy is in the feeding method adopted for animals. In the crisis situation, a conservative calculation is made for milk, which is a vital food from the health point of view during the first weeks following deposition. The main functions offered include:

(i) calculating concentrations in various compartments of the food chain,
(ii) calculating doses received by individuals over a given period via three exposure pathways
(iii) (exposure to deposits, inhalation of resuspended particles from deposits, ingestion of contaminated
(iv) foods),
(v) calculating concentration indexes, the ratio between concentrations and the marketing limit of a foodstuff, used in assessing the radioecological impact,
(vi) dynamic acknowledgement of counter-measures.

The scope of these assessments in terms of time and space is as follows:

— three years to guarantee consideration of at least two complete agricultural cycles,
— point or surface (for a zone with constant deposition and meteorological conditions).

Table IV.4.1 shows the radionuclides which are considered in these assessments.

Table IV.4.1. .Considered radionuclides.

Ag 110m	Co 57	I 131	Np 239	Sb 125	U 232
Am 241	Co 58	Ir 192	Pm 145	Sb 127	U 233
Ba 133	Co 60	La 140	Pm 147	Sm 151	U 234
Ba 140	Cr 51	Mn 54	Pr 143	Sn 113	U 235
Br 82	Cs 134	Mo 93	Pu 238	Sn 121	U 236
Cd 109	Cs 136	Mo 99	Pu 239	Sn 126	U 238
Cd 113m	Cs 137	Nb 93m	Pu 240	Sr 89	Y 90
Ce 141	Eu 152	Nb 94	Pu 241	Sr 90	Y 91
Ce 143	Eu 154	Nb 95	Rb 86	Tc 99	Zn 65
Ce 144	Eu 155	Nd 147	Rh 105	Te 127m	Zr 93
Cl 36	Fe 55	Ni 59	Ru 103	Te 129m	Zr 95
Cm 242	Fe 59	Ni 63	Ru 106	Te 131m	
Cm 244	I 129	Np 237	Sb 124	Te 132	

IV.4.3.2. Calculation sequence chaining

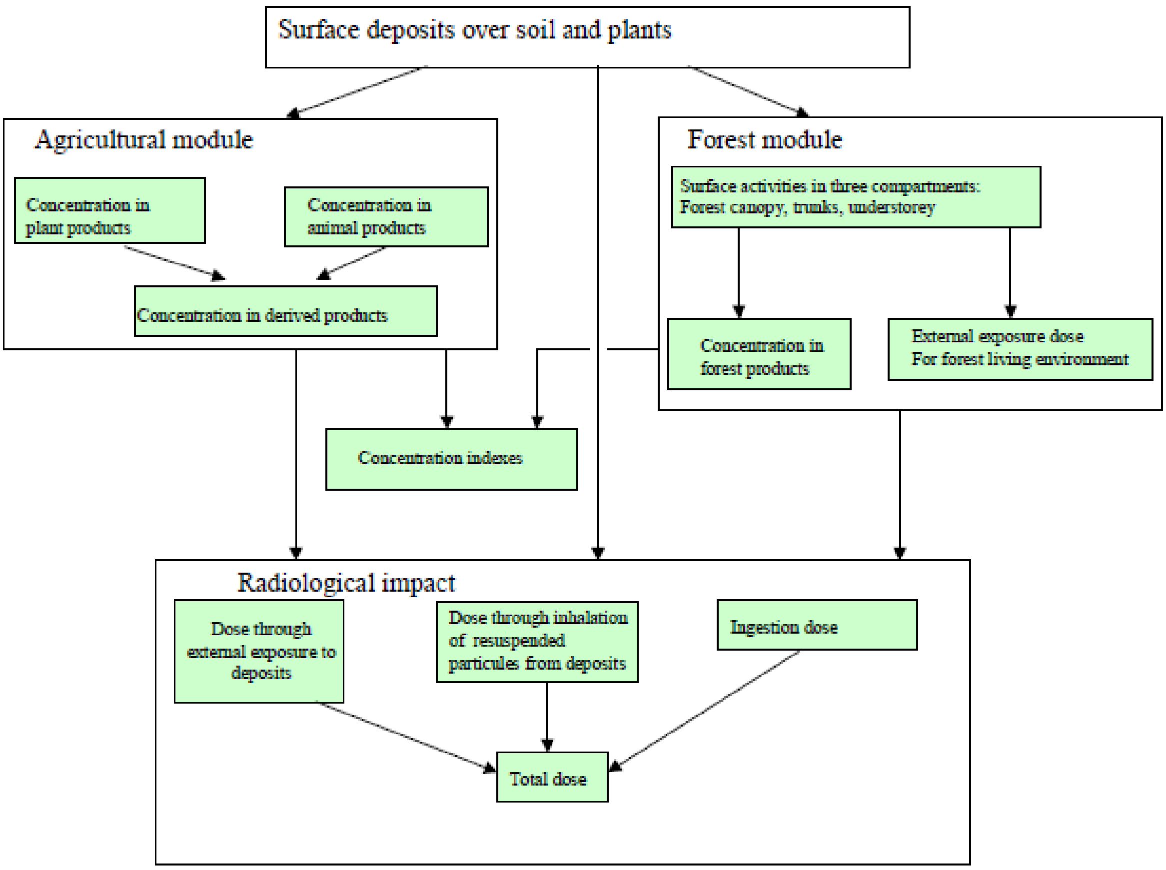


Fig .IV.4.2. Organizational structure of calculations.

IV.4.3.3. Concentration calculations

These calculations are used to determine how the concentration of various radionuclides in basic agricultural products, derived food products and products from the forest ecosystem changes over time. In the case of plant products, the radionuclide concentration must be determined at the time of harvest (or ingestion by livestock for pasture grass), taking into account any counter-measures implemented. The type of transfer (root, foliar, etc.) and, therefore, the equations to be considered and the values of certain parameters, are selected automatically from agricultural calendars (these may be by default or user-defined). ASTRAL calculations are based on two agricultural calendar dates (date of ploughing and date of harvest) or the maximum time spent in the ground for vegetable crops.

In the case of animal products, it is necessary to determine the radionuclide concentration in the three main animal products obtained from cattle, sheep, goats, pigs and poultry, namely meat, milk and eggs, taking into account local animal breeding and feeding techniques. Calculations are based on concentrations in fodder crops or pasture grass at the time of consumption by the animal, the values being provided by the calculations for plant products. In the case of pasture grass, this concerns the in situ concentration during the grazing period. For other foodstuffs, the radioactivity level is that measured at the time of the previous harvest, corrected to take into account radioactive decay during storage or silage. Feeding calendars are taken into account by defining the main elements of the feed ration for each category of animal. The next step is to determine the intensity and kinetic parameters governing the transfer of radionuclides ingested by animals to human food products. In ASTRAL, these transfers are processed dynamically, integrating successive intakes and transfers. This makes it possible to take into account any counter-measures concerning animal feeding practices, such as removal from pasture, delaying slaughter, feeding with uncontaminated fodder, etc.

In the case of foodstuffs derived from basic agricultural products, radionuclide concentrations at the time of human consumption are determined taking into account the way foodstuffs are processed, culinary practices and the length of storage periods between production and consumption. The most common derived products include butter, cheese, flour and canned and other preserved goods. Calculations are performed applying processing coefficients to concentration values in basic agricultural products, taking into account the radioactive decay occurring over the estimated time between production and consumption. Processing methods that lead to a reduction in concentration or longer periods between production and consumption can be used as counter-measures.

The forest ecosystem, which functions in a particular way, is handled separately. It can be divided into four compartments: the forest canopy, trunks, under-storey and soil. Following the deposition phase, transfer calculations are performed to determine the concentration in each compartment at each time interval. Contamination levels determined in the under-storey and soil are used to assess those of the various products considered in the forest ecosystem liable to enter the human food chain, such as mushrooms, berries, and game. Calculations are based on picking, gathering and hunting periods.

Outside these periods, calculations take into account the storage time elapsed since the nearest period.

Concentration results are given for each product by radionuclide or group of radionuclides, as defined by the EEC. Changes in concentration are shown over a maximum period of three years in graphs (see Figure IV.4.3) or tables. Marketing limits can be indicated on the curves so that particularly sensitive periods can be identified quickly.

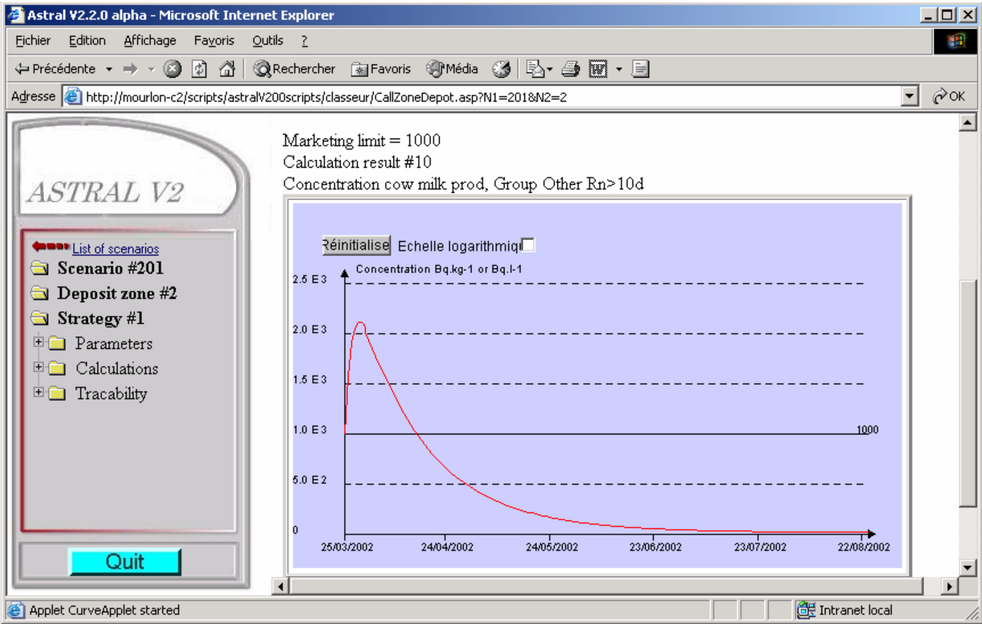


Fig. IV.4.3. Concentration curve for cow's milk.

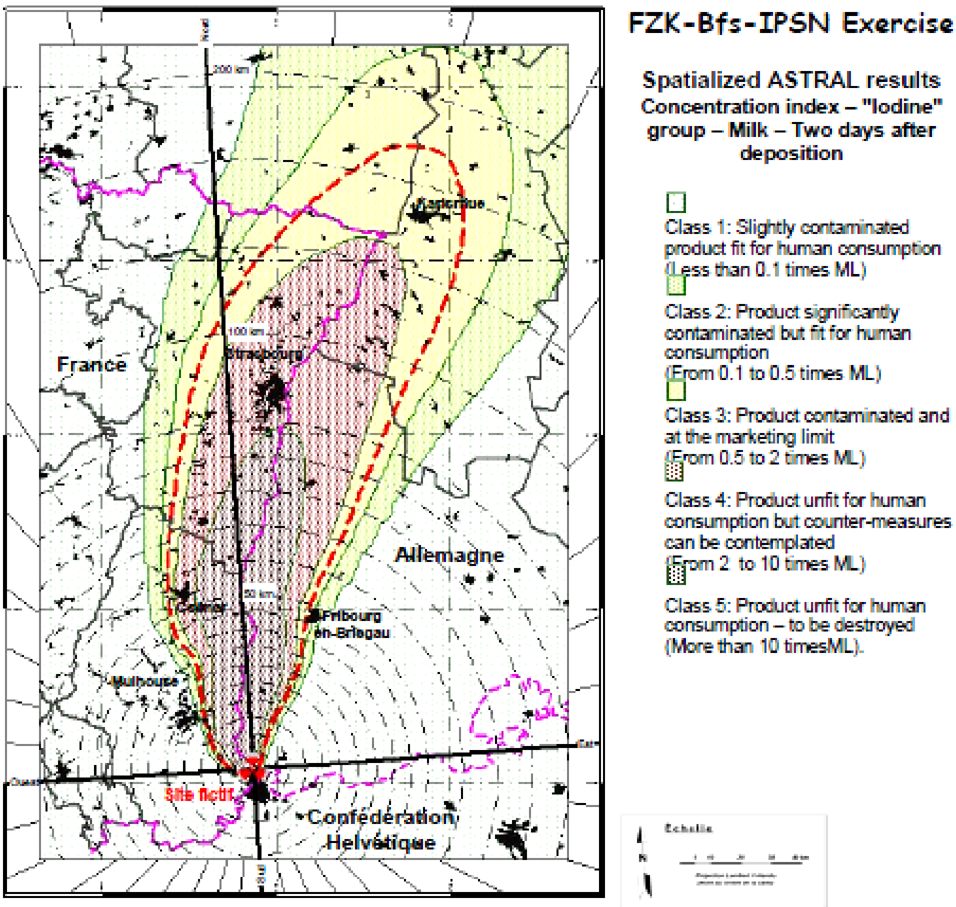


Fig. IV.4.4. Concentration indexes in milk for the iodine group, spatialized during the Rodos/Park/Astral exercise (June 2000).

IV.4.3.4. Concentration index calculations

The key factor for decision-makers is not the absolute value, but the relative value of radioactive concentration with regard to the marketing limit. For this reason, concentration indexes, defined as the ratio of a product's concentration to its marketing limit are calculated to show the results obtained with a GIS outside ASTRAL. The indexes are divided on color-coded classes used to identify the zones where concentrations are well below, close to, or above the defined limit. This classification system is shown on the map given in Figure IV.4.4. The map was created for the Rodos/Park/Astral exercise (June 2000) using ASTRAL results analysed by a GIS (see Figure IV.4.4). ASTRAL results can also be used by a GIS to cross data and offer a wide variety of information, such as the quantity of products in a concentration index class, the area affected, and so on.

IV.4.3.5. Dose calculation (radiological impact)

Doses are determined from exposure scenarios defined to reflect the lifestyle of the population groups studied: time spent in different living environments, ventilation rates, diet and degree of food self-sufficiency.

Lifestyles defined by default can be preselected but the user can modify the above mentioned parameters to define a particular scenario.

Doses, effective or thyroid, are calculated for various exposure periods following deposition and for a given lifestyle, and are personal committed doses up to the age of 70 years. Three exposure pathways are considered: external exposure to deposits, inhalation of suspended particles from deposits, and the ingestion of contaminated foodstuffs. Doses can be obtained:

(i) for adjustable exposure period; for example, from 0 to 30 days following deposition, from 31 days;
(ii) to one year after deposition, more than three years after deposition;
(iii) by exposure pathway;
(iv) as a function of time, daily or cumulated; and
(v) by radionuclide and, for the ingestion pathway, by foodstuff (see Figures IV.4.5 and IV.4.6).

IV.4.3.6. Consideration of counter-measures

The term counter-measure refers to any measure implemented to reduce the impact of an accidental deposition not only on the population but also on agricultural activities.

Counter-measures concerning agricultural products are changes in agricultural practices intended to reduce the concentrations in these products and the foodstuffs derived from them. Users can select the products and, when necessary, the periods, to which they wish to apply counter-measures. For example, they can decide to treat dairy cows with Prussian blue (cyanoferrates) for a six-month period from the second month after deposition onwards, to divide by five the caesium activity of the milk produced during that period. If compatible, several counter-measures (e.g. deep ploughing and adding fertilizer) can be applied simultaneously to the same product, in which case the effects are cumulated.

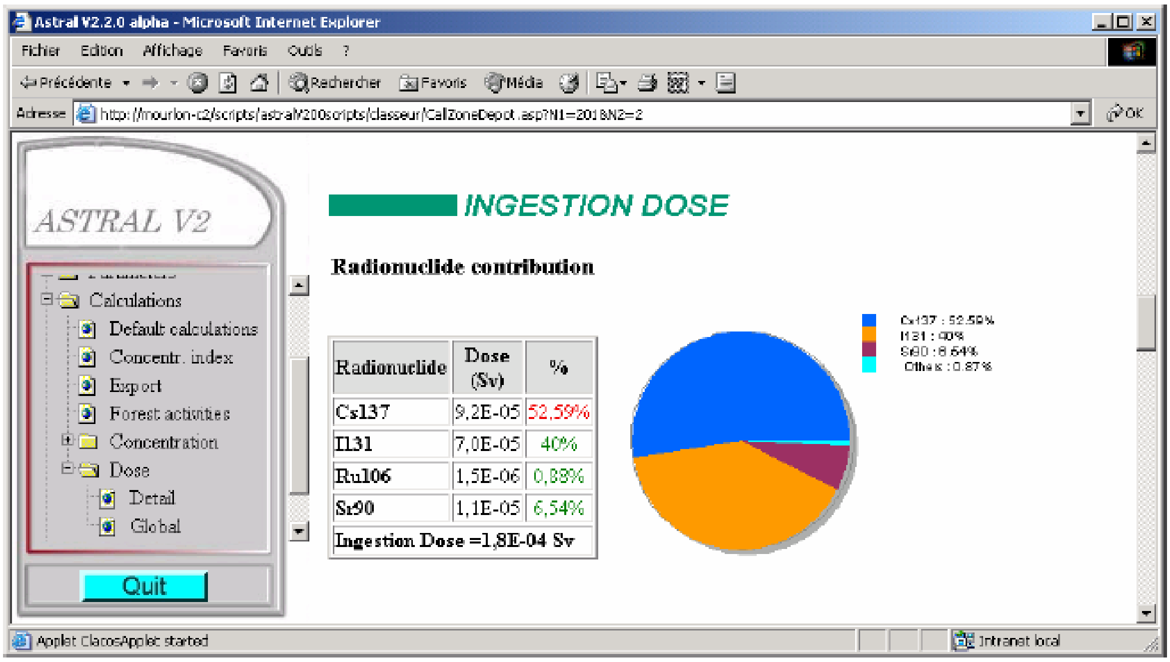


Fig. IV.4.5. Diagrams showing ingestion dose over one month, broken down by radionuclide.

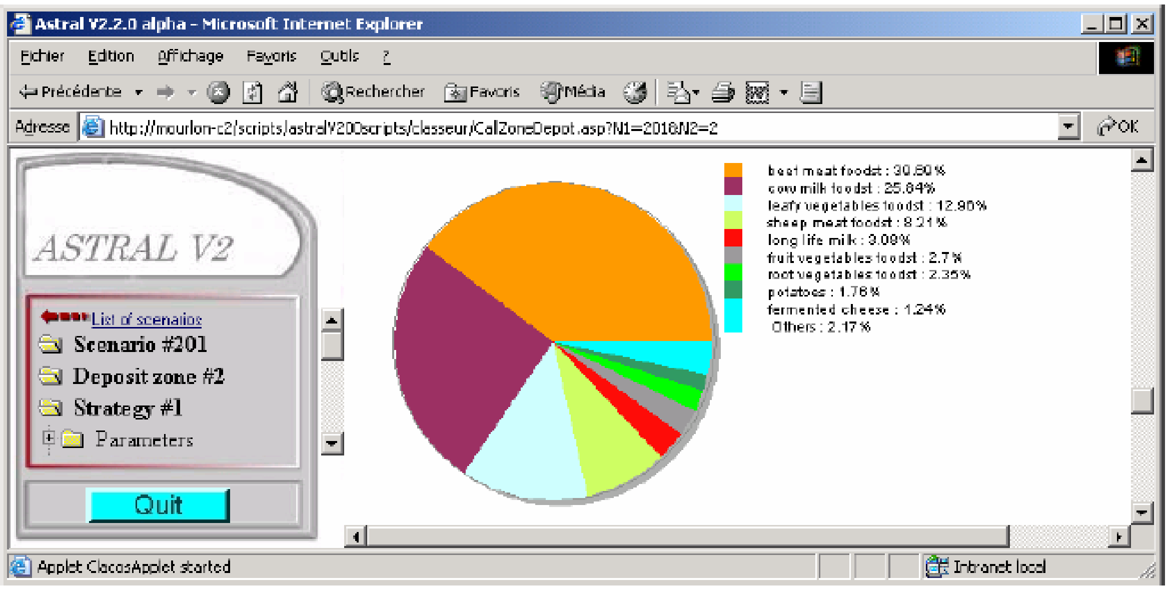


Fig. IV.4.6. Diagrams showing ingested dose calculated over one month and broken down according to type of food and radionuclide.

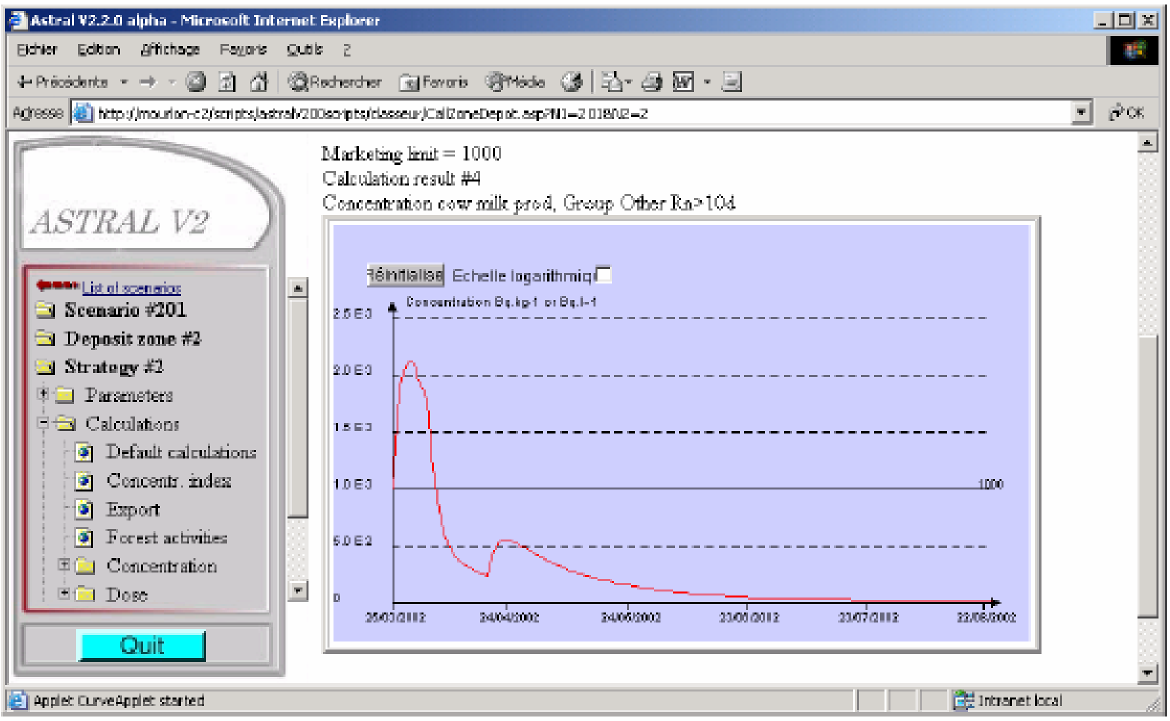


Fig. IV.4.7. Concentration curve for cow's milk, implementing a counter-measure for two weeks, starting 10 days after deposition.

The example given in Figure IV.4.7 shows the expected caesium-ruthenium concentration in cow's milk, taking into account the administration of clay to the animals for a period of two weeks, starting on the tenth day after deposition. This curve should be compared with the one shown in Figure IV.4.3 obtained under the same conditions, but with no counter-measure. It can be seen that the counter-measure causes values to fall below the marketing limit more quickly.

Health counter-measures are those intended to reduce human exposure and thus reduce the doses received. Bans on consumption and iodine administration are examples of this. ASTRAL users can simulate a ban over a given period on the consumption of those foodstuffs contributing the most to the ingestion dose – milk and leafy vegetables for example – and assess the benefit in terms of dose.

IV.4.4. Databases

IV.4.4.1. Contextual data

This term refers to data depending on the date or location of the accident. Default values are provided for this type of parameter, although they are not an exact reflection of reality. They can be changed by users of either profile. Calendars of agricultural practices depending on location and data, and varying from one year to another, are examples of this type of data. Other examples concern individual behaviour such as feed ration or time budget.

Some of these parameters, like agricultural calendars (see Figure IV.4.8) and feeding calendars (see Figures IV.4.9) are critical for calculations. In such cases, it is advisable to gather information in the field around key dates: harvest, grazing period, etc.

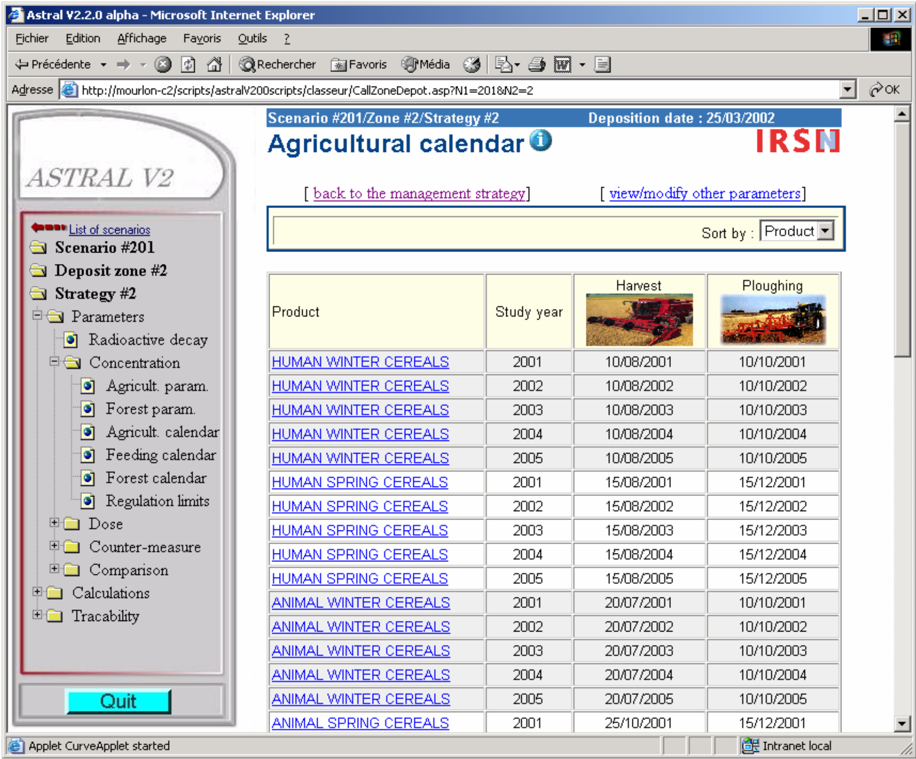


Fig. IV.4.8. Agricultural calendars.

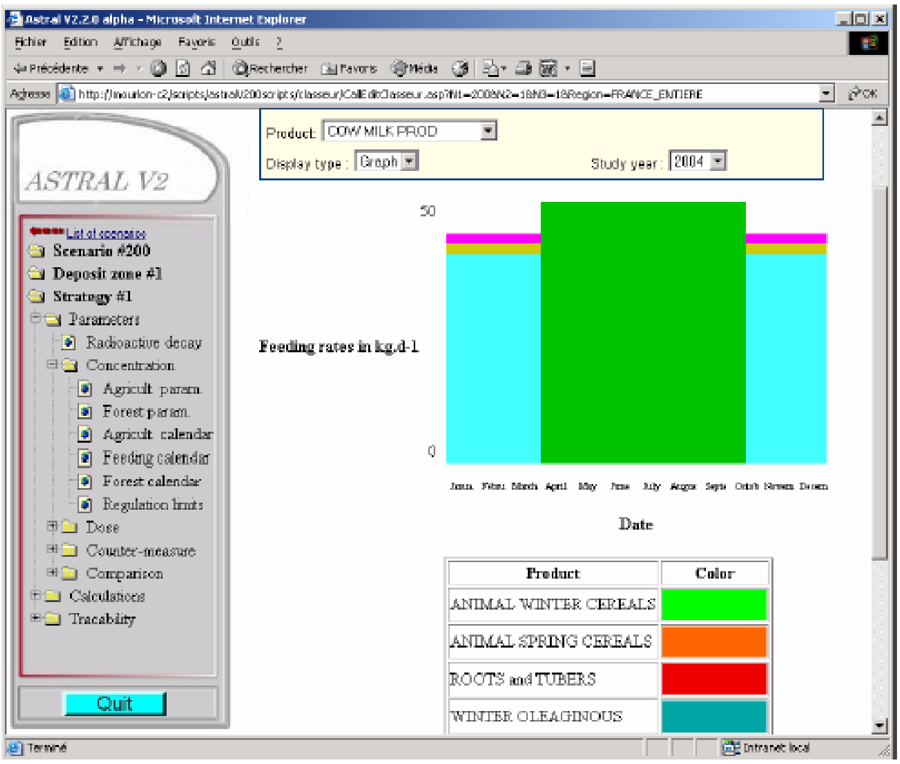


Fig. IV.4.9. Example of a feeding calendar.

IV.4.4.2. Data for radioecological calculations

This concerns all radionuclide-dependent parameters used to determine concentrations in various compartments of the environment. These include:

(i) transfer factors used to link a surface deposit to a concentration in a plant, whether through foliar;
(ii) transfer (depending on the time between deposition and harvest and precipitation when the plume;
(iii) passes over) or root transfer (depending on the type of soil);
(iv) transfer factors used to calculate the concentration in an animal product based on daily activity;
(v) intake;
(vi) food processing factors used to calculate the concentration in a derived product, based on the;
(vii) concentration in the agricultural product from which it derives (e.g. concentration in cheese; and
(viii) depends on that found in milk, concentration in flour depends on that found in the grain, etc.).

IV.4.5. Data for radiological calculations

These are the parameters used to calculate human doses. Some of them, such as dose coefficients, depend on the radionuclide. Those concerning internal exposure pathways (ingestion and inhalation) are taken from ICRP 72 [IV.3] and those for external irradiation come from Federal Guidance 12 [IV.29]. Other parameters are independent of the radionuclide. These are the ones used to characterize personal exposure scenarios: time spent in various living environments (e.g. inside and outside buildings), shielding factor provided by building in the calculation of external exposure dose, ventilation rates, dietary habits, and so on. These parameters come from surveys or, when too little information is available, they are estimated. Most of them depend on the individual's age group. The various lifestyles used in ASTRAL to define exposure scenarios use the six age groups defined in ICRP 72 [IV.3]: [0-1 year], [1-2 years], [2-7 years],[7-12 years], [12-17 years] and >17 years.

IV.4.6. Software ergonomics

IV.4.6.1. General principles

Special attention has been paid to software ergonomics. Owing to the very large volume of data to be handled – whether for initial data or results – it was necessary to define man-machine interfaces allowing the operator to handle complex calculations through simple operations. The owner mandated an "ergonomics" group composed of various potential users to work on a prototype and design screens offering intuitive and logical functions meeting users' needs. Version 2 integrates Internet technology and the now common graphical objects (scroll boxes, html links, drop-down menus, check boxes, help balloons), thereby offering an extremely user-friendly tool and minimizing the need for training.

IV.4.6.2. Selecting and displaying results

The concentration calculation screen (Figure IV.4.10) demonstrates the ergonomics of the results display screens. Users can select the required plant product, a radionuclide or group of radionuclides from the appropriate drop-down list. Radio buttons are available for selecting results for one radionuclide or a group of radionuclides (when users wish to compare the concentration with the marketing limit) and for selecting the display mode (graph or table). The end-of-calculation date is given by default (deposition date plus one year) but can be changed either by entering the date in the field provided or by selecting a date on the calendar next to this field. Lastly, a help balloon at the top of the page provides additional information and practical hints offering guidance for first-time users.

Any page containing input data or calculation results can be printed for transmission purposes or filing in a study or crisis folder. The references of the set of input data and the calculation number are given on each printout for traceability purposes.

IV.4.7. Computer development and quality assurance

Computer development for this software was carried out in accordance with Quality Assurance procedures following a prototype phase in which potential users could adjust the product to meet their expectations. The project itself was covered by a specific Quality Assurance Plan and functional specifications and underwent a test phase. Basic data specifications were prepared with a software engineering workbench with intrinsic Quality Assurance procedures. The purpose of a software engineering workbench is to define the database structure from a statement of requirements, after a Conceptual Data Model (CDM) has been created to model the relevant functions. A document was drafted containing all the equations and parameters used for the calculations. The calculation module was encoded in VB Script. Computer work was validated against the definition and then submitted to a series of routine calculation and function tests.

IV.4.8. Architecture and implementation

ASTRAL architecture is on three levels: a data server, a calculation server, and a client station (see Figure IV.4.11). The data server level uses ORACLE and can run on various computer operating systems: Windows (NT or later), UNIX. The calculation server uses the Internet Information Server (IIS) and must be installed with a Windows operating system (NT or later). The client station only requires an Internet Explorer navigator (version 5 and later) to operate. Optimum computing time is obtained by installing each level on a different workstation. However, the software can be used in "nomad" mode by installing all three levels on a single computer – on a laptop for example.

ASTRAL architecture is designed to ensure easy installation, utilization and maintenance – no installation is required on client stations. The application is currently installed at IRSN's emergency response centre, at EDF/SEPTEN, and in various IRSN departments. It can be accessed on the Internet after entering a user code and password allocated under certain conditions (in service as from version 2.1.0).

IV.4.9. Conclusion

ASTRAL covers many aspects of "post-accident" radioecology and is intended as a relatively easy-to use tool. In the event of accidental radioactive release to the environment, it can be used to test various scenarios for managing accident situations, in particular by simulating counter-measures and assessing the probable benefits. In this way, it provides useful information and can be a valuable decision support tool.

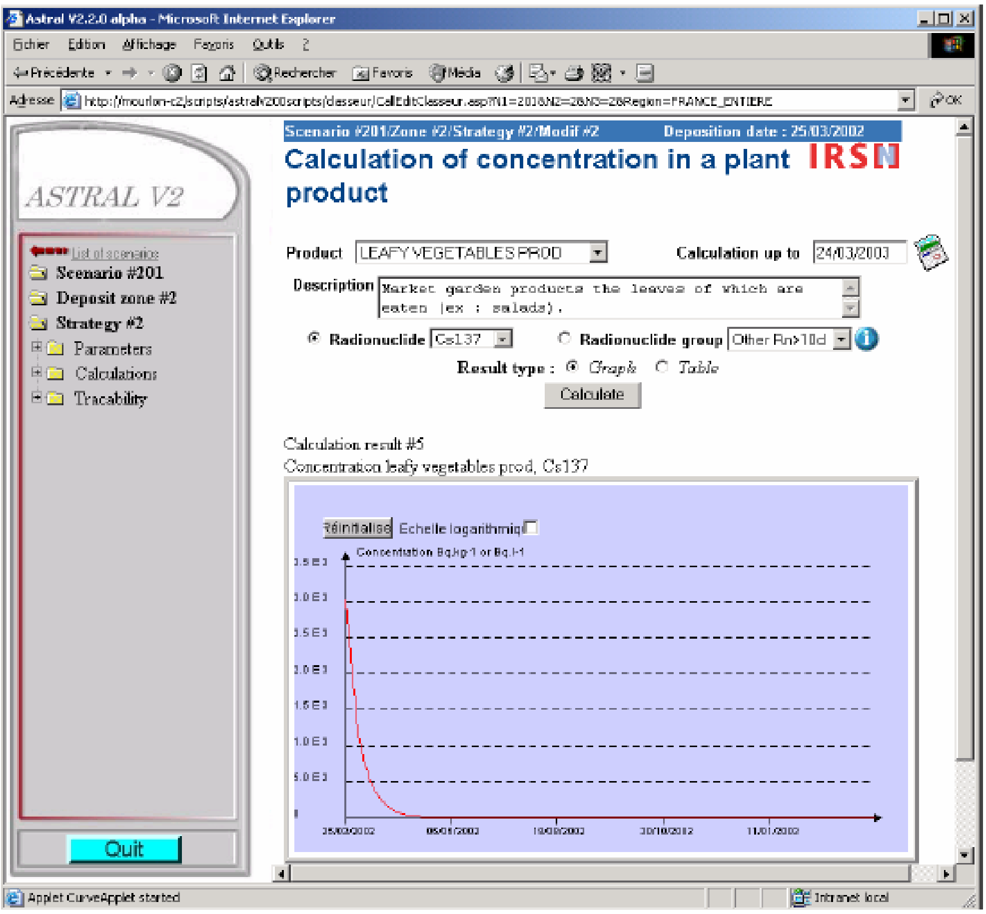


Fig. IV.4.10. Concentration calculation screen for a plant product.

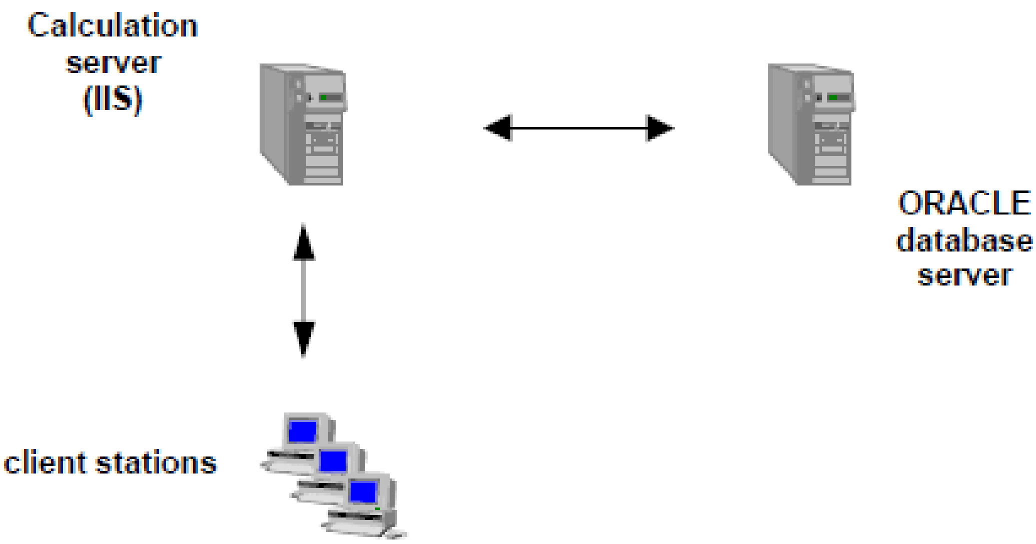


Fig. IV.4.11. ASTRAL architecture – Version 2.

IV.5. Evaluation of the TAM-DYNamic Model predictive performance on the basis of ^{131}I Public Exposure Scenario

Kanyar, B., Facankoz 12/2, H-2030, Erd, Hungary

IV.5.1. Introduction

The first version of the dynamic model and software tool TAMDYN was developed within an IAEA-support visit to the RISO National Laboratory in Denmark [IV.30]. The source software was the TAM3, written by R. H. Gardner, Oak Ridge National Laboratory, USA and provided it to use for all the participants taking part in the IAEA-project of Validation of Model Prediction (VAMP), 1988-93. The computer program TAM written in Turbo Pascal was a tool for uncertainty analysis of mathematical models given in explicit analytical forms and it had been extended by the Expert here to the dynamic models of radioecology given by differential equations and other complex forms, 20 years ago. This software tool was used for many models introduced by the Expert both in national and international projects until the beginning of 2000. Later on the models developed turn to use a more comfortable and effective software tool, the ModelMaker [IV.31] and the recent models introduced to the IAEA project EMRAS Working Group Iodine [IV.32] are formed and used by the representation of the software ModelMaker.

The iodine kinetics has been studied by the Expert for many years. The first steps began with experimental work [IV.33] and continued by modelling of the iodine transfer both in the environment and human body [IV.34, IV.35]. The initiation of the models used was the basic work from J.R. Johnson [IV.21]. In addition to the research work and use of the models for environmental assessments within the nuclear energy program in Hungary, later on to the dose assessments in Hungary due to the Chernobyl accident the models have been implemented in education of students in graduate and post graduate courses.

Within the framework of the EMRAS Iodine WG our model was extended for age groups and adapted to the new software tool ModelMaker.

The models developed during the last 20 years have been collected and renamed as UniVes to summarize the modelling actions in radioecology at the University of Pannonia, Veszprem/Hungary (former name: University of Veszprem).

IV.5.2. Model used in EMRAS Project, Iodine Working Group

The main purpose of the recent work was to extend the former models to the age dependence of the I-kinetics and dose assessments of human body. The seasonal variation of growing vegetation and feeding profiles of the dairy cows has been taken into consideration by sigmoid-type functions.

IV.5.2.1. Structure of the model and mathematical expressions

Figure IV.5.1 shows the structure of the model of the kinetics of stable iodine in human body.

To prepare details for modelling the first step was a reconstruction of the air contamination of ^{131}I from the data of ^{137}Cs deposition in the different areas. Therefore in modelling the air has been chosen as the source of the ^{131}I-contamination (variable Cair. Bq/m^3) and due to the dry and wet deposition () the soil, pasture and vegetables became contaminated. The precipitation (variable: Prec) given by the scenario is also involved as input data without variation inside the whole area.

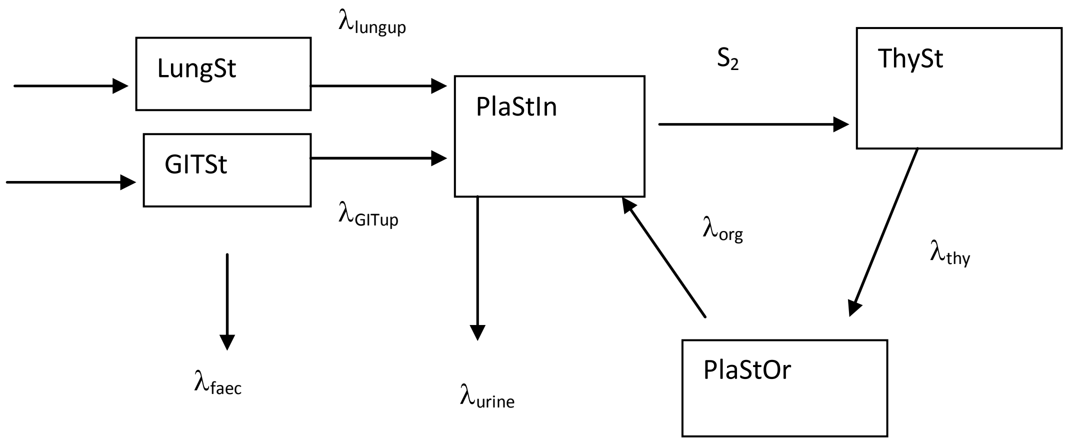


Fig. IV.5.1. The I kinetics in human body (compartmental structure).

The rate of atmospheric deposition (D_a. Bq/d) and the interception factor of the vegetation (R) are determined by the forms of:

$$D_a = C_{air} \cdot (v_d + w \cdot Prec) \text{ . } R = 1 - exp(-\mu Y) \quad \text{(IV.5.1)}$$

where:

C_{air} is the concentration in air (Bq/m^3);
v_d is the dry deposition velocity (m/d);
w is the wet deposition coefficient (-)
Prec is the precipitation (m/d)
μ is the absorption coefficient to the vegetation (m^2/kg); and
Y is the yield of vegetation (kg/m^2).

The seasonal variation of the growing vegetation is taken into consideration by a sigmoid-type function (YieVar). in the following form:

$$YieVar = 1.0\text{-}exp(-exp(2.5*ln((10+t)/30))) \quad \text{(IV.5.2)}$$

The beginning of grazing (feeding profile) is determined by a Weibull-distribution function (FeedProf) with mean value of the t_{beg}:

$$FeedProf = 1.0\text{-}exp(-((t/ t_{beg})\text{^}5)) \quad \text{(IV.5.3)}$$

The beginning of feeding by fresh pasture the scenario description are taken into consideration [IV.36].

For vegetation (pasture and leafy vegetables) the edible parts have been derived by a simple coefficients (edible parts: variable Pas and Veg).

Cow milk contamination (variable Milk. Bq/L) is assessed by the steady-state form of:

$$Milk = U \cdot F_m \cdot exp(-\lambda \cdot \tau). \quad \text{(IV.5.4)}$$

where:

U is the daily feeding (kg/d wet);
F_m the transfer coefficient (d/L);
λ the radioactive decay constant; and
τ the time delay between the feeding and use the milk.

The biokinetics of ^{131}I and stabile I in human are modelled by parallel compartments (GITAc and GITSt. PlaAc and PlaSt etc). The radioactive I uptake of the thyroid as a zero-order kinetics is influenced by the amount of stabile I in plasma. The flow rate (r_2. Bq/d) is expressed in the following form:

$$r_2 = PlaAc/PlaInSt \cdot S_2. \tag{IV.5.5}$$

where:

PlaAc is the radioactivity in the plasma compartment (Bq);
PlaInSt is the stabile I in plasma inorganic form (μg); and
S_2 is the daily thyroid uptake of stable I (μg/d).

The ingestion of stable I is given as input data (variable IngS. μg/d).

IV.5.2.2. Kinetic parameters

Most of the parameters (S_2. λ_{thy} etc.) used are derived from the data in the working sheets provided by the WG Leader (P. Krajewski) and attached to the scenario descriptions. According to the literature the values of the age independent parameters are the following:

$$\lambda_{GITup} = \lambda_{lungup} = 190\ (d^{-1}).\ \lambda_{faec} = 5\ (d^{-1}). \tag{IV.5.6}$$

$$\lambda_{org} = 0.053\ (d^{-1}).$$

The age dependent and zero-order I uptake of thyroid (S_2) takes:

$$S_2 = 65 * M_b / 70\ (\mu g/d). \tag{IV.5.7}$$

where:

M_b is the body mass (kg) and it involves the age dependence.

In steady state conditions the stable I inflow to each compartment must be equal to the proper outflow. Therefore the transport coefficients from thyroid to organic plasma (λ_{thy}) can be assessed by:

$$\lambda_{thy} = S_2 / ThySt\ (d^{-1}). \tag{IV.5.8}$$

Due to the mass conservation the age dependent stable I in organic plasma is calculated in the following way:

$$PlaOrSt = .\ \lambda_{thy} * ThySt / \lambda_{org}. \tag{IV.5.9}$$

By similar ideas and methods the urinary excretion coefficient (λ_{urin}. d^{-1}) is determined by the form of:

$$\lambda_{urin} = (M_{I\text{-}up} + \lambda_{thy} *ThySt - S_2) / PlaInSt . \qquad \text{(IV.5.10)}$$

where:

ThySt and PlaInSt are the stable I in equilibrium in the compartments of Thyroid and inorganic plasma

Respectively, and $M_{I\text{-}up}$ is the daily uptake of I by the plasma. From the analysis of the stable iodine uptake and the body mass in different ages we have introduced a simple form to assess the age dependent uptake:

$$M_{I\text{-}up} = IngCoe * M_b . \qquad \text{(IV.5.11)}$$

where the value of IngCoe (ingestion coefficient) was estimated as 2.8. It gives a proper approximation for the scenarios studied.

Dose coefficients are derived from the volume of Int. Basic Safety Standards [IV.37].

All the parameters of the I-kinetics in human used are summarized in Table IV.5.1. The consumption of different foods and other local parameters are determined according to the scenario descriptions [IV.36–IV.39].

IV.5.2.3. Model form in representation of the software tool ModelMaker

Figure IV.5.2 shows the model form used for simulation by the software ModelMaker including the atmospheric deposition, terrestrial foodchain and kinetics of both the stable and radioactive iodine. Compartments between them either stable or radioactive I can be flow are represented by rectangular boxes. The rounded boxes are variables mainly for output of the values in tables and graphs. The icon of boxes with more parts, like CaiA (air concentration), Prec (Precipitation) and IngS (Ingestion of stable I) are to define time dependent input values. By the hexagonal box (DMi) a time delay can be provided for consumption of milk. The arrows of full lines represent the flow of iodine.

Table IV.5.1. Age-dependent parameters used for input.

Parameter	Newborn	1 –2 a	3-7 a	8-13 a	13-17 a	Adult
Body mass (kg)	3.5	11	22	40	60	70
Stab I in Thyroid. normal (mg)	0.3	0.3	1.0	3.5	8.0	12
Stab I in Plasma inorg.. normal (mg)	0.05	0.015	0.030	0.06	0.08	0.1
Stab I intake (μg/d)	10	30	60	110	160	180
Inhal. rate (m^3/d)	2	4	10	15	18	22
DC inges (Sv/Bq)	3.8e-6	3.6e-6	2.0e-6	1.0e-6	7.0e-7	4.5e-7
DC inhal (Sv/Bq)	1.5e-6	1.4e-6	7.5e-7	3.8e-7	2.2e-7	1.5e-7

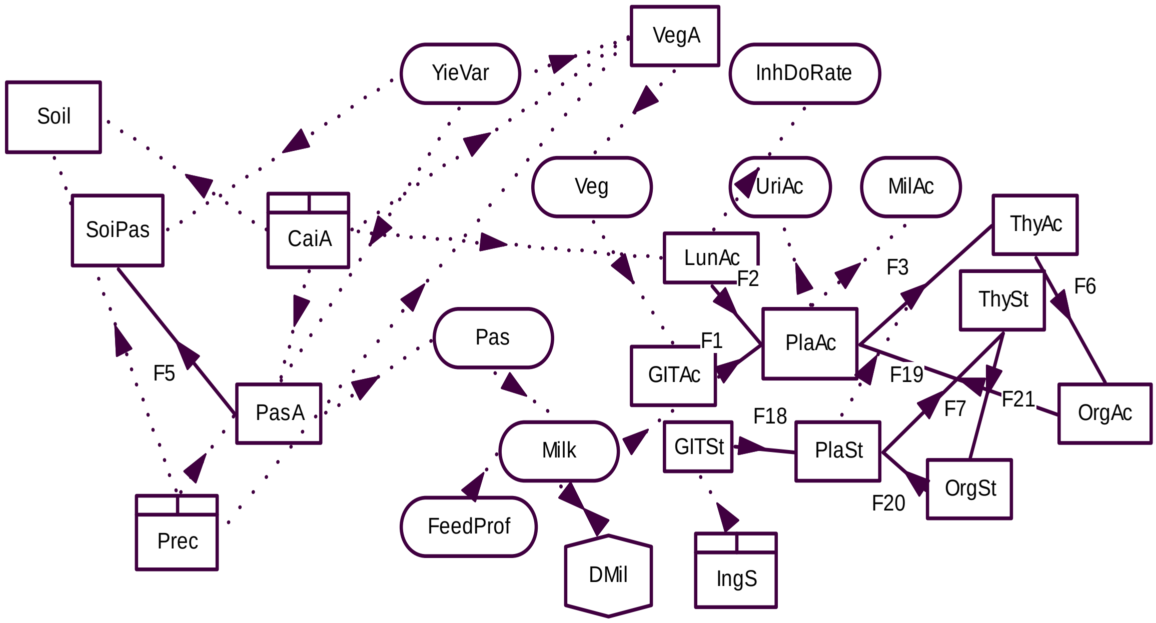


Fig. IV.5.2. The compartmental system in ModelMaker-nomenclature used for modelling the ^{131}I kinetics in the terrestrial food-chain and human body. The effect of stable iodine to the kinetics of radioactive one is taken into consideration by the uptake from human plasma to thyroid (variables of arrows F3 and F7). Therefore the kinetics of stable and radioactive iodine are parallel modelled.

IV.5.3. Experience in the EMRAS Project, Iodine Woking Group (scenarios: Plavsk, Warsaw and Prague)

The atmospheric dispersion, surface deposition, contamination of the food chain and internal dose are rather influenced by the chemical form of Iodine. In spite of the relatively short half life time of the studied ^{131}I (8 days) the models due to the various chemical forms of I became more complex. Another problem might be provided from the seasonality, namely at the beginning of May the contamination of vegetation (pasture, vegetables etc.) is determined by the external area of the vegetation (especially leafy vegetables and pasture) and interception due to the atmospheric deposition. Another factor to the food contamination might be the feeding profile of the cattle, namely whether the cattle are fed by fresh pasture or hay from the last year. Especially for the scenario Plavsk was important the growing of vegetation and feeding profile of the cows, where the ^{131}I deposition and contamination had to be assessed from the ^{137}Cs contaminations and observed parameters got by years later after the accident. The local parameters provided by the scenario descriptions of Warsaw and Prague reflected mainly the real situations during the accident.

According to the preliminary analysis of all the data got by simulations and provided by P. Krajewski our results from Veszprem/Hungary usually overpredicted the values of observed and/or the other participants ones. In this performance mainly the reason of our overprediction is studied and interpreted.

IV.5.3.1. Scenario Plavsk (Plavsk: region in Russian)

To take into consideration of the time delays of beginning of grazing at the different farm a sigmoid type function was introduced with the central value corresponded to time dependent feeding profile given by the farms themselves and included in the scenario description. Therefore the time dependence of the air contamination and deposition to the pasture has had a high influence to the contamination of the pasture used. Due to the misunderstanding of the text in the scenario description about the time distribution of the contaminated air over the region Plavsk the modeller took a chronic distribution (Figure IV.5.3) between the 4-20 days after the accident. The real situation was a peak type contamination of the air. The effect of that misunderstanding the scenario description is shown by the ^{131}I activity in milk, as an example for the farm “Druzba”. Namely in the real situation (peak contamination) the feeding of cows by pasture began 10 days after the peak concentration in air meanwhile according to the misunderstood situation during the feed/grazed pasture got a fresh contamination due to the air deposition even days after the beginning of grazing. Therefore the intake of the cows and the milk contamination was higher than in the real situation (Figure IV.5.4). According to the graphs the misunderstanding of the description caused about a doubled over prediction in milk and so in the thyroid activity and ingestion dose.

The model parameters derived mainly from the scenario descriptions and other former issued volumes, including our home measured data during the accident. In spite of the model developed by us is rather a research type one with proper flexibility some of the parameters are chosen by a high conservatism because the model was used even for decision making. Usually the parameters determine the atmospheric deposition (dry and wet ones), the interception and the transfer from pasture to milk are overestimated and due to them the activity concentrations in pasture, in milk and in the human body show over predicted figures with respect to the observed ones.

IV.5.3.2. Warsaw scenario

The main purpose of the modelling was the study of the effect of stable I intake and other countermeasures during the accident. Our model with the parameters used usually assessed again over predictions by a factor of 2-5, like most of the participants of the scenario. As an example the effect of the stable I intake is presented in Figure IV.5.5. The upper curve shows the thyroid activity without any stable I tablet (full line). In case of 60 mg stable I intake on 29. April the dotted line gives drastically lower values in the first days after administration. The later intake of stable I has a delayed effect, namely due to the inhalation on the 29. April the thyroid activity starts similar as the no stable I line but the followed activity was practically the same as for the administration on the 29. April.

In addition to the simple simulation of the activity concentration in pasture, milk, thyroid etc. and radiation impact of the different age groups there were assessed confidence intervals. In most of the cases the upper and lower intervals were about 3 times higher/lower than the mean values got by uncertainty analysis.

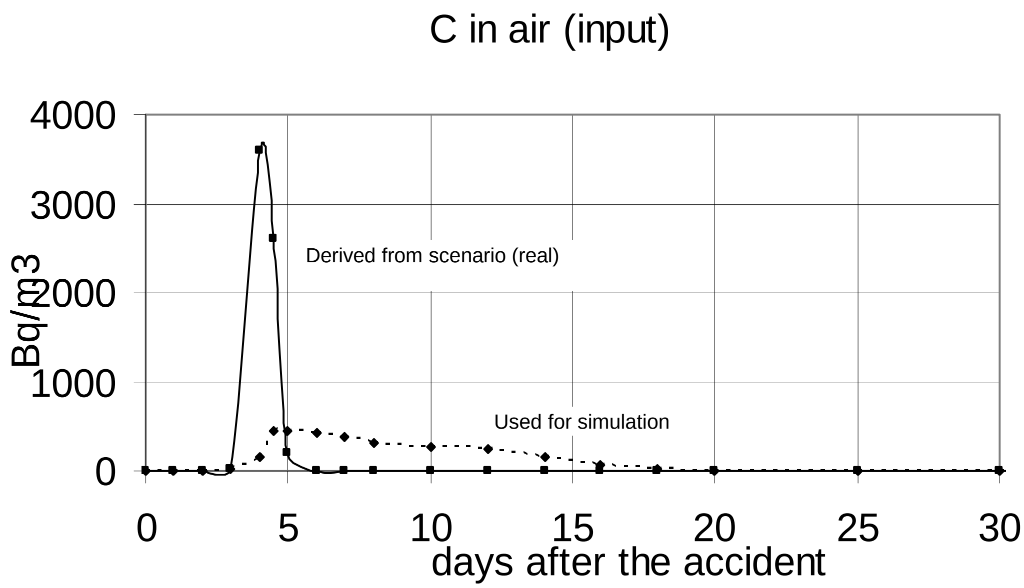


Fig. IV.5.3. The ^{131}I concentration in air at the farm "Druzba" as input data derived from measured total deposition of ^{137}Cs (full line: derived according to the scenario description – real situation, dashed line: used by the modeller and derived from discharges during the accident. The time integrals of both curves are equal.).

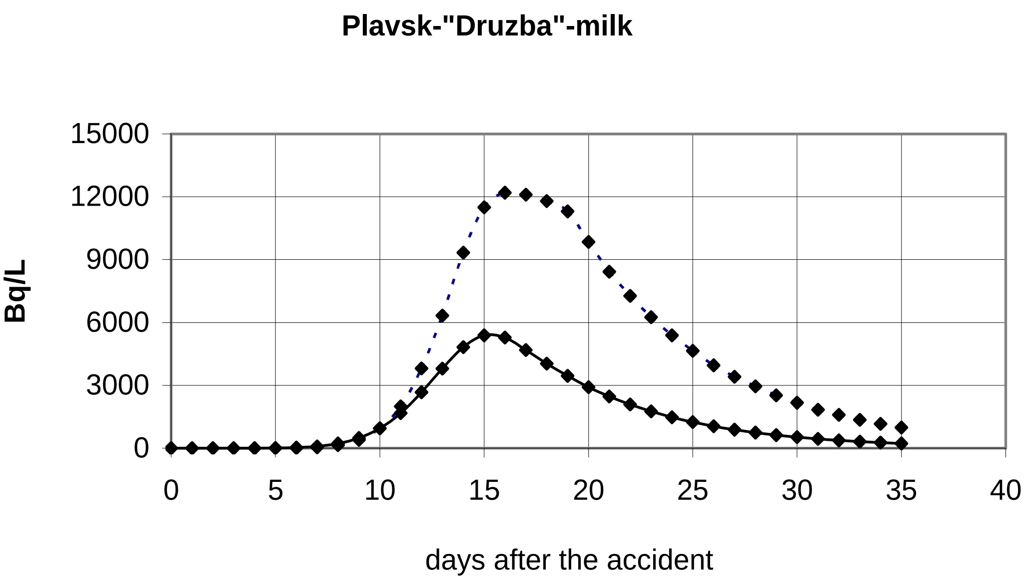


Fig. IV.5.4. The ^{131}I concentration in milk at the farm "Druzba" got by the air contamination of the sharp peak (full line) and by the chronic contamination (dashed line). The sharp pike type air contamination provides about two times less contamination in milk than the chronic one

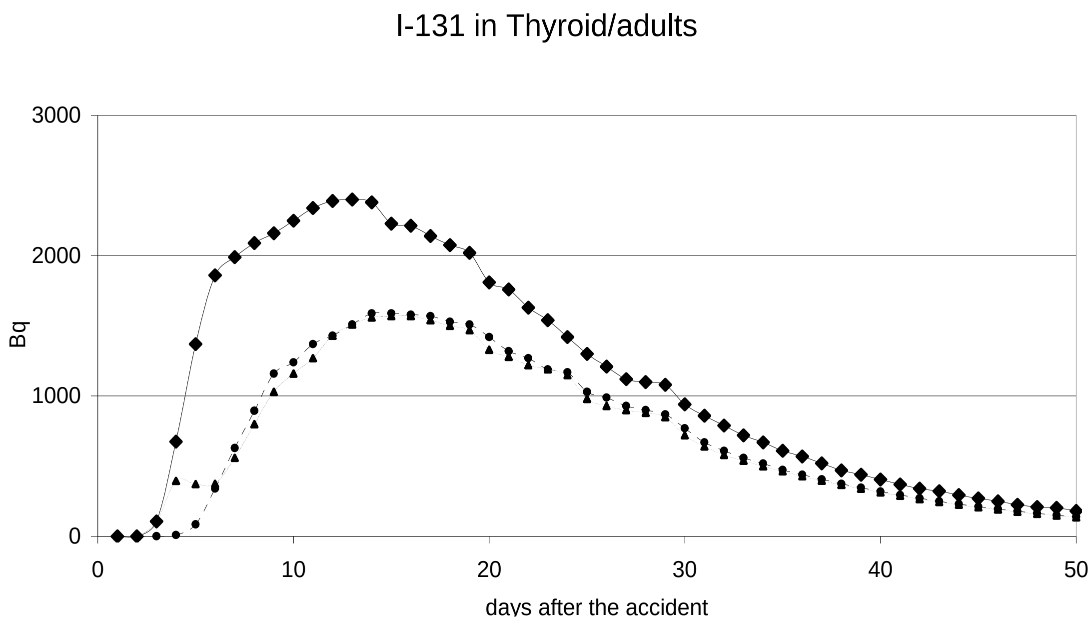


Fig. IV.5.5. The simulated effect of stable I tablets to the ^{131}I-content (Bq) in the thyroid of adults in the city Warsaw (During the first days the activity is rather determined due to inhalation but later on by milk consumption. The effect of the stable I might be important only for 12–24 hours after intake of it).

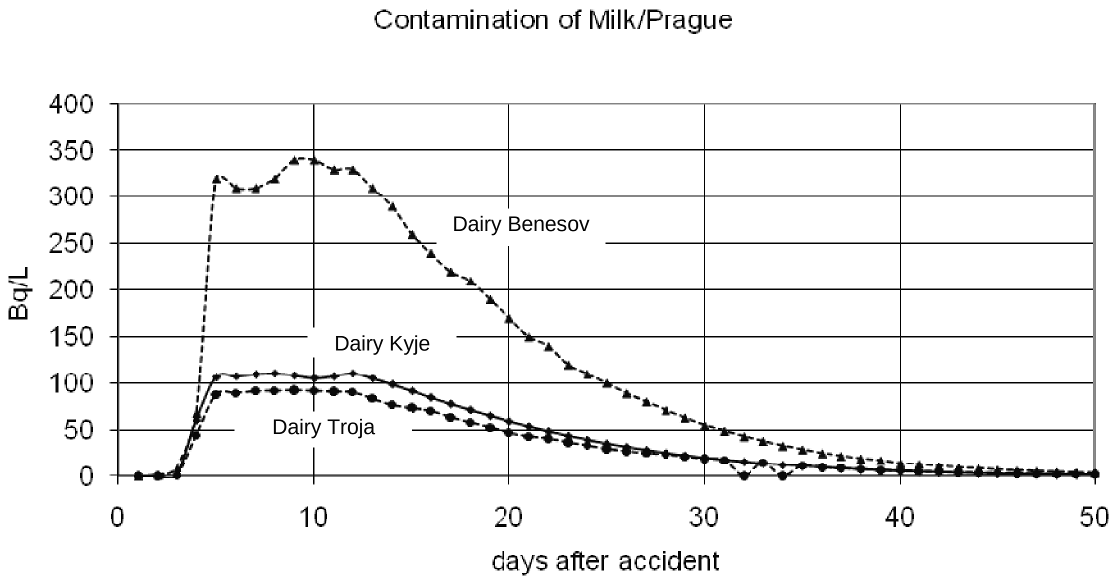


Fig. IV.5.6. Assessed milk contamination by ^{131}I in scenario Prague (full line: dairy Kyje, dotted: dairy Benesov and dashed: dairy Troja).

IV.5.3.3. Prague scenario

According to the experience got by study of the scenario Prague the local meteorological conditions could have a high influence to the contamination of the environmental and food elements. In spite of the very far source from Prague (more than 1000 km) the variation of the contamination within a 10 km box show a factor of 5-10 in differences, mainly due to the variation of I species in the air (aerosol, reactive and organic forms) and the precipitation.

Learned from the former scenarios (Plavsk and Warsaw) and taken into consideration of the pasture contamination got for validation of the model parameters we had decreased by a factor of nearly 2 both the atmospheric deposition rates and the transfer coefficient from pasture to the milk. Until now the observed data are not yet opened therefore a comparison of the simulated results to the observed ones could not yet provided.

Figure IV.5.6 presents results on the milk activity concentration of three different dairies in the region of Prague. The contamination of the region Benesov (south part of region Prague) is the highest mainly due to the atmospheric wet deposition to the vegetation.

The assessed internal doses to the thyroid (committed equivalent dose) of the different age groups are provided in Tables IV.5.2 and IV.5.3. The first table shows the inhalation doses and the 2nd one the ingestion doses. The critical pathway to determine the total dose was the milk consumption.

IV.5.4. Summary

The models formerly used to assess the ^{131}I concentration in the different components of the biosphere and the radiation impact to man have been extended for taking into consideration the seasonality and the age groups of human individuals.

The dynamic model used in the project EMRAS has been developed mainly in connection with research work. It involves compartments addressed to the scenarios studied (regions of Plavsk, Warsaw and Prague) and the computational form is realized by differential equations including parameter values and uncertainties.

The software used in the former IAEA projects (VAMP and BIOMASS) was written in computer language Turbo Pascal, named TAM and TAMDYN. For the EMRAS project a more comfortable and effective software, the tool of ModelMaker had been introduced.

The model takes into consideration the following processes and relations continuously in time:

- time variation of the air contamination (as the source term), precipitation and stable I in food during the calculations, defined by the user
- seasonal variation of the vegetation, feeding profile of cows and human consumption
- effect of the stable iodine administered, defined by the user.

According to the experience got by the assessment studies the contamination calculated in the scenarios Plavsk and Warsaw provided overpredictions compared to the observed values opened after the assessed results presented. Therefore the parameter values of the atmospheric depositions and the pasture-milk transfer of cows have been decreased by a factor of nearly 2 for the calculation of the last (Prague) scenario.

Table IV.5.2 Mean doses to thyroid from inhalation for inhabitants of Prague, in mSv (represented by Kyje) (in Benesov the dose values are higher, in Troja less).

Countermeasures	age 1 in 1986			Age 5 in 1986			age 10 in 1986			adult (age 20 in 1986)		
	Mean	95% Confidence interval		Mean	95% Confidence interval		Mean	95% Confidence interval		Mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
24 hours in building	0.49	0.25	0.68	0.72	0.31	1.2	0.51	0.22	0.78	0.44	0.24	0.65
16 hours in building	0.67	0.35	0.93	0.99	0.42	1.5	0.69	0.30	1.05	0.58	0.32	0.85
8 hours in building	0.76	0.40	1.02	1.12	0.48	1.7	0.78	0.34	1.20	0.66	0.36	0.96

Table IV.5.3. Mean doses to thyroid from ingestion for inhabitants of Prague, in mSv (represented by Kyje) (In Benesov the dose values are nearly 2.3 times higher, in Troja by 0.73 times less).

Assumptions	age 1 in 1986			Age 5 in 1986			age 10 in 1986			adult (age 20 in 1986)		
	Mean	95% Confidence interval		Mean	95% Confidence interval		Mean	95% Confidence interval		Mean	95% Confidence interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
Cows on pasture on 27th April	2.3	0.55	5.6	2.4	0.45	6.5	1.3	0.32	4.5	0.53	0.08	1.8
Cows kept in cows-shed and fed with uncontaminated fodder	0.011	0.002	0.045	0.013	0.003	0.058	0.0065	0.002	0.042	0.0034	0.001	0.011
Based on milk data obtained in the validation study	1.22	0.30	3.7	1.4	0.35	4.5	0.68	0.15	2.5	0.29	0.07	1.0

IV.6. Overview of the CLRP Code performance of ^{131}I dose assessments

Krajewski, P., Central Laboratory for Radiological Protection, Warsaw, Poland

IV.6.1. Introduction to the CLRP Code

IV.6.1.1. Important model characteristics

The model CLRP was created in 1989 as a part of research project "LONG-LIVED POST-CHERNOBYL RADIOACTIVITY AND RADIATION PROTECTION CRITERIA FOR RISK REDUCTION" performed in co-operation with U.S. Environmental Protection Agency. The aim of this project was to examine the fate of long-lived radionuclides in the terrestrial ecosystem. Following the next years the model was intensively developed and extended for other radionuclides especially for iodine.

The initial aim of this code was to simulate the transport of radionuclides through environment to human body due to examine the fate of some radionuclides in the ecosystem. The Input Parameters Data Base allowed the evaluation of the radiological impact for: I, Cs, Ru, Te, Sr. One is able to set up to 20 radionuclides of 44 elements in the one scenario.

All dynamic processes were described by differential formulas and are solved numerically. Radionuclides concentrations in the particular components of terrestrial ecosystem e.g. soil, vegetation, animal tissues and animal products are calculated as a function of time following calculated deposition from the atmosphere. The model considered seasonal changes in the biomass of vegetation and animal diets, also specific ploughing and crop-harvest dates. Human dietary data were included to enable calculation of time -dependent radionuclide ingestion rates as well as critical organ content of radionuclide for seven different age group of population.

The program calculates doses from the following pathways: external (cloud, ground exposure); internal (inhalation, ingestion) and simulates many different radiological situations (chronic or acute releases) and dose affecting countermeasures as some diet components ban, buildings shielding as well as stable iodine prophylactics. Figure IV.6.1 provides a flowchart of the CLRP calculation process.

During the 1989–1995 period the CLRP code performance for ^{137}Cs was check out in a frame of several follow-up the International IAEA programmes. These include BIOMOVS (BIOspheric Model Validation Study) and BIOMOVS II, initiated by the Swedish Radiation Authority in 1985, and the programmes sponsored by the IAEA: VAMP (Validation of Model Predictions, 1988-1996) and BIOMASS (BIOsphere Modelling and ASSessment, 1996–2001).

In 2007 the new version of the CLRP code was written in the Microsoft Visual Basic 6.5 for Microsoft Office Excel 2007, 7.0 as an Ad-In application and consists with UserForms and programs that enable to communicate simultaneously with one Scenario File. Scenario File comprises a set of worksheets of Excel - one worksheet for particular component’s input and prediction data. In 2008 the CLRP has been “equipped” with the GIS driver to produce maps of specific zones.

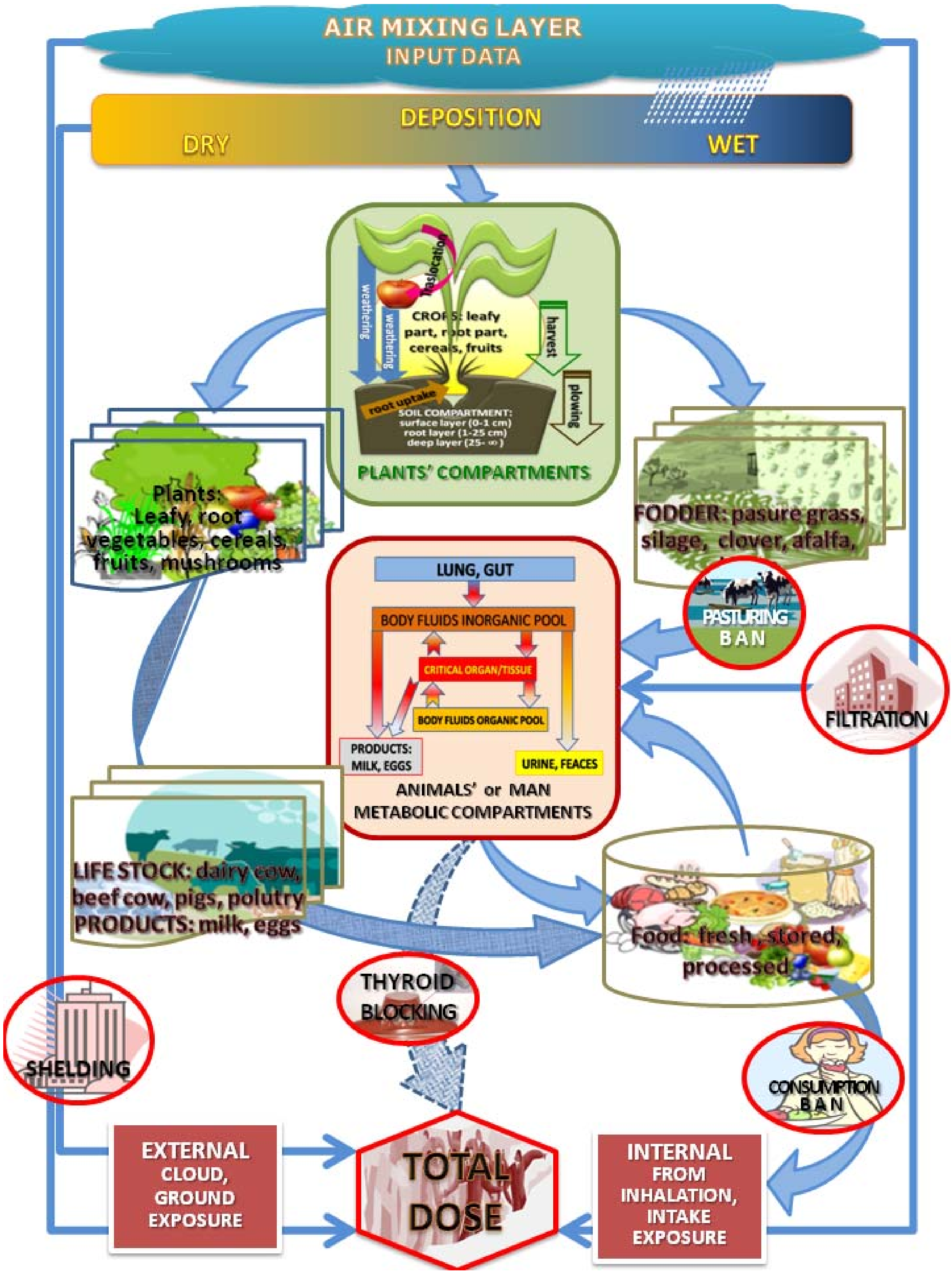


Fig. IV.6.1. Flowchart of CLRP calculation sequence. Blue arrows show an order of calculations in the particular compartments, where the results obtained in one compartment (output data) are used as an input data in the next compartment.

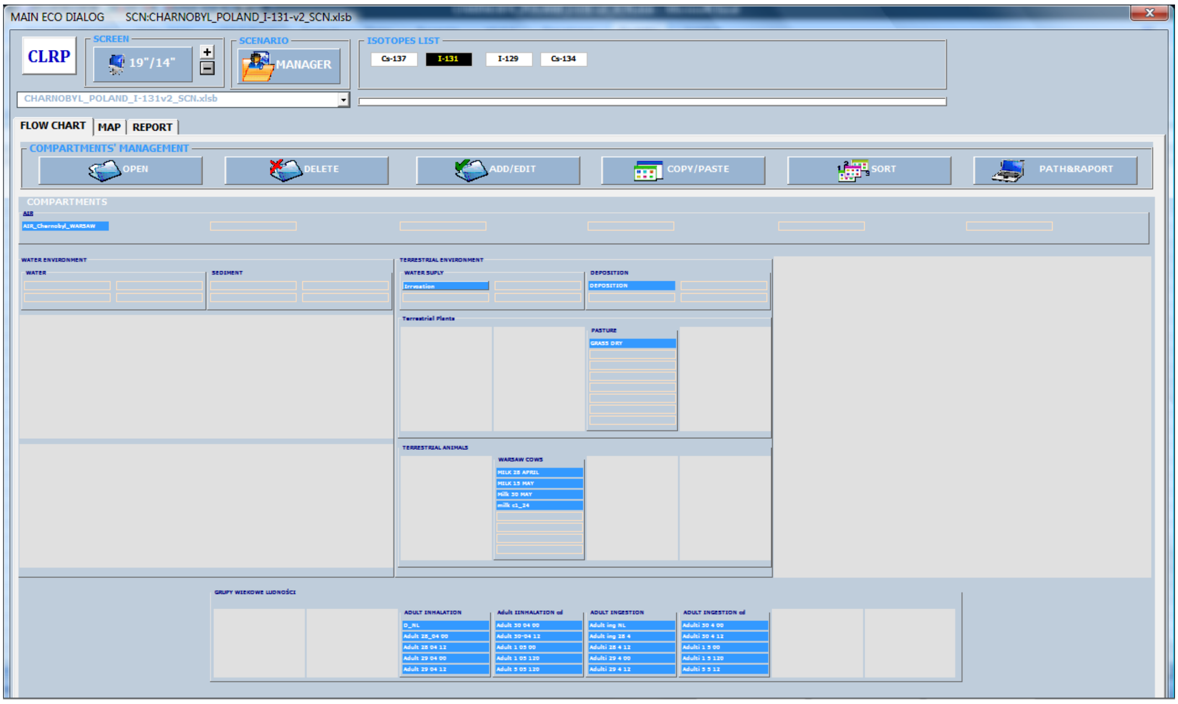


Fig. IV.6.2. Main CLRP UserForm for Scenario design purposes.

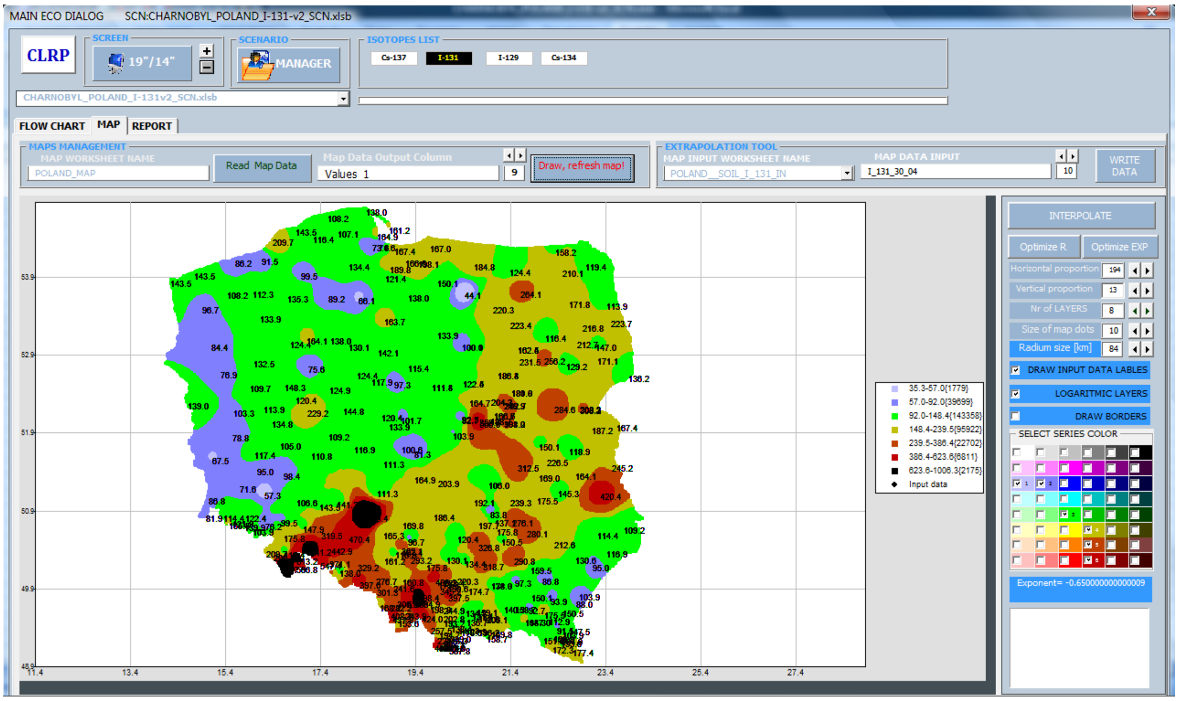


Fig. IV.6.3. GIS UserForm driver installed in CLRP – example of map of ^{137}Cs concentration in soil – the study zones were calculated by IDW Shepard interpolations from 370 measured point in 1km×1km grid.

IV.6.1.2. Method used for deriving values of quantity dependent on time

The estimate of given radioisotope concentration or contents in the particular compartment is calculated based on data calculated from previous compartment (compartments), by recurrence method as follows:

$$C_y^t = \dots - (\lambda + \lambda_b) C_y^{t-3} \pm \sum_{k=1}^{N} \gamma_k C_{xk}^{t-3} - \lambda C_y^{t-2} \pm \sum_{k=1}^{N} \gamma_k C_{xk}^{t-2} - \lambda C_y^{t-1} \pm \sum_{k=1}^{N} \gamma_k C_{xk}^{t-1} \qquad \text{(IV.6.1)}$$

where:

C_y^i is the radionuclide concentrations (contents) in the given compartment C_y at period of time i;

λ is the radionuclide decay constant (expressed in the time calculation period (d, h, min, s);

λ_b is the biological or environmental losses constant (expressed in the time calculation period (d, h, min, s);

$\gamma_k C_{xk}^i$ is the inflow from the compartment C_{x_k} in given period *i* to the compartment C_y; and

γ_k is the inflow rate.

The standard step of calculation is one day, however to get better accuracy for calculation of short lived radionuclide hourly or minute step is required.

The data of calculation are stored automatically in Excel worksheets. One worksheet contains both input parameters and calculation results.

The CLRP UserForms contains simultaneously input parameters and calculation results as well as graphic presentation of the data. CLRP make able to import measurement data and compare them with predictions (Figures IV.6.4 to IV.6.9).

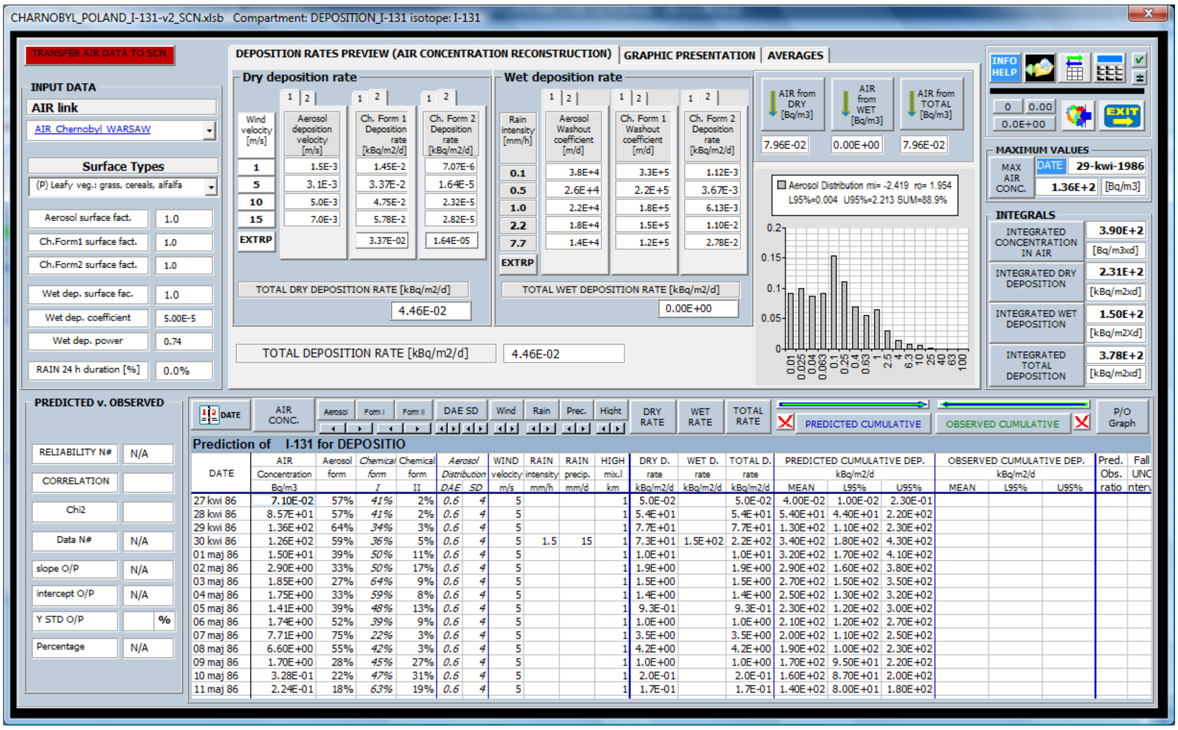


Fig. IV.6.4. Deposition UserForm.

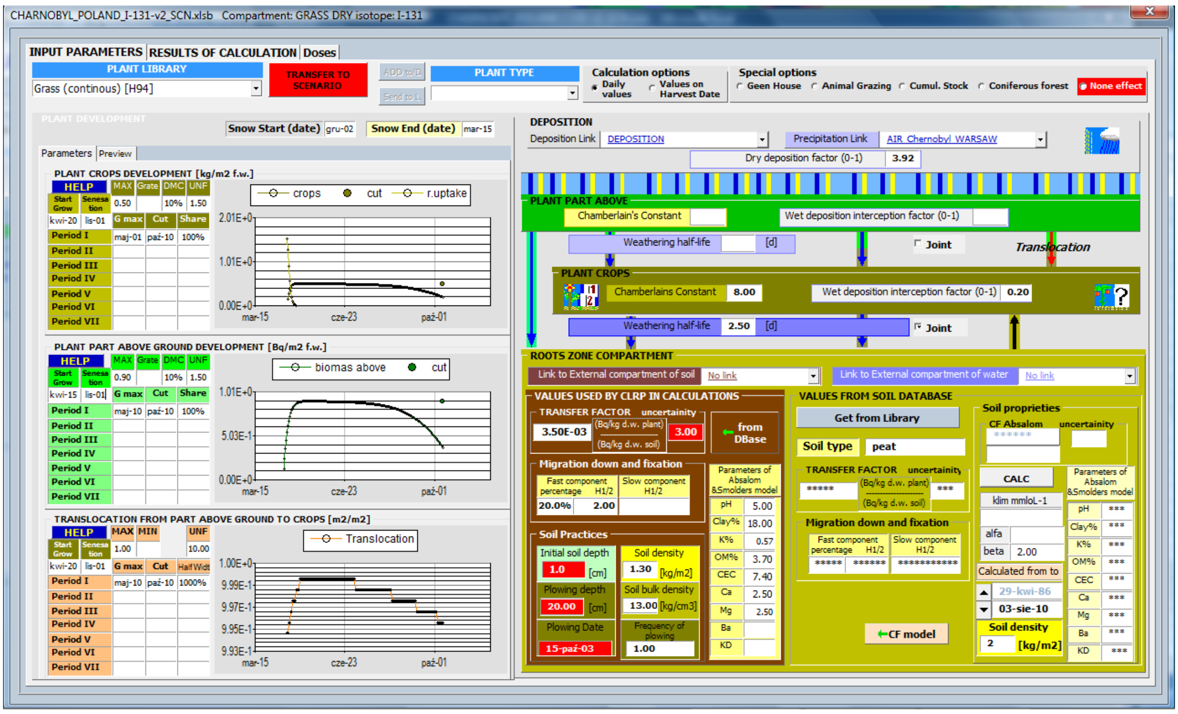


Fig. IV.6.5. Plant input parameters UserForm. Leafy part and 'crops' part development during the growing period can be set independently. CLRP contains plants' library of 20 species.

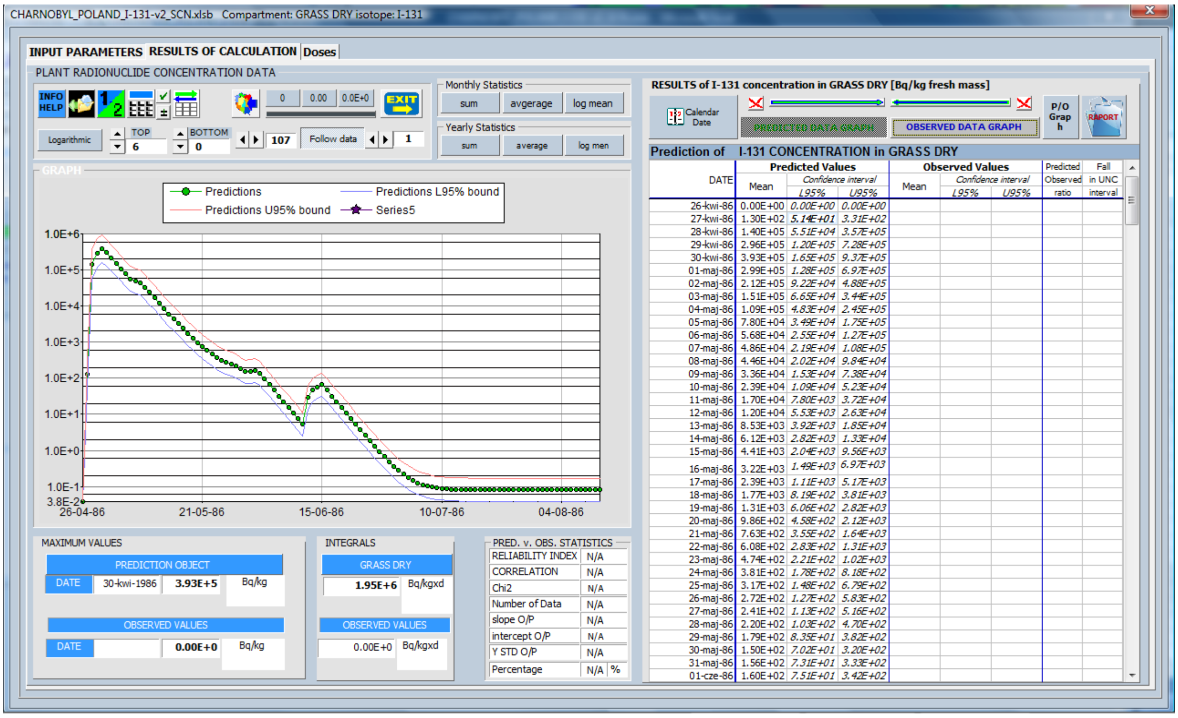


Fig. IV.6.6. Plant output results UserForm. Example shows predictions of ^{131}I concentration in pasture grass in Mazovia area during Chernobyl period.

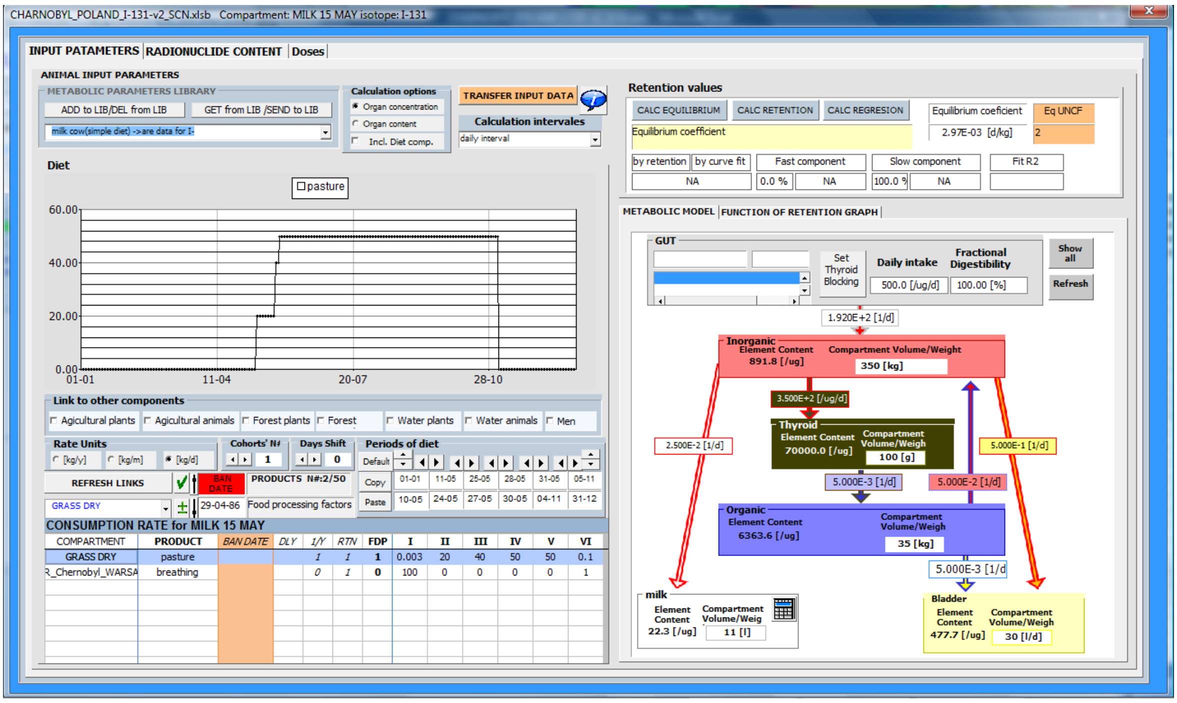


Fig. IV.6.7. Animal input parameters UserForm. On the left side: example of pasturing pattern divided on six independent periods. On the right side: iodine metabolic behaviour for cows' milk. One can set various mathematical models of metabolic variants by working only with graphic driver.

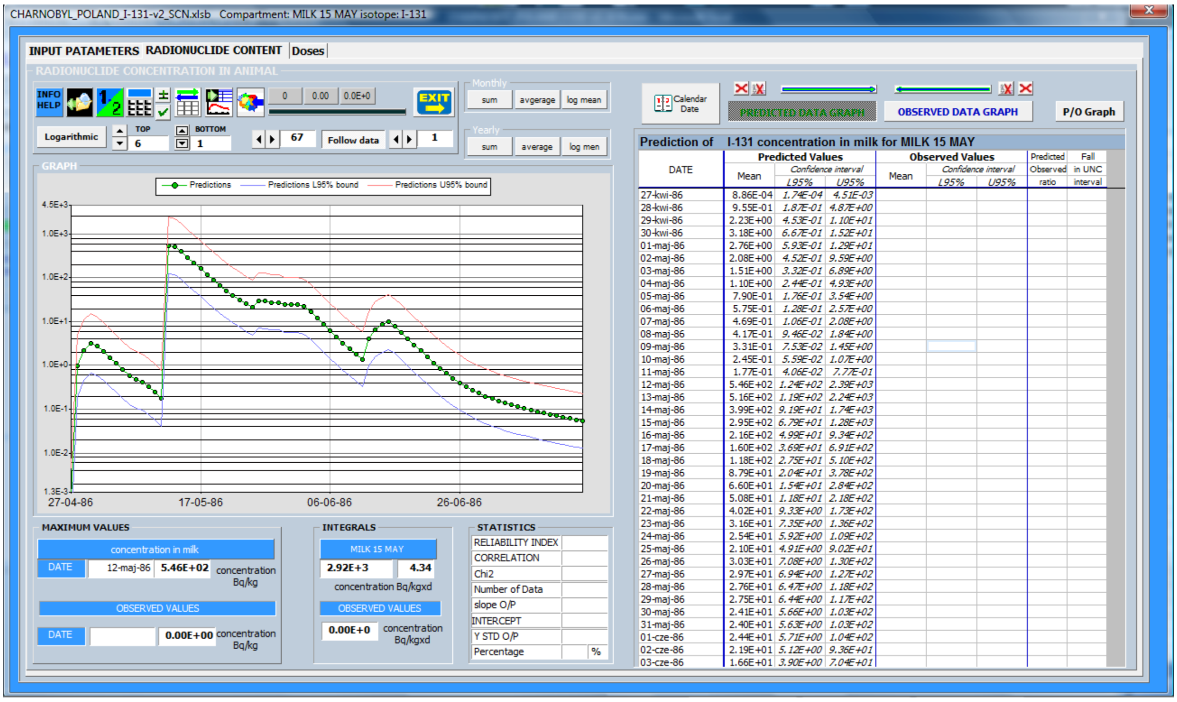


Fig. IV.6.8. Animal output results UserForm. Example shows predictions of ^{131}I concentration in milk in Mazovia area during Chernobyl period.

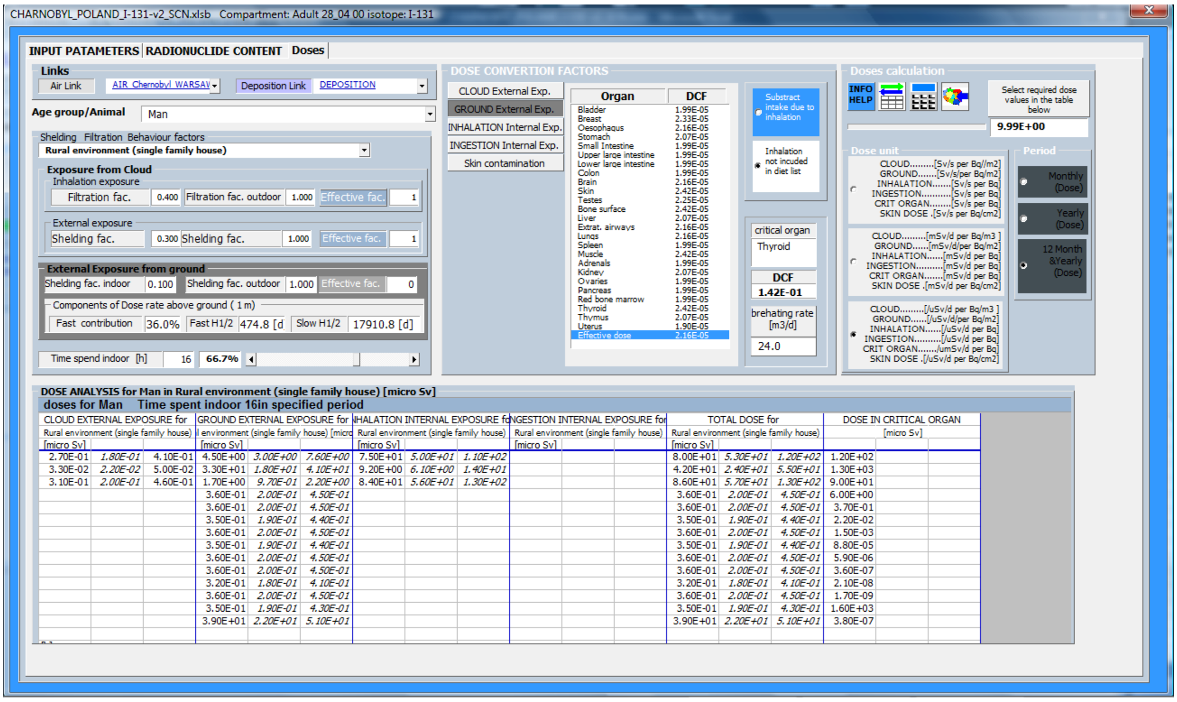


Fig. IV.6.9. Dose output results UserForm. Example shows predictions of ^{131}I external, internal and total dose for adult inhabitant in Mazovia area during Chernobyl period.

IV.6.2. The effectiveness of countermeasures in Poland after the Chernobyl Accident

IV.6.2.1. Development of the radiological situation in Poland in the first days after passage the radioactive cloud over Poland

The origin of contaminated air, which moved up to Poland at probably 28 April 00:00 GMT[13] was unknown, however just preliminary spectrometric measurements (performed in CLOR 28 April 1986 10:10–13:15) of particulates collected on filters indicated that there were fission products and following analysis suggested it was caused by a reactor accident [IV40]. The gamma spectrometric measurements of airborne particulates activity collected on filters allowed identifying of above twenty artificial radionuclides, the presence of Xenonium-133 in air was also evident. In addition, investigations of physic-chemical phases of ^{131}I were carried out by filtration of air trough out the filter set with fibre medium, charcoal and charcoal impregnated paper. About 59 ± 12% of the particulate radioactive iodine was collected during the few days of measurement, later the percentage of airborne particulate decreased. In the period 28 April – 10 May 1986 radioactive clouds moved over the area of the entire country causing radioactive contamination of the ground. It was remarkably inhomogeneous, since increased in areas affected by rain during the radioactive clouds passage [IV.41].

IV.6.2.2. Characteristics of hazard from radioactive iodine - preventive action in Poland

In the first days after Chernobyl accident, the main risk to the population derived from radioactive ^{131}I iodine and it mainly concerned children thyroids as they could be exposed due to inhaling polluted air and throughout milk consumption. One might expect that due to high emission of radioactive iodine from the reactor, contamination would have been widely spread and lasted long time. Particularly, elevated levels of airborne ^{131}I during the first hours of 28 April 1986 (above 200 Bq·m^{-3}) threatened that equivalent doses in thyroids of children could have exceeded 50 mSv[14]. In the late afternoon of 28 April 1986 the message about Chernobyl nuclear power plant accident was revealed by western media. On 29 April 1986 about 06:00 (after all night discussions) the Governmental Commission for Assessment of Nuclear Radiation and Prophylactic Measures was appointed which recommended (on 29 April 1986 11:00) to introduce countermeasures in order to diminish children thyroids exposure to radioiodine [II.42. These countermeasures included: administration of stable iodine in form of solution (so called “Lugol liquid”) to children and teenagers up to 16 of age, consumption ban of milk from cows fed with green fodder, and cows’ pasturage limitation. The distribution of stable iodine liquid started in evening hours of 29 April 1986 and was continued in 30 April 1986 (when 75% of children population get stable iodine) as well as in the first days of May, depending on resources in particular districts. Generally, numerous pharmacies and medical centres were engaged in the distribution of “Lugol liquid” in the kindergartens and schools (Figure IV.6.11). Regarding diet restrictions (milk and milk product and leafy vegetables) and cows’ pasturage ban there were no mains to make items compulsory but only trust on public concern.

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[13] 28 April 1986 at 07:00 monitoring station Mikolajki reported 700 fold higher global beta in air.

[14] One assumed thyroid dose equivalent due to inhalation as 250 [Bq·m^{-3}]×10 [m^3·d^{-1}]×14 [days]×1.5×10^{-3} [mSv Bq^{-1}]≅50mSv.

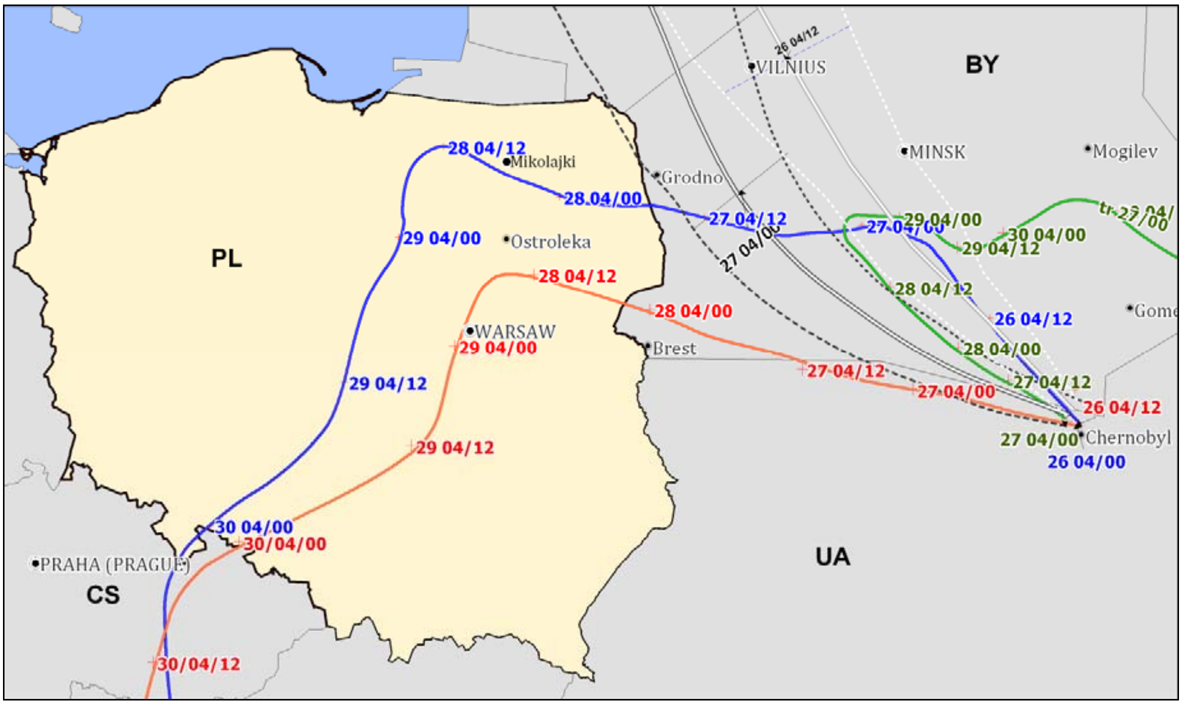

Fig. IV.6.10. The passage of contaminated air over Poland after Chernobyl accident. Trajectories blue, red and green correspond to: surface winds originating from Chernobyl on 26 April 1986 00:00 GMT, 26 April 1986 12:00 GMT, 27 April 1986 00:00 GMT respectively. Trajectories grey and white correspond to 925 mb – 800 m altitude, 850 mb – 1500 m altitude respectively originating from Chernobyl on 26 April 1986 12:00 GMT. (Reconstruction by Polish Institute of Meteorology and Water Management).

Fig. IV.6.11. Administration of stable iodine solution "LUGOL" in one of the medical units on 30 April 1986.

IV.6.2.3. An assessment of doses from radioactive iodine

Assessment of the effectiveness of the preventive dose of stable KI iodine

Reconstruction of doses from ^{131}I for the population of Poland required an assessment of the influence of the preventive dose of stable iodine on the ^{131}I dose equivalent in thyroid gland. The simple ICRP model seemed to be less useful, but model of the biokinetics of iodine in the thyroid gland developed by Johanson [IV.43] and Johnson [IV.44] enabled the quantitative accurate assessment of changes depending on the blocking dose of stable iodine. Although the reduction of radiation dose to thyroid depending on the time span between acute uptake of radioiodine ^{131}I and intake of stable iodine (see Figure IV.6.13) in a case of lasting over a long period of time contamination, evaluation of H_{50} dose reduction required more complicated calculation and it was a fundamental problem in the assessment of ^{131}I hazard for populations of Poland. This assessment was carried with the help of computer simulation on the basis of available measurements data of ^{131}I concentration in air and contaminated foodstuffs, especially in milk and milk products. Figure IV.6.14 shows different dynamic of the ^{131}I activity in the thyroid gland for adult inhaled contaminated air measured in Warsaw (28 April – 30 May 1986) at different dates of thyroid blockade. The effect of thyroid blockade for adult drinking contaminated milk (without inhalation of contaminated air) is shown in Figure IV.6.16. The results of computer simulation of H_{50} reduction for different air and milk contamination variants that might be typical for Poland are presented in Table IV.6.1. The thyroid dose equivalent H_{50} as a result of inhalation could be reduced of about 75% (closely three times) when thyroid blockade was undertaken on 28 April 1986 at 12:00, and of 62% by blockade on 29 April April 1986 at 12:00 assuming short one day cloud passage. For prolonged ^{131}I air contamination the blockade is less efficient. When one consider ingestion pathway the most effective could be blockade on 1 May 1986 12:00 (30%), because it is correlated with maximum of ^{131}I concentration in milk that occurred on 1–2 May 1986 in most contaminated areas in Poland (see Figures UV.6.21 and IV.6.22). From a point of view of the assessment of the effectiveness of this countermeasure, inhalation and ingestion pathways together should be considered, then both term 28, 29, 30 April and 1 May 1986 are comparable giving H_{50} reduction from 10 to 30%. Assuming that “Lugol” solution of KI was given to the majority of children on 30.04.1986r, the reduction in the dose was lower for areas, in which the contamination appeared later.

IV.6.2.4. Assessment of effectiveness of cows' pasturage ban

Theoretical model calculations show that even 10 days delay of start cows pasturage gives 50 times (2%) reduction of integrated ^{131}I concentration in milk (Figure IV.6.13). However in practice this countermeasure was effective for limited numbers of farms because of spring's hay shortage. Measurement of ^{131}I concentration in milk and later analysis indicated that only about 20% of farms were able to obey the ban. The quantitative evaluation this countermeasure is difficult because of lack sufficient measurements data.

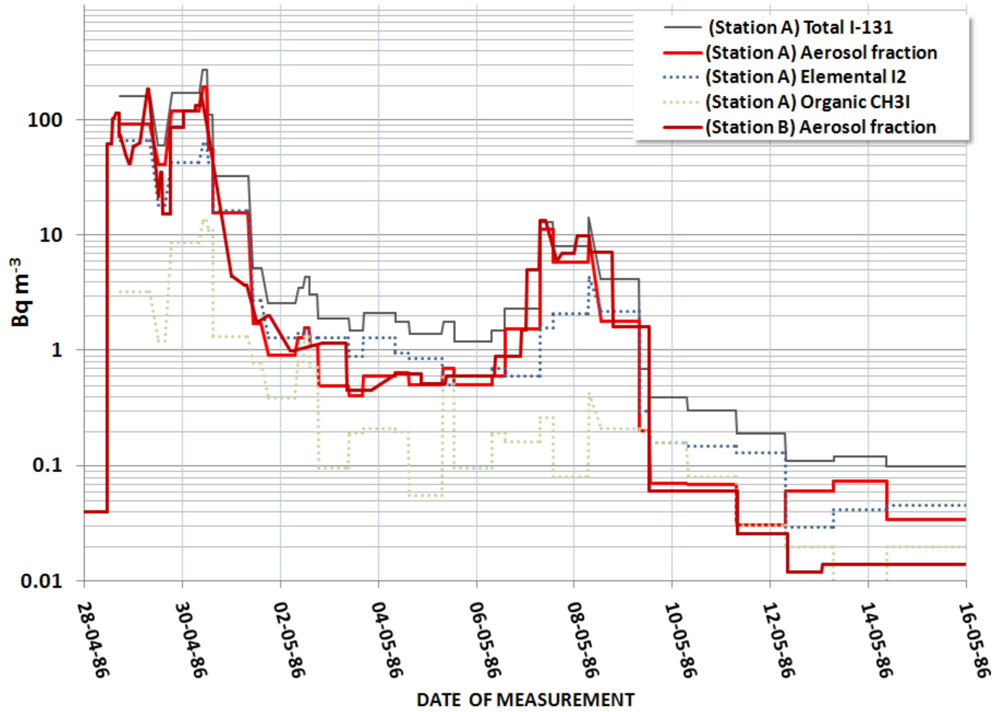

Fig. IV.6.12. ^{131}I concentration in the air above Warsaw reconstructed on the basis of measurements carried out by CLOR.

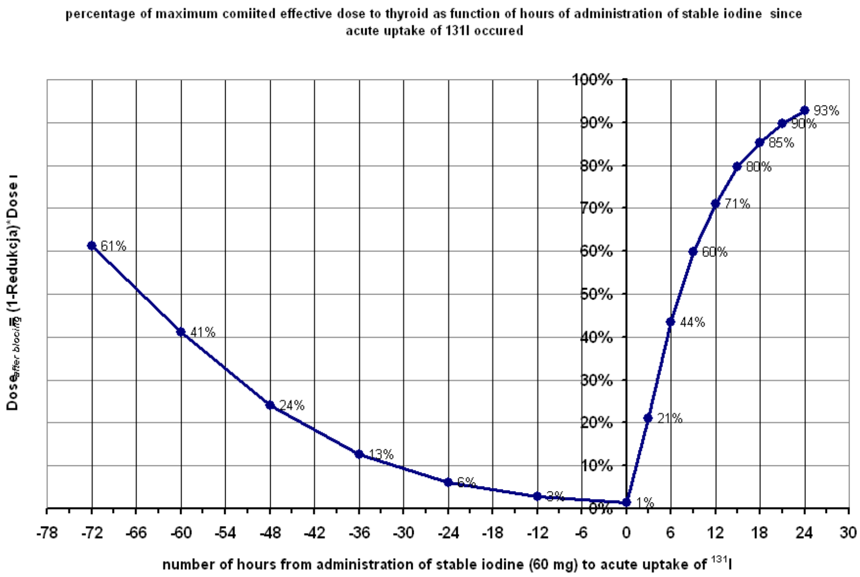

Fig. IV.6.13. Percentage of maximum committed effective dose to thyroid that remains as a function of hours passed after or before intake of stable iodine since acute uptake of ^{131}I occurred.

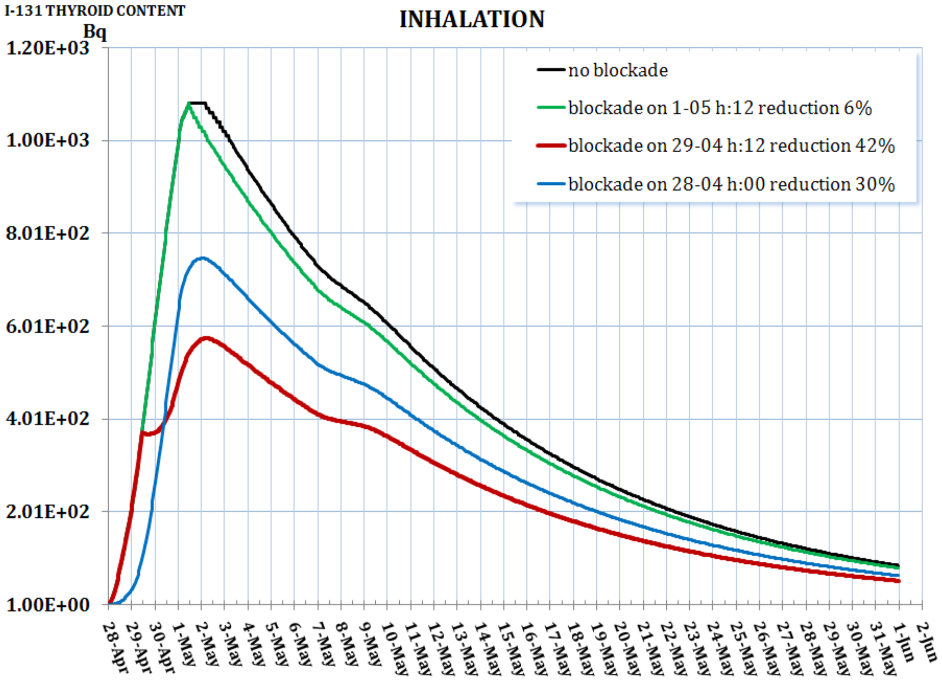

Fig. IV.6.14. Changes of the ^{131}I activity in the thyroid gland of the adult for intakes of radioiodine by inhalation of contaminated air measured in Warsaw (28 April – 30 May) at different dates of thyroid blockade with stable iodine.

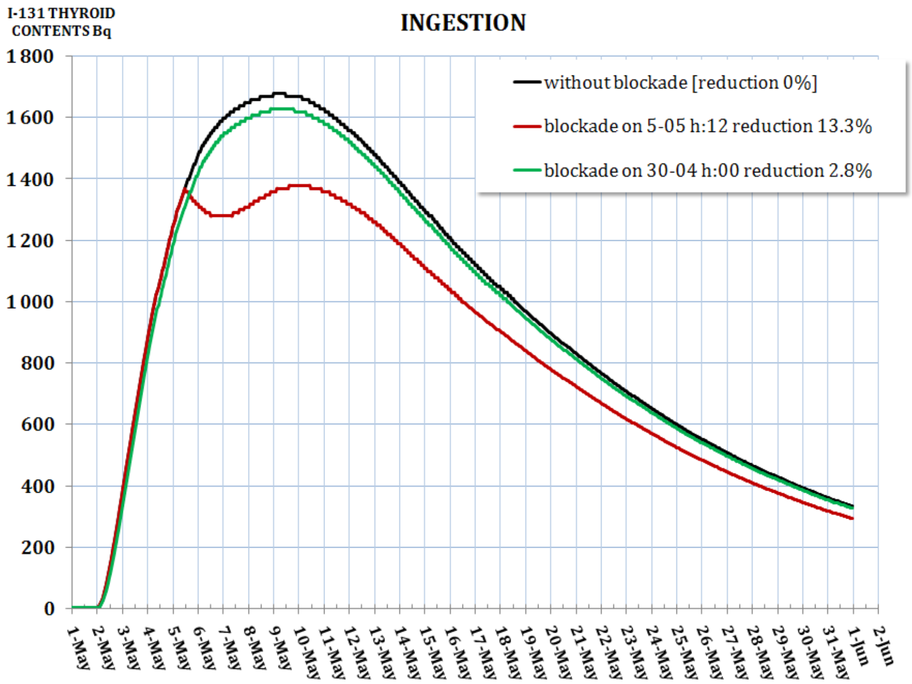

Fig. IV.6.15. Changes of the ^{131}I activity in the thyroid gland of the adult for intakes of radioiodine by ingestion of contaminated milk measured in Warsaw area (28 April – 15 June) at different dates of thyroid blockade with stable iodine.

Table IV.6.1. Reduction in the H_{50} dose depending on the time of the administration of iodine. Recommended amount of stable iodine: 60 mg for teenagers from 10 to 16 of year of the life, 30 mg for children by 1-do 30 of the year of the life, 15 mg for children below 1 year.

Date and time of the administration of stable iodine iodine	Inhalation pathway	Ingestion pathway	Inhalation and ingestion pathway	Contribution to the total dose [%]	
	Reduction [%] Max–Min	Reduction [%] Max–Min	Reduction [%] Max–Min	Inhalation pathway	Ingestion pathway
28 April 1986 00:00	*72–30*	*11–1*	*31–10*	13–25	87–75
28 April 1986 12:00	*76–38*	*14 -1*	*35-13*	12–23	88–77
29 April 1986 12:00	*62–43*	*22 -2*	*35–14*	20–22	80–78
30 April 1986 12:00	*28–26*	*28–5*	*28–12*	33–27	67–73
1 May 1986 12:00	*6 -5*	*29–15*	*21–12*	40–34	60–66
2 May 1986 12:00	*3–2*	*27–14*	*18–10*	40 -33	60–67
5 May 1986 12:00	*5–1*	*18–13*	*14–9*	37–35	63–65
No administration	*0*	*0*	*0*	33	67

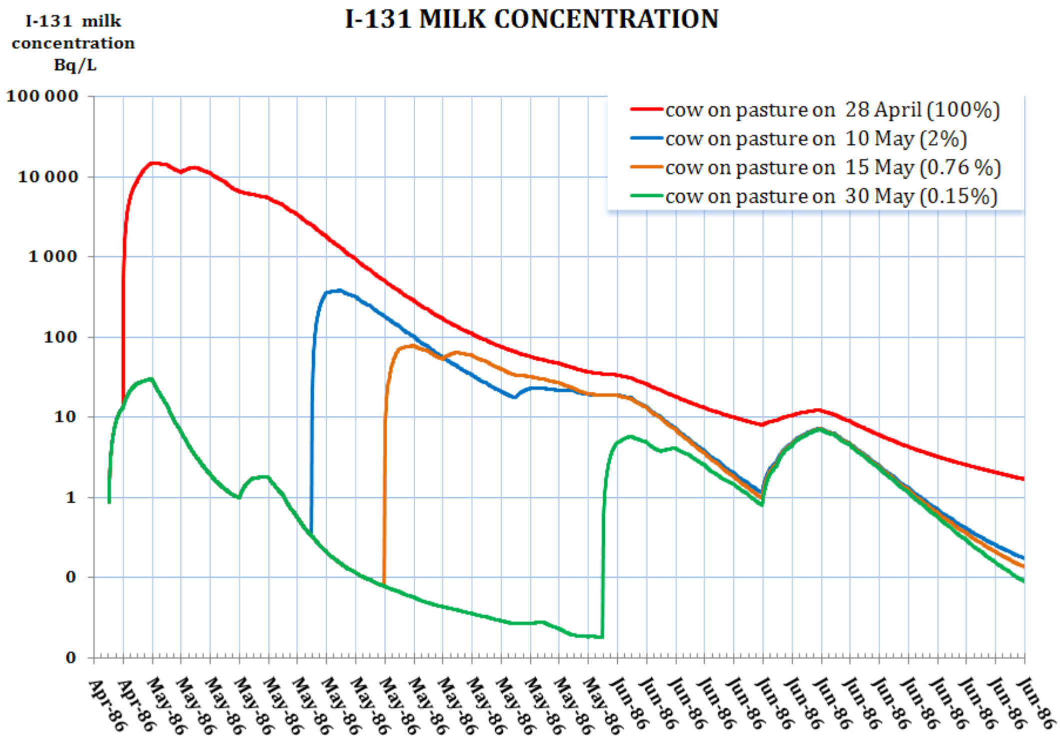

Fig. IV.6.16. Dynamic of ^{131}I concentration in milk versus time for various variants of start cows grazing in open areas. Percentages in parentheses show ratio of integrated ^{131}I concentration in milk for particular term of cows grazing to item on 28 April.

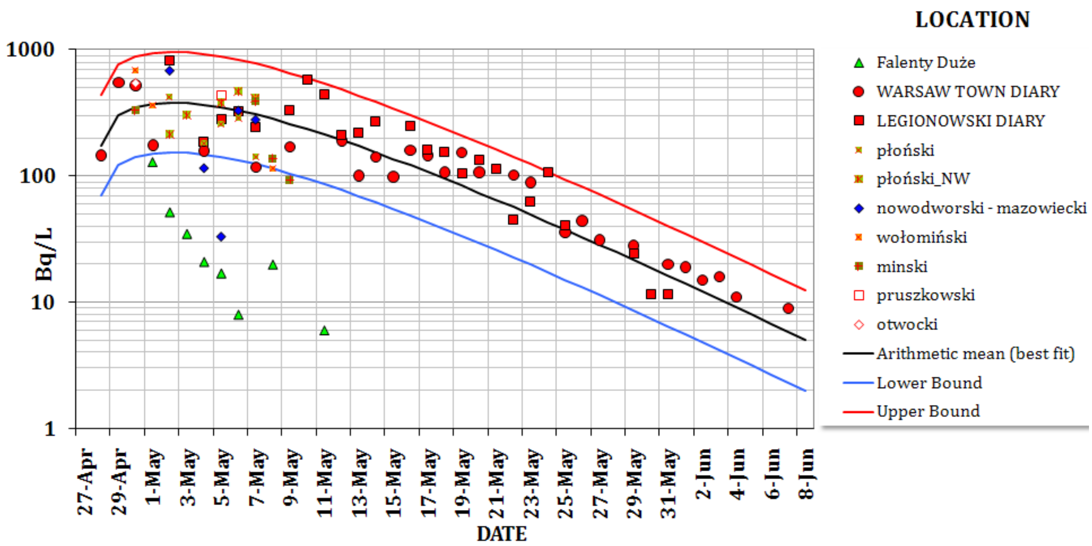

Fig. IV.6.17. Measured ^{131}I milk concentration in Warsaw province in the period (28-04 – 8.06 1986 r). Continuous curves describe: black curve- best fit to measured average ^{131}I concentrations in the milk, red curve: upper bound of average values (x2.5), the blue curve: lower bound of average values (1/2.5). Integrated ^{131}I concentration in the milk= 5954 [Bq·L^{-1}·d]. Green triangles – measured ^{131}I concentration in milk for cows kept in cowsheds.

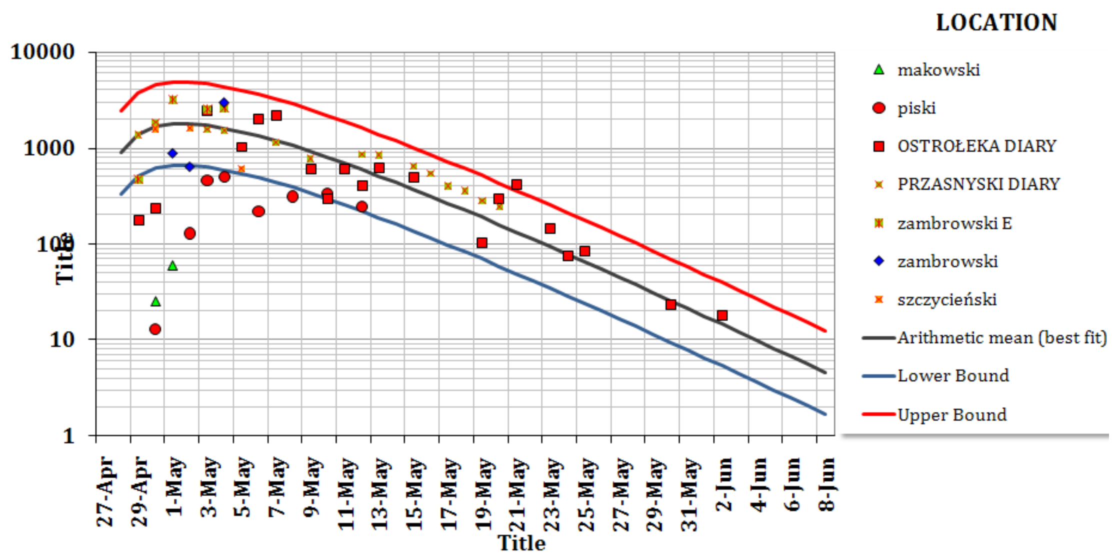

Fig. IV.6.18. Measured ^{131}I milk concentration Ostroleka, Ciechanow and Bialystok provinces in the period (28-04 - 8.06 1986 r). Continuous curves describe: black curve- best fit to measured average ^{131}I concentrations in the milk, red curve: upper bound of average values (x2.5), the blue curve: lower bound of average values (1/2.5). Integrated ^{131}I concentration in the milk= 22282 [Bq·L^{-1}·d]. Green triangles and red dots – measured ^{131}I concentration in milk for cows kept in cowsheds.

Assessment of countermeasures effectiveness and thyroid dose equivalent H_{50} from direct measurements of ^{131}I in the thyroid gland

Credible view on the level of the radiation hazard from ^{131}I for the population of Poland, could be obtained from direct measurements of ^{131}I activities in the thyroid gland. Such measurements were being carried on in CLOR and in the Institute of Atomic Energy in the period 4 May – 27 June 1986 [IV.45, IV.46]. Totally 2020 measurements of the thyroid gland were performed. The largest number of measurements was made for Warsaw province (1405 measurements) including: 1143 measurements of adults, 42 measurements of children of 15 years old, 126 measurements of children of 10 years old, 91 measurements of children of 5 years old. About 760 measurements of adults were made in the Institute of the Atomic Energy. The information about the date of applying the stable iodine blockade was obtained from the interview. Considering the representativeness of measurements only for the Warsaw province – 1405 measurements, Ostrołęka – 133 measurements and Białystok – 195 measurements, an assessment of H_{50} doses could be extended for entire area.

Measured ^{131}I content in thyroid gland both for adults, teenagers and children reveal significant contribution of ingestion pathway (consumption of contaminated ^{131}I milk) to the ^{131}I thyroid burden. These results shows big scattering, as result of very changeable ^{131}I levels in milk, local air contamination as well as various behaviour of population. Although theoretically very effective, ban of cows' pasturage in open areas appeared not very efficient in practice due to spring's shortage of uncontaminated hay in many private farms. The curve predicted by the model was fitted to the measured ^{131}I activity in the thyroid gland in the given day of the measurement, then the computer program calculated the integral of the ^{131}I activity in thyroid and the H_{50} dose, using dose conversion factors characteristic of the given age group. Values of H_{50} doses for inhabitants of some high, average and low contaminated areas in Poland are presented in Table IV.6.2. The averages of thyroid dose equivalent H_{50} for critical age groups i.e., children 1–5 and 5–10 years of inhabitants of majority contaminated areas of Poland, are close to the dose limit for population (20 mSv)[15], however in some areas H_{50} doses excide this limit 3 times; for the Ostrołęka province: 80-56 mSv in the group of children 1–5 years old (maximum dose 279 mSv); 75–56 mSv in the group of children 5–10 years old (maximum dose 256 mSv). There is no reason however to exclude possibility of occurrence similar values in the other high contaminated areas (i.e. in south of Poland).

Administration of preventive stable iodine liquid ("Lugol") might reduce H_{50} doses of about 40% but this factor can considerably change in individual cases due to it's significant dependence both from the individual parameters as well from local differences in the dynamic of radioiodine contaminations.

[15] Dose equivalent of 20 mSv in thyroid ≅ 1mSv effective dose (dose limit for population in normal operation of nuclear installation).

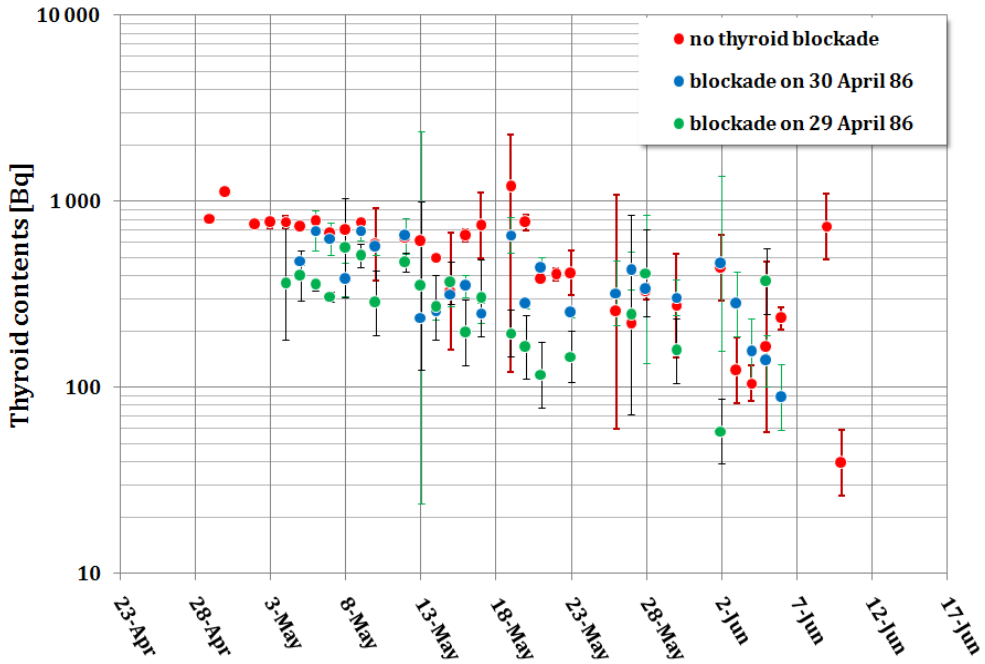

Fig. IV.6.19. Daily averages of measured ^{131}I thyroid contents for Warsaw inhabitants (Adults).

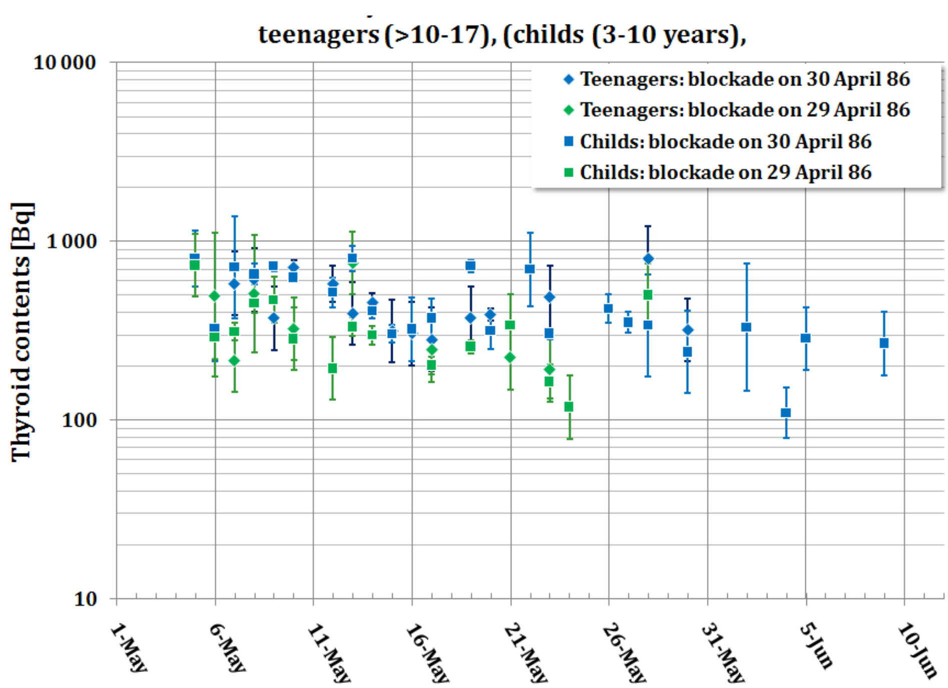

Fig. IV.6.20. Daily averages of measured ^{131}I contents for Warsaw inhabitants (teenagers, children).

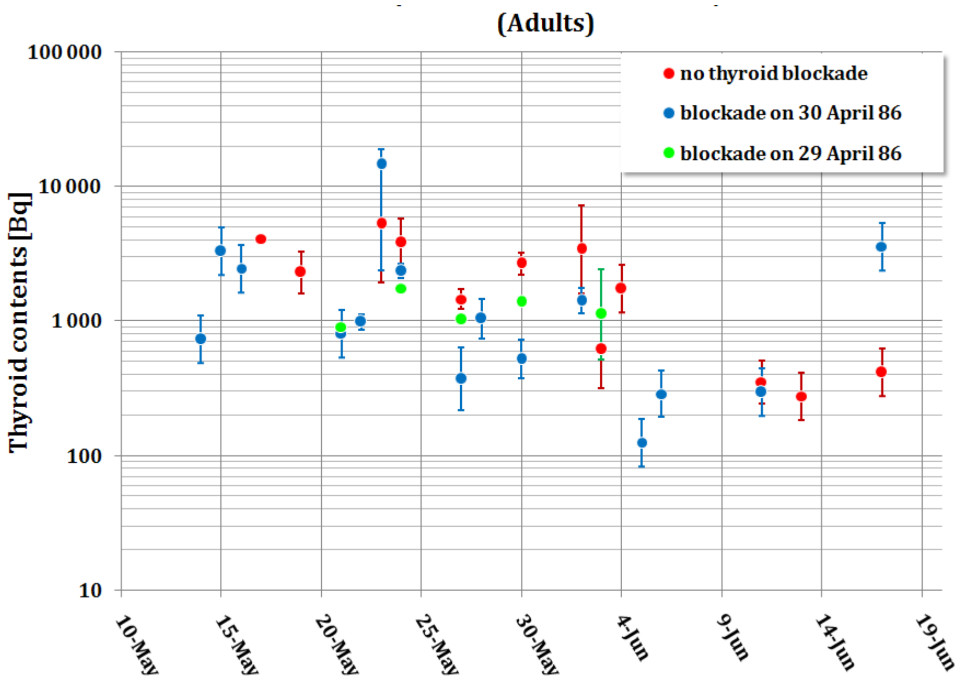

Fig. IV.6.21. Daily averages of measured ^{131}I thyroid contents for Ostrołeka inhabitants (Adults).

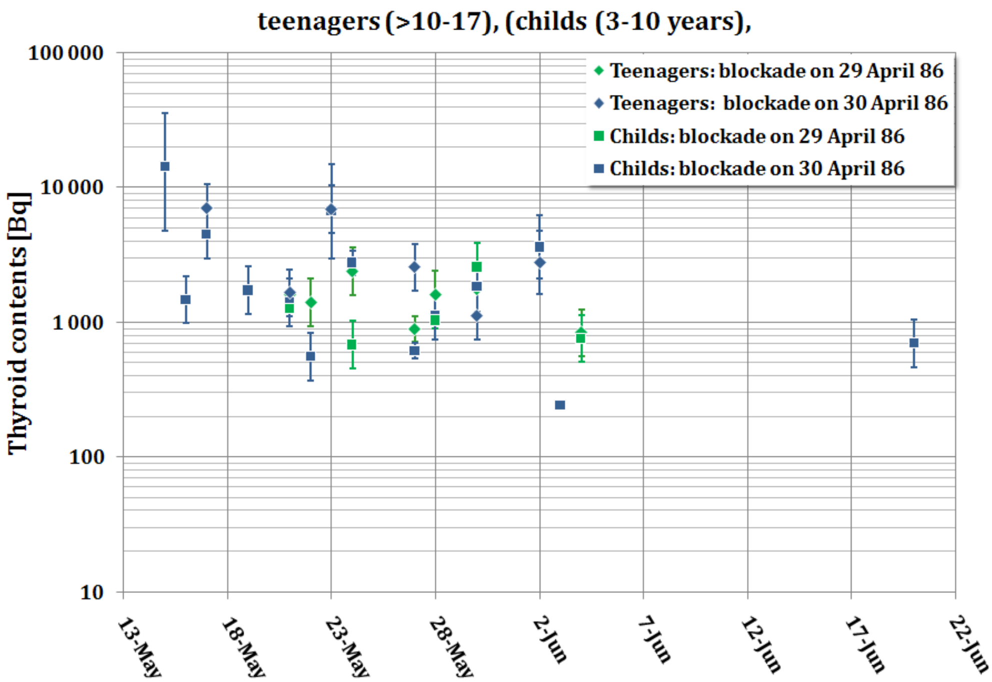

Fig. IV.6.22. Daily averages of measured ^{131}I contents for Ostroleka inhabitants (teenagers, children).

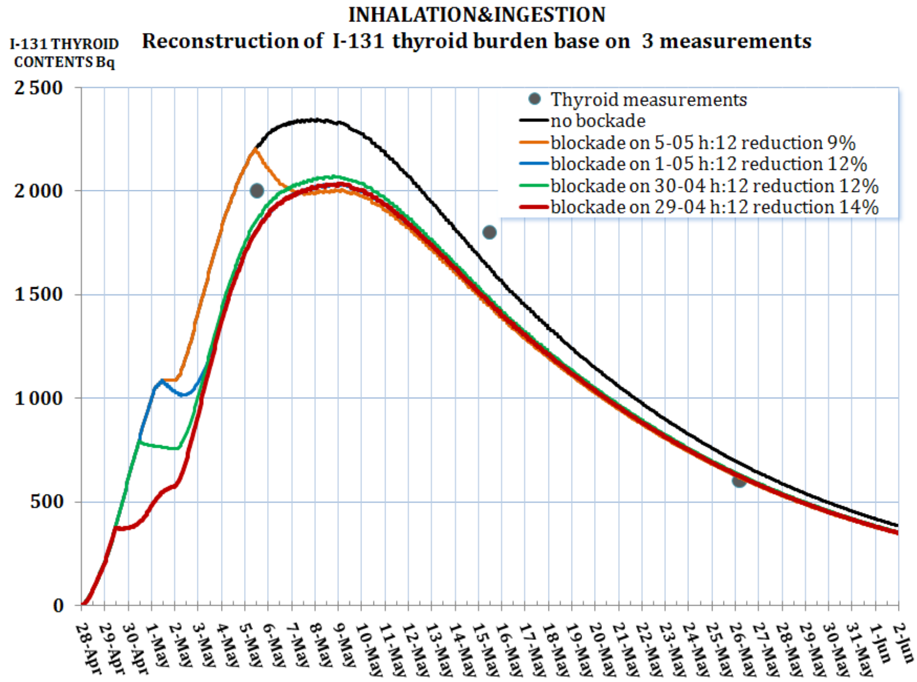

Fig. IV.6.23. Example of method used for evaluation of H50 on the basis of direct measurement of ^{131}I content in thyroid. Dots represent three measurements of ^{131}I content in thyroid for the one person. Curves present predicted ^{131}I thyroid content versus time for different variants of thyroid blockade.

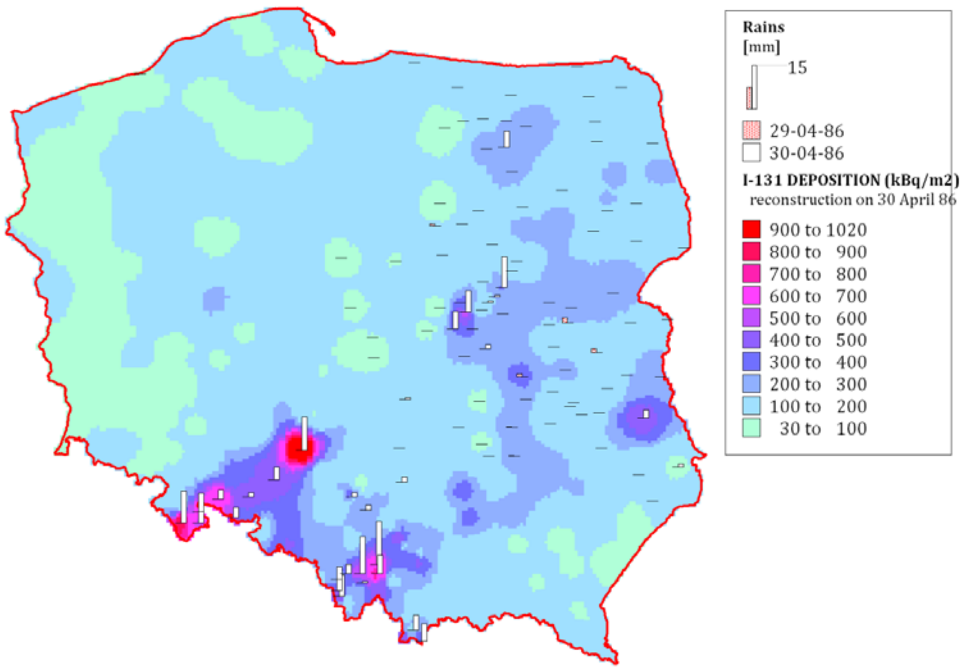

Fig. IV.6.24. Reconstruction of ^{131}I deposition (calculated on 30 April 1986) from ^{137}Cs surface contamination.

Table IV.6.2. Thyroid dose equivalent H_{50} of inhabitants high, medium and low contaminated regions in Poland. An assessment on the basis of direct measurements of ^{131}I in thyroids.

WOIWODSHIP	DATE OF BLOCKADE	DOSE EQUIVALENT TO THYROID H_{50} [mSv] FOR STANDARDIZED AGES GROUPS				
		ADULT **AVERAGE*(N#)**** **$L_{95\%} \div U_{95\%}$**** **Min – Max*****	**TENAGER 15Y** **AVERAGE*(N#)*** **$L_{95\%} \div U_{95\%}$** **Min - Max**	**CHILD 10 Y** **AVERAGE*(N#)*** **$L_{95\%} \div U_{95\%}$** **Min - Max**	**CHILD 5 Y** **AVERAGE*(N#)*** **$L_{95\%} \div U_{95\%}$** **Min - Max**	**CHILD 1 Y** **AVERAGE*(N#)*** **$L_{95\%} \div U_{95\%}$** **Min - Max**
Ostrołęckie	No blockade	**25.8***(33)* 20.0÷33.3 **3.1 – 139.9**			**245.6***(1)*	
	After 1-May	**13.3***(2)* **10.3 – 15.6**				
	29 or 30 April	**18.9***(33)* 13.3÷26.7 **2.1 – 216.8**	**41.2***(10)* 28.5÷59.5 **12.2 – 96.7**	**75.3***(22)* 54.8÷103.5 **15.1 – 251.9**	**55.8***(30)* 43.4÷71.6 **15.5 – 279.3**	**79.9***(2)* **52.8 – 99.1**
Łomżyńskie	No blockade	**22.0***(1)*				
	After 1-May	**23.9***(1)*				
	29 or 30 April	**9.9***(3)* 8.9÷11.0 **8.6 – 10.5**	**42.5***(3)* 20.9÷86.7 **16.5 – 57.9**	**54.6***(2)* **7.9 – 55.7**	**39.8***(1)*	
Suwalskie	No blockade	**6.4***(4)* 2.5÷16.3 **1.8 – 9.5**	**2.7***(1)*			
	After 1-May	**11.3***(1)*				
	29 or 30 April	**3.1***(7)* 1.9÷5.1 **1.0 – 8.5**	**2.7***(1)*	**11.8***(3)* 4.4÷32.7 **3.3 - 18.2**	**29.2***(4)* 4.8÷177.1 **2.4 - 39.7**	
Białostockie	After 1-May	**6.8***(1)*				
	29 or 30 April	**6.0***(42)* 5.1÷7.0 **0.6 -14.4**	**16.9***(70)* 15.3÷18.6 **5.9 – 57.4**	**20.3***(60)* 18.4÷22.4 **6.0 – 56.5**	**28.7***(19)* 18.2÷45.3 **4.2 – 86.9**	**7.4***(3)* 5.0÷11.0 **5.4 - 10.8**
Siedleckie	After 1-May			**4.9***(1)*	**5.4***(1)*	
	29 or 30 April	**9.3***(4)* 2.4÷35.6 **0.8 – 9.6**		**20.5***(1)*	**17.2***(2)* **15.4 - 18.7**	**17.7***(1)*
Płockie	29 or 30 April		**10.4***(1)*		**18.5***(1)*	
Olsztyńskie	No blockade	**8.6***(3)* 5.9÷12.7 **5.8 – 12.3**				
	After 1-May	**8.4***(1)*				
	29 or 30 April			**17.2***(2)* **4.7 - 20.9**		
Toruńskie	No blockade	**11.2***(1)*				
	After 1-May	**10.1***(5)* 8.1÷12.6 **6.7 – 14.3**				
	29 or 30 April		**14.8***(1)*			
Warszawskie	No blockade	**4.1***(864)* 3.9÷4.3 **0.1 – 37.0**		**9.0***(2)* **7.9 – 9.9**	**2.7***(1)*	
	After 1-May	**2.6***(33)* 2.0÷3.4 **0.5 – 11.9**	**4.8***(4)* 3.3÷7.0 **2.3 – 5.9**	**6.9***(4)* 4.6÷10.5 **4.1 – 10.6**	**5.2***(1)*	
	29 or 30 April	**2.1***(256)* 1.9÷2.3 **0.1 – 38.0**	**5.0***(36)* 4.1÷6.1 **1.3 – 22.4**	**6.6***(119)* 6.0÷7.6 **1.5 – 29.8**	**11.8***(88)* 9.5÷14.8 **0.6 – 110.5**	**4.0***(4)* 2.1÷7.5 **1.4 – 6.9**
	28-04 April	**0.9***(4)* 0.7÷1.2 **0.6 – 1.3**			**8.5***(1)*	

* w nawiasach kursywą podano liczbę pomiarów.
** podano dolny i górny zakres 95% przedziału ufności średniej log-norm.
*** najmniejsza i najwieksza wartości w serii pomiarów.

IV.6.2.5. Forecast doses

For areas where there were sparse or none ^{131}I measurements in the thyroid gland (particularly in west and north-western and southern Poland), assessment of H_{50} doses was only possible with the help of radioecological model, on the basis of ^{137}Cs measurements in the soil (conducted in 1989-1991) [IV.47], and of ^{131}I measurements in the milk [IV.40]. To assess thyroid doses, two pathways of ^{131}I uptake into the human body were assumed i.e. inhalation pathway due to breathing of air polluted with ^{131}I iodine and ingestion pathway due to consumption of contaminated milk. The total thyroid dose equivalent H_{50} was calculated a sum of inhalation and ingestion doses. One could assume that "true" individual thyroid dose lied between minimal inhalation dose and maximal ingestion doses predicted for particular area.

Forecast of inhalation doses

Determination of inhalation doses required reconstruction of the integrated ^{131}I concentration in air from calculated deposition of this radionuclide on the soil surface. ^{131}I deposition could be estimated from semi-empirical ratio $^{131}I/^{137}Cs$ in the fallout. Similar methodology was being taken in the last works concerning reconstruction of doses from ^{131}I for strongly contaminated Russia, Ukraine and Belarus areas [IV.48–IV.52]. However, relationship between ^{131}I fall-out and concentration in air is rather complex and depends on contribution of chemical and physical forms of radioiodine in air, particularly elemental fraction I_2 and aerosol bound fraction, moreover this relationship is strongly dependent on the rain intensity and precipitation amount. The fraction of elemental radioiodine (molecular-gaseous) I_2 changed from about 30% in the period of the highest ^{131}I concentrations in air (28–30 April 1986) to above the 60% in the later period of the declining of the ^{131}I concentration in air (1–4 May 1986), and then to value about 40% in the more late period of the clouds passage (5–20 May 1986). The participation of the fraction of the iodine bound with aerosol changed from 60% to the 35% in the same periods respectively. Considerable influence on the ^{131}I fallout had rainfalls which occurred locally in Poland on the 30 April 1986 [IV.53]. For the hypothetical region of about 300 kBq m^{-2} of ^{131}I (dry deposition 180 kBq m^{-2} (…), wet deposition 120 kBq m^{-2} (…)) one could calculate back an integrated ^{131}I concentration in air equal to about 400 $Bq\cdot m^{-3}\cdot d$ (aerosol fraction of 237 $Bq\cdot m^{-3}\cdot d$, molecular-gaseous fraction I_2 of 147 $Bq\cdot m^{-3}\cdot d$ and organic CH_3I fraction of 16 $Bq\cdot m^{-3}\cdot d$). This conditions correspond to thyroid dose equivalent $H(0)^{inh}{}_{50}$ for adult of 2.2 mGy (at filtration of the building 0.4; 16 hours in building and breathing rate 1 m^3 h^{-1} at low activity and 1.5 m3 h^{-1} at increased activity). $H(0)^{inh}{}_{50}$ one could consider as reference value for inhalation pathway.

A detailed analysis of the relationship $^{131}I/^{137}Cs$ activity in soil was carried by Knatko, et al., [IV.51] on the basis of 213 measurements of the activity of these isotopes in the soil. A logarithmic relation of the $^{131}I/^{137}Cs$ relationship was received according to the formula:

$$\ln\left(\frac{S_{I-131}}{S_{Cs-137}}\right) = \alpha - \beta \times \ln\left(S_{Cs-137}\right) \qquad \text{(IV.6.1)}$$

where:

S_{I-131}, S_{Cs-137} are the ^{131}I and ^{137}Cs surface concentration in soil in [kBq m^{-2}]; and
α= 3.52; β= 0.37 is the semi-empirique factor.

Analysis of sparse results of soil the ^{131}I and ^{137}Cs concentration in soil measurements as well as ^{129}I determination indicated on similar relationship i.e. α= 4.214, β = 0.301 [IV.54]. Figure IV.6.24 shows spatial distribution of ^{131}I deposition derived on the basis of this relation (see Equation IV.6.1). The ^{131}I deposition pattern correlates well with the location of the rainfall in Poland during the period 29–30 April 1986. It is worth to emphasise that maximal and minimal values of the ^{131}I deposition i.e. 900 kBq m^{-2}, 100 kBq m^{-2} not exceeding the factor of 3 of the average 300 kBq m^{-2}.

Forecast of ingestion doses

During the period 29 April – 6 June 1986 about 700 measurements of the ^{131}I concentration in the milk and milk products were carried out for about 152 locations in Poland [IV.40]. These measurements have been carried on not always in the systematic way and in most cases only single samples have been taken in the particular location they were these are measurements of the isolated charged sample in the given town (see Figure IV.6.25). Nevertheless these results enabled to calculate integrate concentrations of ^{131}I in milk[16] in this period by fitting the curve to measuring points in particular locations. Spatial distribution of integrated ^{131}I concentrations in milk interpolated with IDW Shepard function[17] is shown in Figure IV.6.26. As a result, the interpolating surface of Poland consists of sets interpolated values for 34786 cells (each cell represented by 3×3 km square). Comparing the map of the ^{131}I deposition and map of integrated ^{131}I concentrations in milk one could notice that areas with elevated ^{131}I concentration in milk not necessary correlate with areas of higher ^{131}I deposition. The differences are resulting mainly from hay storage ability of particular region to follow the ban on pasturage of cows in open areas. It became apparent for the area of the Ostrołęka province, were not effective observances the ban on pasturage of cows yielded the local ^{131}I high concentrations in milk and in consequence the ^{131}I high concentrations measured in thyroid glands, whereas for the Warsaw province where farmers had enough storage of hay and obeyed the ban, the lower ^{131}I concentrations in milk were observed. For hypothetical region the integrated ^{131}I concentration in milk equal to 22 kBq L^{-1} d yields to $H(0)^{ing}{}_{50}$ thyroid dose equivalent for adult equal to 3.8 mSv (for the milk equivalent 0.4 milk products d^{-1} L). $H(0)^{ing}{}_{50}$ one could consider as reference value for ingestion pathway.

Forecast of total doses

Conditions described previously in this section (IV.6.25) resulted in the total thyroid dose equivalent for adult amounted to 6 mSv. For other conditions and different age groups the total thyroid dose was calculated according to formulas:

$$H_{50}^{tot}(i) = H_{50}^{inh}(i) + H_{50}^{ing}(i) \tag{IV.6.2}$$

$$H_{50(age)}^{inh}(i) = H_{50}^{inh}(0) \times f^{inh}(i) \times g_{age} \tag{IV.6.3}$$

$$H_{50(age)}^{ing}(i) = H_{50}^{ing}(0) \times f^{ing}(i) \times g_{age} \tag{IV.6.4}$$

where:

f^{inh} (i) is the ^{131}I deposition factor;
f^{ing} (i) is the ^{131}I integrated concentration factor; and
g_{age} is the age group [18] correction factor derived from DCF and different milk consumption rate.

Therefore, to every 3×3 km cell of the map the values of $H^{tot}{}_{50(age)}$ for 6 ages group were assigned. Results of calculation are presented in Figures IV.6.27 and IV.6.28 respectively.

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[16] Integrated ^{131}I concentration in milk in Bq·L^{-1}·d
[17] Inverse distance weighted interpolation is sometimes called "Shepard's method" [IV.55].
[18] Assumed: teenager 15 years old = 1.7; child 10 years old = 2.5; child 5 years old = 4.8; child 1 years old = 8.5, new born 3 month old = 11 (bottle fed).

Fig. IV.6.25. Location of milk samples measured in the period from 29.04.1986r. to 6.06.1986r.

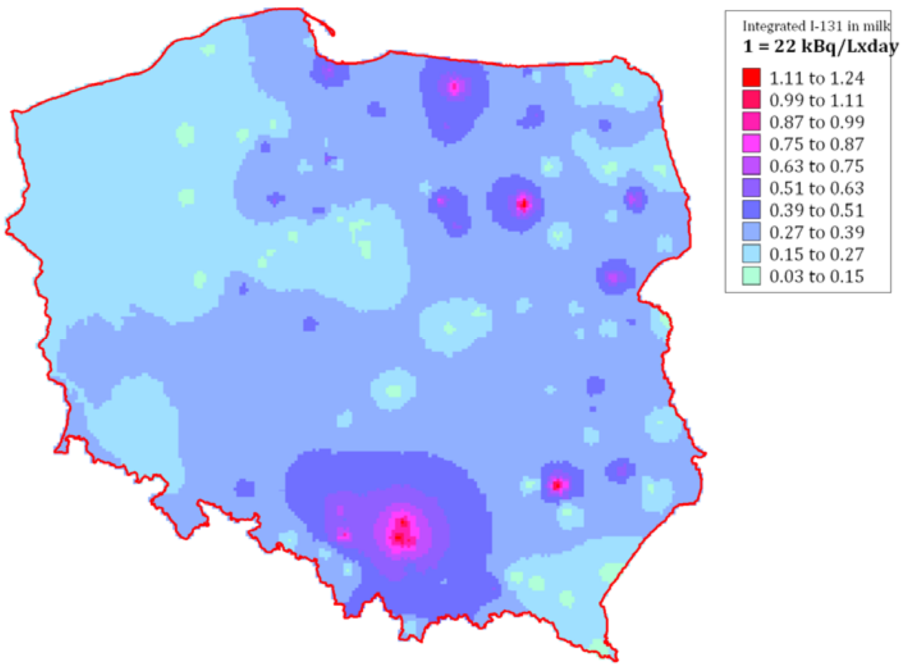

Fig. IV.6.26. Special distribution of ^{131}I integrated concentration in milk averaged with IDW Shepard interpolator.

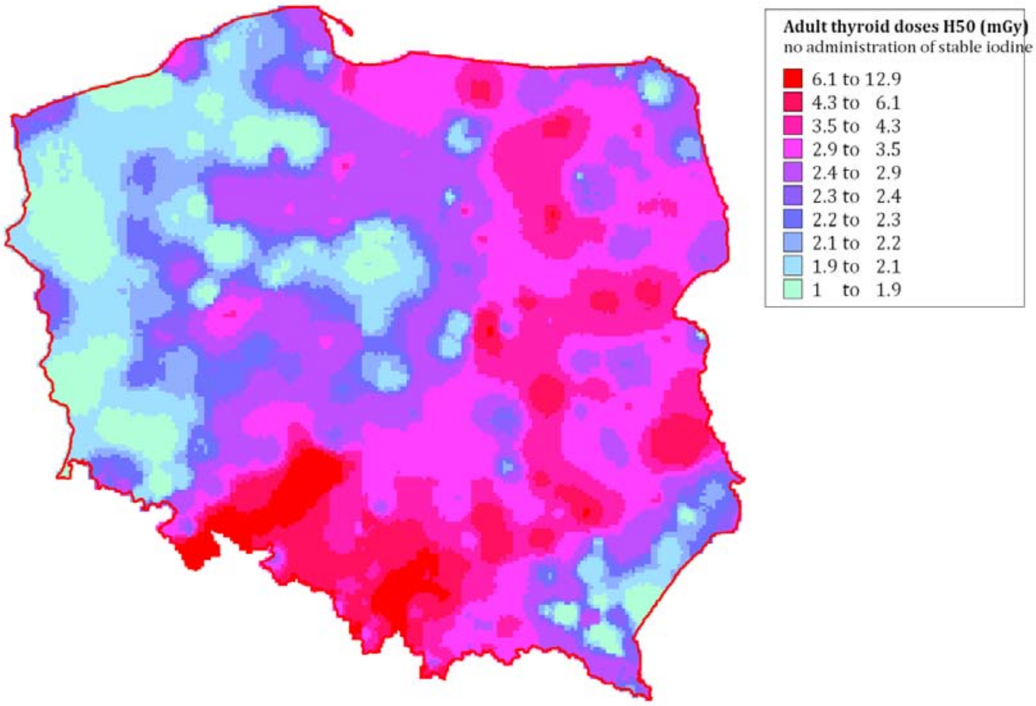

Fig. IV.6.27. Spatial distribution of total thyroid ^{131}I equivalent doses for adult (without administration of stable iodine).

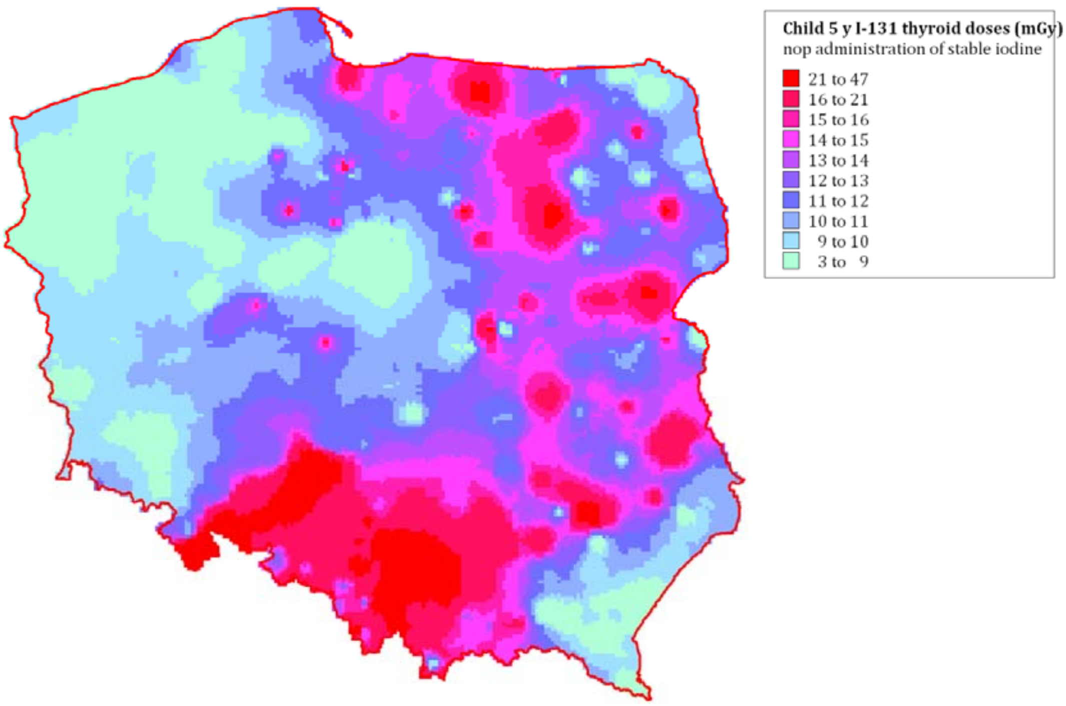

Fig. IV.6.28. Spatial distribution of total thyroid ^{131}I equivalent doses for of child 5 years (without administration of stable iodine).

Table IV.6.3. Standardized daily supply of stable iodine and thyroid mass characteristic for the given age group.

Age group	Standardized daily supply of stable iodine	Standardized thyroid mass
Standard man	200 μg	20 g
Woman	166 μg	17 g
Tenager 15 years old	168 μg	12 g
Child 10 years old	116 μg	8 g
Child 5 years old	63 μg	4.4 g
Child 1 years old	21 μg	2.1 g
New born 3 months	10 μg	1.6 g

Table IV.6.4. Changes of thyroid dose equivalent H_{50} for different daily supply of stable iodine.

Percentage of standardized daily supply of stable iodine	25%	50%	75%	100%	125%	150%	175%	200%	225%	250%
Corrector factors of thyroid dose equivalent H_{50} in relation to standard daily supply of stable iodine	2.5	1.6	1.25	1	0.8	0.7	0.6	0.55	0.5	0.45

Correction of forecast doses with respect to deficiency of stable iodine with the diet

This correction considers the fact, that at the deficiency of stable iodine with daily diet, thus for so-called endemic area, a higher radioiodine ^{131}I uptake might result in higher thyroid doses. Daily supply of stable iodine in the diet was estimated for particular regions in Poland after Chernobyl accident [IV.56, IV.57]. Supply of iodine in the diet and the degree of its deficiency was being determined based on excretion of iodine in the morning sample of urine. Representative calculations of ^{131}I thyroid burden and H_{50} thyroid dose equivalent were performed for seven age groups with iodine metabolic model [IV.43] for various levels of standardized daily supply of stable iodine characteristic of the given age group Table IV.6.3. Results of calculations indicated that deficiency of the 25% of standard supply of stable iodine gives an increasing of ^{131}I thyroid dose[19] of 2.5 fold (see Table IV.6.4). In this case compensatory effect of thyroid mass on H_{50} calculation i.e. endemic thyroid goitre effect was omitted.

IV.6.3. Conclusions

The average thyroid equivalent doses H_{50} for critical age groups i.e. children 1–5 and 5–10 years of inhabitants of majority contaminated areas of Poland after Chernobyl accident are close to the dose limit for population (20 mSv)[20], however in some areas H_{50} doses excide this limit 3 times; for the Ostrołęka province: 80–56 mSv in the group of children 1–5 years old (maximum dose 279 mSv); 75–56 mSv in the group of children 5–10 years old (maximum dose 256 mSv). There is no reason however to exclude possibility of occurrence similar values in the other high contaminated areas (i.e. in south of Poland).

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[19] 2.5 fold increasing of integrated ^{131}I thyroid burden (Bq·d).

[20] Dose equivalent of 20 mSv in thyroid ≅ 1mSv effective dose (dose limit for population in normal operation of nuclear installation).

Theoretical model calculations show that even 10 days delay of start cows' pasturage gives 50 times reduction of integrated ^{131}I concentration in milk. However in practice this countermeasure might be effective for well-developed agricultural area with sufficient hay storage. Measurement of ^{131}I concentration in milk and later analysis indicated that only about 20% of farms in Poland were able to obey the ban. The quantitative evaluation this countermeasure is difficult because of lack sufficient measurements data.

Assuming short one day cloud passage, thyroid blockade could reduce the thyroid dose H_{50} of about 75% when stable iodine was taken on 28 April 1986 at 12:00, and of 62% when taken on 29 April 1986 at 12:00. For prolonged ^{131}I air contamination the blockade is less efficient. When one consider ingestion pathway the most effective could be blockade on 1 May 1986 at 12:00 (30%), because it is correlated with maximum of ^{131}I concentration in milk that occurred on 1–2 May 1986 in most contaminated areas in Poland. From point of view of the assessment of the effectiveness of this countermeasure, inhalation and ingestion pathways together should be considered, then both term 28, 29, 30 April and 1 May 1986 are comparable giving H_{50} reduction from 10% to 30%.

Forecast H_{50} doses, determined on the basis of reconstructed ^{131}I radioactive fallout and ^{131}I milk concentration data, are approximately comparable with doses assessed on the basis of direct measurements of ^{131}I in the thyroid gland. Although, a method of reconstruction of the ^{131}I fallout on the basis of the concentration in the ^{137}Cs soil was widely used for the assessment of doses from ^{131}I to the thyroid gland in the most contaminated lands of Russia, Ukraine and Belarus, one should take the uncertainty of this method into consideration. Particularly, local hot-spots of ^{131}I activity might be omitted and not taken into consideration in the doses assessment. However, considering even such unfavourable circumstances like highest observed air and ground contamination, lack of thyroid blockade, consumption of contaminated milk, critical group of children age of 1-5 years, the maximum thyroid dose equivalent H50 should not excide value of 400 mSv e.g. dose limit for occupationally exposed[21].

[21] 400 mSv of thyroid dose equivalent gives 20 mSv od effective dose at thyroid weight 5%.

IV.7. Brief introduction to the OSCAAR Code
OSCAAR (Off-Site Consequence Analysis code for Atmospheric Releases in reactor accidents)[22]

IV.7.1. Intended purpose of the model in radiation assessment

OSCAAR has been developed within the research activities on probabilistic safety assessment (PSA) at the Japan Atomic Energy Research Institute [IV.59]. OSCAAR is primarily designed for use in PSA of nuclear reactors in Japan. OSCAAR calculations, however, can be used for a wide variety of applications including sitting, emergency planning, and development of design criteria, and in the comparative risk studies of different energy systems. Figure IV.7.1 shows a schematic representation of the OSCARR code system. OSCAAR consists of a series of interlinked modules and data files that are used to calculate the atmospheric dispersion and deposition of selected radionuclides for all sampled weather conditions, and the subsequent dose distributions and health effects in the exposed population. OSCAAR can consider the countermeasures which might be taken to reduce the dose received by the exposed population. Several stand-alone computer codes and databases can also be used to prepare, in advance, necessary input data files for OSCAAR, such as dose conversion factors, population and agricultural product distributions, and lifetime risks for exposed population. The principal endpoints of OSCAAR can be roughly divided on health effects, effects of countermeasures and economic impacts.

IV.7.2. Model type

For the validation of OSCAAR, the CHRONIC module has been applied to the Chernobyl scenario (Scenario A4) of BIOMOVS Phase I, which starts with daily concentrations of I-131 in air and requests the prediction of concentrations of I-131 in vegetation and milk for several locations in the northern hemisphere [IV.60]. In the Hanford test scenario we can examine the performance of other OSCAAR modules such as ADD, EARLY, and CHRONIC by implementing atmospheric dispersion and deposition calculations, food chain transport analysis, and dose calculations. ADD implements a Gaussian multi-puff trajectory model for calculating time-integrated air concentrations and surface contamination. CHRONIC uses time-dependent analytical equations for estimating the radionuclide transport in the food chain.

IV.7.3. Method used for deriving uncertainty estimates

OSCAAR has been coupled with the uncertainty and sensitivity analysis techniques to quantify uncertainty associated with accident consequence assessment and to identify uncertain processes and important parameters contributed to consequences. Among a number of techniques available for propagating parameter uncertainties through complex models, a Monte Carlo method has been implemented to perform uncertainty and sensitivity analyses of OSCAAR. The software package PREP/SPOP is used to allow for an automatic performance of all necessary steps in uncertainty and sensitivity analysis. The different sampling schemes, such as pure random, Latin hypercube (LHS) and quasi-random sampling, are allowed to be used in PREP [IV.61]. SPOP performs the uncertainty and sensitivity analyses on the output of the model. SPOP includes several parametric and non-parametric techniques, based on regression-correlation measures, as well as some “two-sample” tests [IV.61]. Variance-based methods are also available for ascertaining if a subset of input may account for the output variance without any linearity assumptions [IV.62].

[22] This Section was taken from IAEA-BIOMASS-2, [IV.58] OSCAAR and summarized by P. Krajewski.

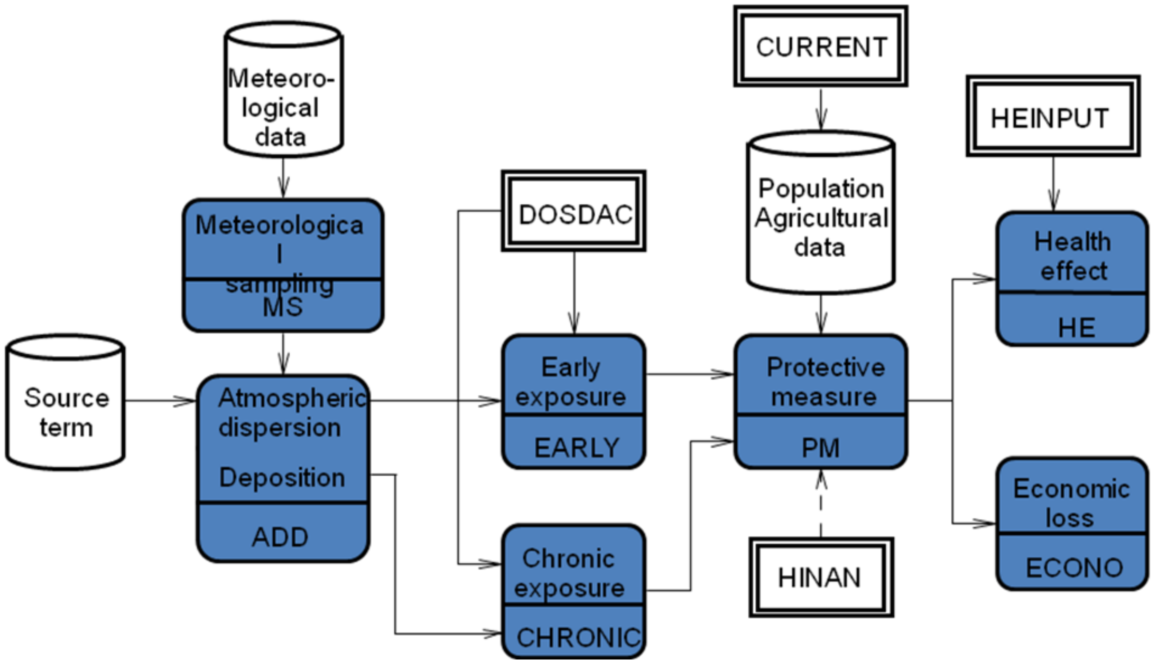

Fig. IV.7.1. Schematic representation of the OSCAAR code system.

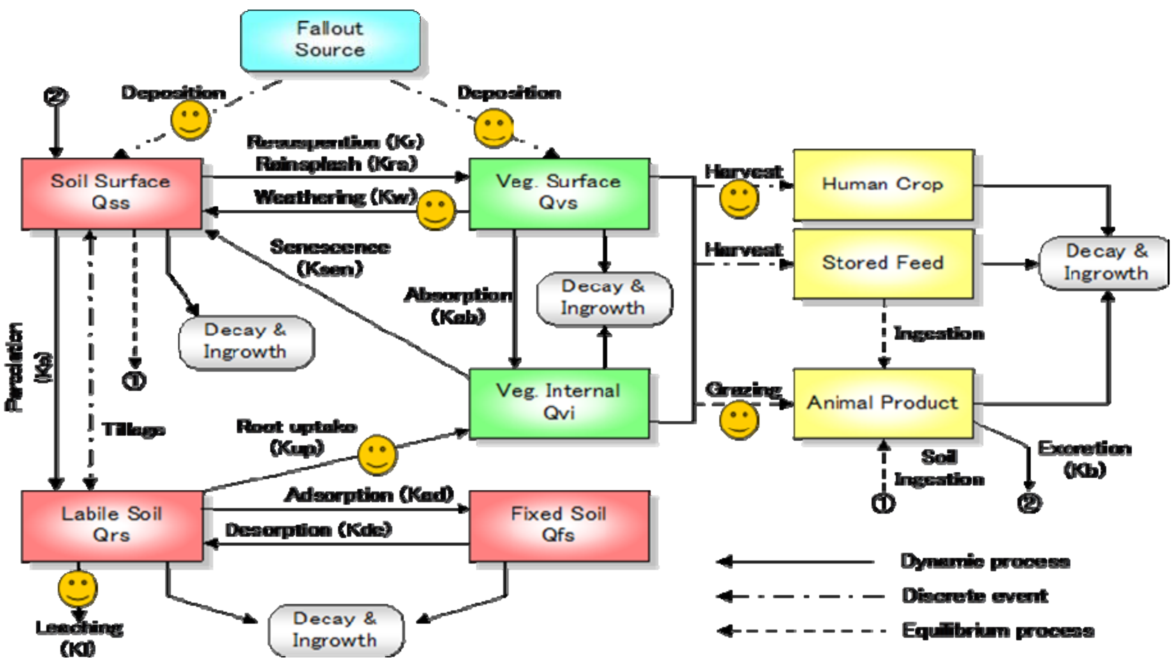

Fig. IV.7.2. Pathways in the Food-chain model: OSCAAR – chronic – simple analytical approach, COLINA – numerical dynamic approach.

IV.7.4. Parameters and approaches implemented in MAZOVIA Scenario

(1) Starting point-Air concentration of I-131;
(2) Warsaw: Daily averages of ^{131}I concentrations in air and radioiodine forms evaluated on the basis of the monitoring data two independent stations;
(3) Ostroleka: Warsaw ^{131}I concentrations in air ×Cs-137 ratio(Ostroleka/Wwrsaw) in soil;
(4) Wet deposition was considered as a function of rainfall data;
(5) Dry deposition velocity & washout ratio;
(6) Elemental(1 cm/s), Aerosol(0.2 cm/s), Organic(0.01 cm/s);
(7) Elemental(2. 10^5), Aerosol(3. 10^5), organic(2. 10^3);
(8) Weathering half-life: 8 day;
(9) Max yield of pasture: 0.5 kg/m^2;
(10) Feed to milk transfer factor: 4.4 10^{-3};
(11) Contaminated pasture was fed on the basis of the percentage data of the Table: An assessment of fodder resources in particular counties of Mazovia province in 1986.

IV.7.5. Dose calculations

Two kinds of modules are used to convert the predicted spatial and temporal distributions of activity in the atmosphere and on the ground to distributions of dose in population. The EARLY module calculates early exposure which occurs during and shortly after plume passage. External irradiation from material in the passing cloud (cloudshine), internal irradiation following inhalation of the material, and external irradiation from the deposited material (groundshine) are taken into account in EARLY within several hours to several weeks since the accident occurs. The cloudshine is basically calculated with the submersion model, but the finite cloud model based on isotropic puff assumptions [IV.63] is used to estimate the irradiation at the places close to the source. The CHRONIC module calculates the long-term groundshine dose, internal doses via inhalation of radionuclides resuspended from the ground, and internal doses via ingestion of contaminated foodstuffs. The migration of deposited material in soil as well as the radioactive decay is taken into account for the calculation of the long-term groundshine doses. The food chain model in CHRONIC is an extension of the methodology used in WASH-1400 [IV.64] and is available for important CHRONIC derives the human intake of I-131 through the pasture-cow-milk pathway by:

$$I = U_m e^{-\lambda t_m} \int D \frac{r}{Y_v} e^{-(\lambda + \lambda_w)t} Q_F F_m(t) dt \tag{IV.7.1}$$

where:

D is the total deposition (Bq/m^2);
r/Y_v is the mass interception fraction (m^2/kg-dw);
$\_{}_w$ is the environmental loss constant (day^{-1}) (T_w = 1n 2/$\_{}_w$;
Q_F is the daily intake of a dairy cow (kg-dw/day);
F_m is the fraction of daily intake of radioiodine secreted per litre of milk by Lengemann [IV.65]: 0.0091 exp(0.021t) [1 – exp(-0.292t)], transfer rate;
t_m is the time between milk secretion and milk consumption (day); and
U_m is the milk consumption rate (L/day).

CHRONIC does not treat deposition of activity as a function of time, while ADD calculates hourly time-integrated air concentrations and deposition of activity. The human intake of radionuclides for each spatial grid element is calculated from the amount of activity deposited, the concentration of activity in foods for unit deposition, and the consumption rate. CHRONIC does not treat deposition of activity as a function of time, while ADD calculates hourly time-integrated air concentrations and deposition of activity. The human intake of radionuclides for each spatial grid element is calculated from the amount of activity deposited, the concentration of activity in foods for unit deposition, and the consumption rate. CHRONIC also does not have the function of predicting the thyroid burdens of I-131. For the comparison with the measurements, however, we used a Johanson model made available by Scenario provider as an Excel calculation module.

IV.7.6. Dosimetry data

The internal dose conversion factors and the external dose rate conversion factors can be used in the EARLY and CHRONIC modules to determine the dose in different organs following an intake of radionuclides and exposure to external irradiation, respectively. A computer code system DOSDAC calculates these quantities from most updating data, such as radioactive decay data, atomic, anatomical and metabolic data and generates the dose conversion factors required for OSCAAR.

Estimates of the internal dose factors resulting from inhalation and ingestion of various radionuclides are made by the methods in the ICRP Publication 30 [IV.66] in the DOSDAC system. For external exposure the method of Kocher [IV.67] is used to compute the dose-rate conversion factors which concept is based on the idealized assumptions that the source region can be regarded as effectively infinite or semi-infinite in extent and that the radionuclide concentration is uniform throughout the source region. The breathing rate for the adult test persons and dose and dose-rate conversion factors for I-131 for thyroid in this calculation are given in Table IV.7.1. In this calculation we did not consider any reduction of either external exposure due to the shielding by buildings or inhalation exposure due to the filtering by the buildings.

Table IV.7.1. Parameter values used in dose calculations.

Variable	Description	Distribution	Mean	μ*	σ*	Units
B_r	Breathing rate for adults	constant	2.66×10^{-4}	–	–	m^3/s
DF_c	Dose rate conversion factor for thyroid for immersion in I-131 contaminated air	constant	5.65×10^{-7}	–	–	Sv/yr per Bq/m^3
DF_g	Dose rate conversion factor for thyroid for exposure 1 m above I-131 contaminated ground surface	constant	1.32×10^{-8}	–	–	Sv/yr per Bq/m^3
DF_{ihn}	Committed dose equivalent in thyroid per intake of unit I-131 by inhalation	constant	2.67×10^{-7}	–	–	Sv/Bq
DF_{ing}	Committed dose equivalent in thyroid per intake of unit I-131 by ingestion	constant	4.35×10^{-7}	–	–	Sv/Bq

* μ and σ are the mean and standard deviation, respectively, of the normally distributed parameters. If the parameter, *x* is log-normally distributed, μ and σ refer to those of the log-transformed parameters ($\log_{10}(x)$).

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LIST OF PARTICIPANTS

Ammann, M.	Radiation and Nuclear Safety Authority (STUK), Helsinki, Finland
Balonov, M.	International Atomic Energy Agency
Berkovskyy, V.	International Atomic Energy Agency
Bartusková, M.	National Radiation Protection Institute (SURO), Ostrava, Czech Republic
Duffa, C.	Institut de Radioprotection et de Sûreté Nucléaire (IRSN), Cedex, France
Filistovic, V	Institute of Physics, Vilnius, Lithuania
Homma, T.	Japan Atomic Energy Agency (JAEA), Tokaimura, Japan
Horyna, J.	State Office for Nuclear Safety, Czech Republic
Kanyár, B.	University of Pannonia, Veszprém, Hungary
Krajewski, P.	Central Laboratory for Radiological Protection, Warsaw, Poland
Malátová, I.	National Radiation Protection Institute (SURO), Prague, Czech Republic
T. Nedveckaite	Institute of Physics, Vilnius, Lithuania
Simon, S.	National Cancer Institute (NCI), Bethesda, Maryland, United States of America
Vlasov, O.	Medical Radiological Research Center (MRRC RAMS), Obninsk, Russian Federation
Webbe-Wood, D.	Food Standards Agency (FSA), London, United Kingdom
Zvonova, I.	Institute of Radiation Hygiene of the Ministry of Public Health, St. Petersburg, Russian Federation

EMRAS Combined Meetings

1–5 September 2003 (78 participants, from 24 countries)
8–11 November 2004 (84 participants, from 24 countries)
21–25 November 2005 (106 participants, from 31 countries)
6–10 November 2006 (101 participants, from 32 countries)
5–9 November 2007 (99 participants, from 30 countries)

Interim Working Group Meetings, Theme 1, Working Group 3

Madrid, Spain: 31 May – 2 June 2004; Warsaw, Poland: 29–31 August 2005;
Prague, Czech Republic: 6–9 June 2006; St. Petersburg, Russian Federation: 3–7 September 2007

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