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Validation of models using Chernobyl fallout data from the Central Bohemia region of the Czech Republic

Scenario CB

First report of the VAMP Multiple Pathways Assessment Working Group

Part of the IAEA/CEC Co-ordinated Research Programme on the Validation of Environmental Model Predictions (VAMP)

INTERNATIONAL ATOMIC ENERGY AGENCY

April 1995

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FOREWORD

Following the Chernobyl accident and on the recommendation of the International Nuclear Safety Advisory Group (INSAG) in its Summary Report on the Post-Accident Review Meeting on the Chernobyl Accident (Safety Series No. 75-INSAG-1, IAEA, Vienna, 1986), the IAEA established a Co-ordinated Research Programme on "The Validation of Models for the Transfer of Radionuclides in Terrestrial, Urban and Aquatic Environments and the Acquisition of Data for that Purpose". The programme seeks to use the information on the environmental behaviour of radionuclides which became available as a result of the measurement programmes instituted in countries of the former Soviet Union and in many European countries after April 1986 for the purpose of testing the reliability of assessment models. Such models find application in assessing the radiological impact of all parts of the nuclear fuel cycle. They are used in the planning and design stage to predict the radiological impact of nuclear facilities and in assessing the possible consequences of accidents involving releases of radioactive material to the environment and in establishing criteria for the implementation of countermeasures. In the operational phase, they are used together with the results of environmental monitoring to demonstrate compliance with regulatory requirements concerned with radiation dose limitation.

The programme, which has the short title "*Va*lidation of Environmental *M*odel *P*redictions (VAMP)", was started in 1988; it is jointly sponsored by the Division of Nuclear Fuel Cycle and Waste Management and the Division of Nuclear Safety and is also supported by the Commission of the European Communities. There are four working groups within the VAMP programme: the Terrestrial Working Group, the Urban Working Group, the Aquatic Working Group, and the Multiple Pathways Assessment Working Group.

The **VAMP Multiple Pathways Assessment Working Group** is an international forum for the testing and comparison of model predictions. The emphasis is on evaluating transfer from the environment to humans via all pathways which are relevant in the environment being considered. This Technical Document is the first report of the Group and contains the results of the first test exercise on the validation of multiple pathways assessment models using Chernobyl fallout data obtained from the Central Bohemia (CB) region of the Czech Republic (**Scenario CB**).

The document is the outcome of a joint effort by the participants of Scenario CB. Their names are listed at the end of the document. A special acknowledgement is due to the Chairman of the Working Group, F.O. Hoffman (USA), for directing the work of the group and drafting the main text of the report, also to I. Bucina, I. Malatova and V. Kliment (all from the Czech Republic), for providing and analysing the test data. The IAEA staff members responsible for the document were H. Koehler (from 1988 to 1991) and S. Hossain (from 1991 to 1994) of the Division of Nuclear Fuel Cycle and Waste Management.

Other reports issued under the VAMP programme are:

Modelling of Resuspension, Seasonality and Losses during Food Processing. First Report of the VAMP Terrestrial Working Group, IAEA-TECDOC-647 (1992).

Assessing the Radiological Impact of Past Nuclear Activities and Events, IAEA-TECDOC-755 (1994).

Modelling the Deposition of Airborne Radionuclides into the Urban Environment. First Report of the VAMP Urban Working Group, IAEA-TECDOC-760 (1994).

CONTENTS

1. INTRODUCTION

1.1. GENERAL BACKGROUND

There is a general need to be able to evaluate the impact of radionuclide releases on humans and on the environment, i.e. to be able to quantify the risks which arise from radionuclides present in the environment due to past human activities and to be capable of predicting the possible future risks associated with planned and unplanned (accidental) releases from nuclear facilities. The risks from these releases arise as a result of the transport of radionuclides from their release point to humans via air and water and through transfer in food chains. Evaluating the impact of releases requires an understanding of the processes and mechanisms by which radionuclides can reach humans. The knowledge gained over the last few decades has enabled the construction of mathematical models which represent the processes of transport from source to man. Figure 1 shows typical environmental compartments and processes which must be included in an assessment model for terrestrial pathways [1].

Although a good understanding has been developed of many of the most important transfer processes, it must be recognized that our knowledge is imperfect and that radioecological models can only approximate the actual transfer processes. There is, therefore, a constant need to improve the reliability of models by testing their predictions in real situations in the environment.

1.2. BACKGROUND AND OVERALL OBJECTIVES OF VAMP

Following the Chernobyl accident and on the recommendation of the International Nuclear Safety Advisory Group (INSAG) in its Summary Report [2], the IAEA established a Co-ordinated Research Programme in 1988 on "The Validation of Models for the Transfer of Radionuclides in Terrestrial, Urban and Aquatic Environments and the Acquisition of Data for that Purpose". The programme, which has been given a short title "*Va*lidation of Environmental *M*odel *P*redictions (VAMP)", seeks to use the information on the environmental behaviour of radionuclides which became available as a result of the measurement programmes instituted in countries of the former Soviet Union and many European countries after April 1986. The information is utilized to test the reliability of assessment models used in assessing the radiological impact of all parts of the nuclear fuel cycle.

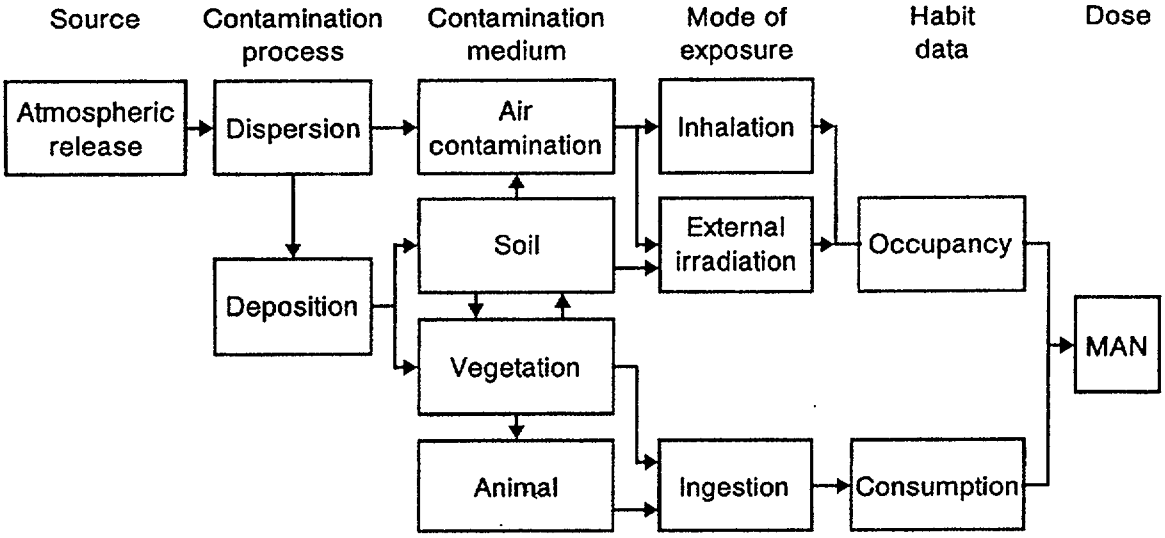

FIG. 1. Schematic representation of compartments and processes in an assessment model.

There are four working groups within the VAMP programme: the Terrestrial Working Group, the Urban Working Group, the Aquatic Working Group, and the Multiple Pathways Assessment Working Group. The overall objectives of the VAMP programme are:

- to provide a mechanism for the validation of assessment models by using the environmental data on radionuclide transfer which have resulted from the Chernobyl release;
- to acquire data from affected countries for that purpose; and
- to produce reports on the current status of environmental modelling and the improvement achieved as a result of post-Chernobyl validation efforts.

1.3. MULTIPLE PATHWAYS ASSESSMENT WORKING GROUP

1.3.1. Objectives

The Multiple Pathways Assessment Working Group was established for testing predictions of radionuclide transfer from surface air or ground deposition to humans. The emphasis of the working group is on evaluating radiation dose via all pathways which may be relevant in a given environmental situation. The specific objectives of the group are:

- to test the predictive capability of models for multiple pathways of exposure;
- to identify the most important reasons for model misprediction; and
- to demonstrate the effect of model improvement on predicted results.

1.3.2. Method of work

Suitable data sets for testing biospheric models exist in several countries. These are used to test a modeller's ability to predict the time variation of radionuclide concentrations in various foodstuffs and in the bodies of human populations, given, as input, the air concentration during the deposition event. These data sets, which include both model input and observed data, represent the essential component (the test scenario) of the model testing exercise.

Input data included within a test scenario comprise:

- measurements of environmental radionuclide concentrations in air and soil samples in the region;
- environmental information such as meteorological characteristics, soil and water source characteristics, agricultural practices, topographic and orographic features;
- population information such as residency habits, and age- and sex-specific characteristics for food consumption; and
- information about food production, consumption, and distribution in the region.

Observed data are prepared by the originators of the scenario from measurements taken at different intermediate steps and end points of the scenario. These include time variation of radionuclide concentrations in forage, vegetation and food, and time variation of whole body concentrations. To account for the variability and uncertainty of the observation data, both arithmetic mean values and 95% confidence intervals about these means are carefully prepared using statistical techniques and expert judgment, as necessary.

The exercises in this working group are carried out as so called "blind tests", i.e. the modellers receive a scenario description (input data) and are provided with the observed data only after their predictions, including uncertainty estimates, have been submitted to the Secretariat. For subsequent analysis of results, modellers are requested to submit their individual evaluation of model predictions based on comparison of predictions vs. observations, subsequent improvement of their models, and revised predictions. Because both the model predictions and observed data are associated with

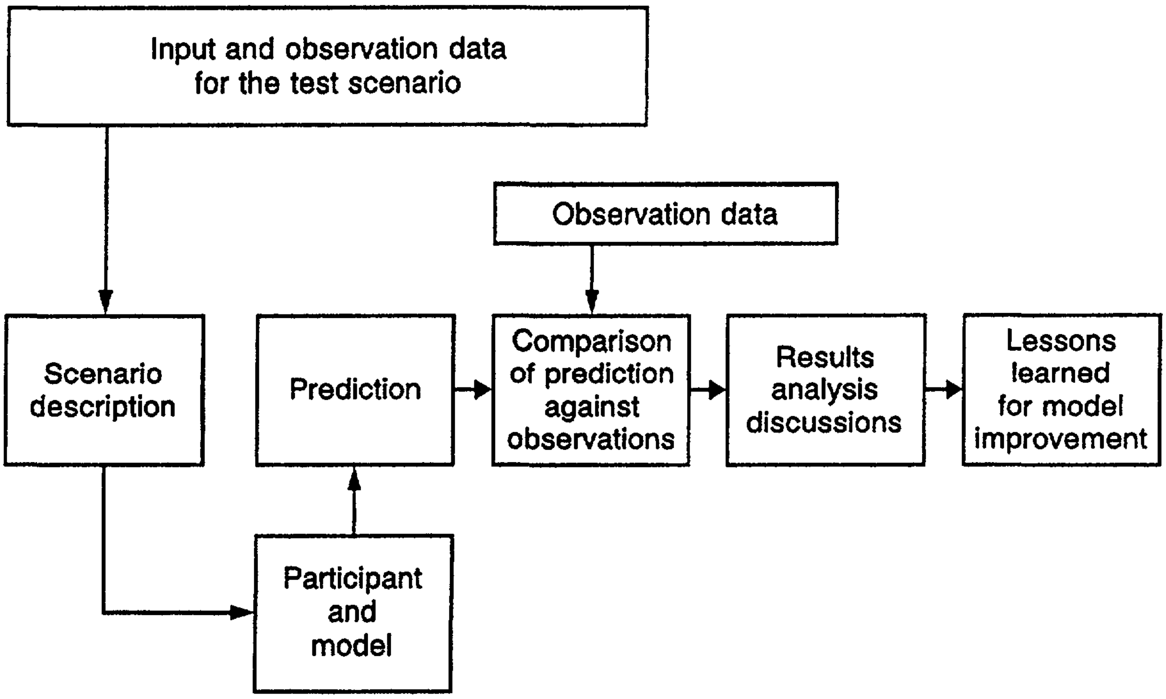

FIG. 2. Method of work: VAMP Multiple Pathways Assessment Working Group.

uncertainties, for proper analysis of results, comparisons are made with respect to arithmetic mean values as well as confidence intervals about these means for both model predictions and observed values. Figure 2 describes schematically the method of work within this working group.

1.4. SCENARIO CB EXERCISE

Scenario CB is the first test exercise of the Multiple Pathways Assessment Working Group. Data sets were collected in the Central Bohemia (CB) region of the Czech Republic for the ^{137}Cs contamination of various environmental media following the Chernobyl accident in 1986. The main purpose of the exercise and a description of the scenario are given below.

1.4.1. Purpose

The main purpose of the exercise was to predict doses to members of the given population from external and internal radiation exposure. The input data for the calculations were ^{137}Cs concentrations in the air and on the ground. To enable a thorough comparison between model predictions and observations and a detailed analysis thereof, working group participants were requested to calculate the following quantities:

- average total deposition in the whole area;
- contamination of fodder;
- contamination of food;
- intake by humans;
- content of ^{137}Cs in the whole body for humans; and
- dose estimates for ingestion, inhalation, and external exposure pathways.

While the dose calculations (for different time periods up to lifetime) were requested within the context of radiation protection purposes only (they could not be validated, only compared), the actual validation exercise was performed against the observations of ^{137}Cs body content and the contamination of food and fodder for a three-year period following the accident.

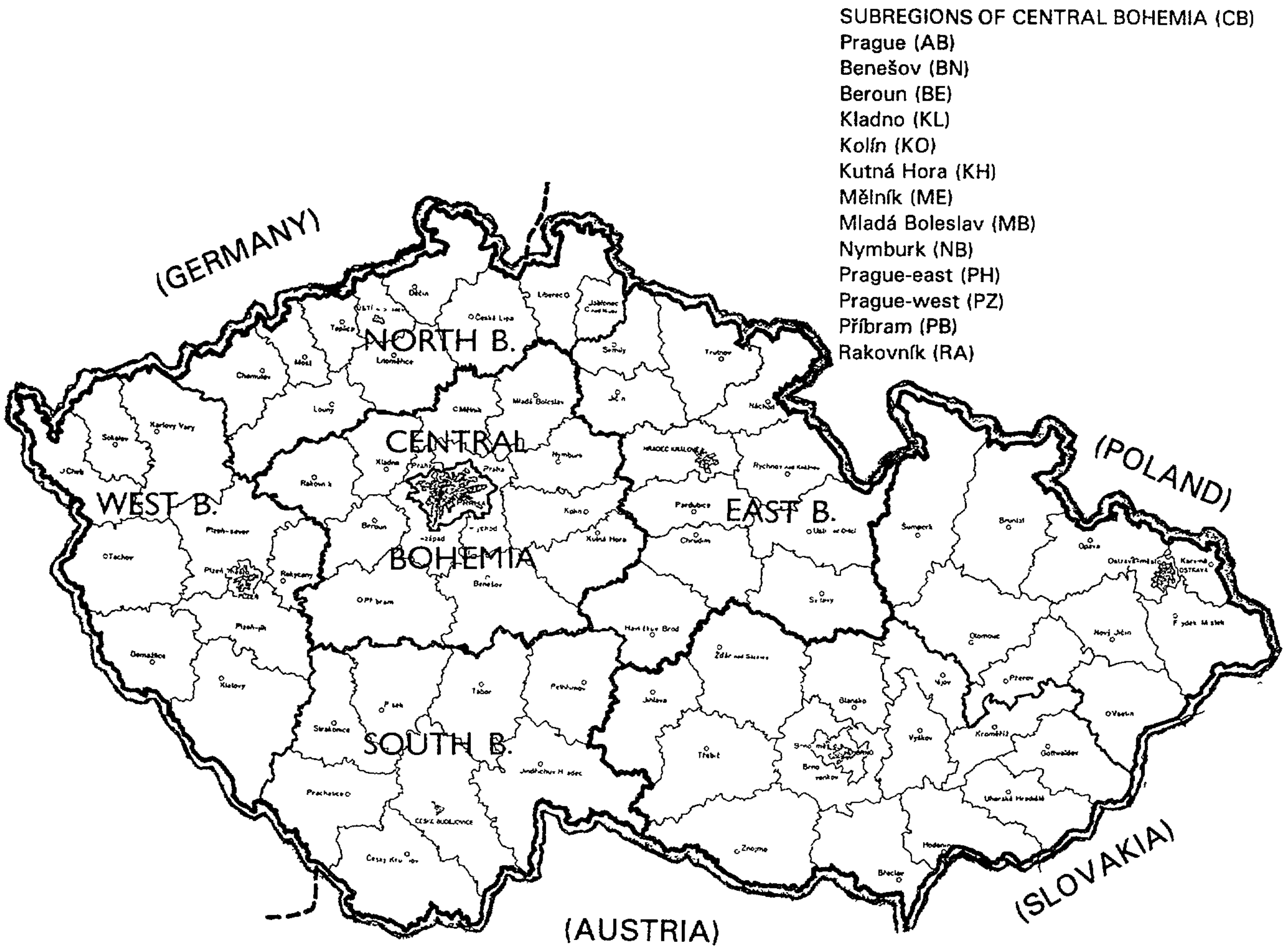

FIG. 3. Region of Central Bohemia (CB) around Prague in Czech Republic.

1.4.2. Scenario description

For this test exercise, the location of the CB region (see Figure 3) was not disclosed until after the submission of predictions. The data sets of input and observation data were provided by the Centre of Radiation Hygiene (CRH) of the National Institute of Public Health (former Institute of Hygiene and Epidemiology) in Prague. The main features of the scenario are given below; a full description of the scenario is given in Appendix I.

For model predictions, participants were provided with input data and assessment tasks for model testing. The input data contained the following main items:

- *General information* containing topographic features and climatic data;
- *Radionuclide concentration in ground-level air* collated from measurements of aerosol samples at two sites in Prague, along with wind data from a site located approx. 10 km away and rainfall data for 14 sites in CB;
- *Soil contamination data* collected mid-June 1986 at 152 sites for 13 subregions of CB, with soil characteristics (i.e. granularity, permeability, humus content and humus quality), and a map of areas of 34 different soil types relevant for plant production, including ranges of pH values for these areas;
- *Agricultural information* containing land use for agricultural production and actual production rates of different kinds of plants, including details of seeding and harvesting, animal production rates for 13 subregions of CB, and feeding practices in the region CB; and

- *Demographic information* on area and population by subregions, age distribution, and details of annual consumption of food products by age categories.

The above information was provided in the form of maps and tables; most of the tables were also available on diskette from the IAEA Secretariat.

For model validation (assessment task), predictions for the following time-dependent quantities of ^{137}Cs were requested:

- total (wet and dry) deposition;
- concentration in leafy vegetables;
- concentration in winter wheat;
- concentration in spring barley;
- concentration in apples/pears;
- concentration in milk;
- concentration in beef;
- concentration in pork;
- concentration in pasture vegetation;
- concentration in alfalfa;
- concentration in silage;
- human intake;
- concentration in whole body;
- distribution of whole body concentrations;
- external dose (cloud and ground);
- committed dose due inhalation in the cloud and resuspended material;
- committed dose due to ingestion; and
- total dose.

For most of the quantities listed, predictions were requested for the average values for each quarter-year period from the spring of 1986 to the spring of 1990. Total deposition, external dose, inhalation and ingestion doses, and total dose were either single, non-time-dependent predictions or time-averaged predictions. Distributions of whole body calculations were requested for two time points, the 2nd quarter of 1987 and the 1st quarter of 1989. For the prediction of quantities requested above, estimates of both the arithmetic mean and a 95% confidence interval thereof were solicited for the time periods specified for the entire region CB.

For comparison of predictions vs. observations, information on ^{137}Cs contamination of the CB environment (observed data) concerning the above mentioned assessment tasks was collected, measured, and evaluated by the CRH. Because different data sets were collected for different purposes, the quality of data varied. The data on soil contamination were provided systematically. Data on feed and food contamination were not collected specifically for model validation purposes. However, data on human whole body content and the supporting data on excretion used for whole body concentrations and their distribution were acquired among others for the purpose of dose estimation for model validation. The aim of the collection of intake data was to study differences between model prediction and whole body counting. For the estimation of arithmetic means and upper and lower bounds of the 95% confidence intervals of the requested quantities, standard statistical techniques assuming log-normal distribution of measured values were applied, including the maximum likelihood method if censored (i.e. less than detection limit) observations were present. In cases where uncensored data were scarce, large geometric standard deviations and consequently large values of confidence intervals were obtained. Estimates of arithmetic means and confidence intervals by expert judgment based on enforced realistic values of geometric standard deviation as given in Table I.61 of Appendix I were provided. This is discussed in detail in Appendix I. Tables I.24 to I.60 of Appendix I give all the resulting observed data and their confidence limits.

1.5. STRUCTURE OF THE REPORT

In Section 1, the introduction to VAMP and its Multiple Pathways Assessment Working Group, and the purpose and description of the first test exercise (Scenario CB) are given. Section 2 summarizes the participation in the exercise and provides a description of the characteristics of the models used. A summary and discussion of the results of the test exercise based on a limited number of important endpoints is given in Section 3. Explanations for the main mispredictions described in Section 3 are provided in Section 4. Section 5 concludes the report with general comments on model validation exercises.

The main text of this report is supplemented by four appendices. Appendix I contains a detailed description of Scenario CB, including both input and observed data. A description of the models used in the CB exercise is provided in Appendix II. Appendix III contains the individual evaluations of model predictions by the participants in the exercise. Detailed documentation of both the initial and revised model predictions is given in Appendix IV.

2. PARTICIPANTS AND MODELS

2.1. PARTICIPANTS

Fourteen contributions were received from thirteen participants (one participant submitted results from two models). Table 1 identifies all participants, the codes they used, and the countries of their origin; a summary of the results submitted is also provided. The table also indicates whether a participant submitted confidence intervals for his results, revised predictions, or an individual evaluation of his model predictions. It should be noted that in many cases, the modelling work was done on a volunteer basis, and the quality of predictions may have reflected the lack of structured time available to do the work.

2.2. MODELS

As mentioned above, a principal objective of the Multiple Pathways Assessment Working Group is to test the predictive capability of models for multiple pathways of exposure. Most of the models tested in the Scenario CB exercise have been developed over several years, and many have already been tested in previous international exercises, e.g., BIOMOVS I Scenario A4 [3]. However, in order to make calculations for Scenario CB, a number of computer codes had to be modified; in particular, codes which had been designed for their own local conditions had to be altered to allow the input to be accepted as specified in the scenario description.

The models tested in this exercise are all compartment-type models, but they vary in complexity from ones that use simple algebraic equations to some which use sophisticated numerical approaches. To predict the requested time course of concentrations in various environmental media, most of the models are time-dependent (dynamic) except GENII, HEDR, and HUMOD, all of which provide only time-integrated averages. Although the participating models were developed for various purposes, most of the model predictions are intended to be best estimates. In response to the request for uncertainty estimates, seven out of fourteen participants provided, along with the means, the 95% confidence intervals about the means of the predicted quantities. However, most of the modellers used their subjective judgment to estimate these values. The exceptions were Kanyar/TERNIRBU, Napier/HEDR, and Peterson/CHERPAC (revised estimates only), all of whom used Monte Carlo calculations to propagate uncertainties in parameter values through their models. Table 2 summarizes the important characteristics of the models tested. The models are identified by both model name and user name, in part to emphasize the effect of the user on the outcome of the model.

TABLE 1. SUMMARY OF PARTICIPATION IN SCENARIO CB EXERCISE

Participant/MODEL	Country	Initial prediction	Revised prediction	Individual evaluation of model prediction
Sohier/DOSDIM	Belgium	mean	mean	yes
Peterson/CHERPAC	Canada	mean	mean, conf. interval	yes
Hu/HUMOD	China	mean	mean	yes
Horyna/SCHRAADLO-T	Czech Republic	mean, conf. interval	mean, conf. interval	yes
Kliment/ENCONAN	Czech Republic	mean	none	yes
Müller/ECOSYS	Germany	mean, conf. interval	mean	yes
Kanyar/TERNIRBU	Hungary	mean, conf. interval	mean, conf. interval	yes
Krajewski/CLRP	Poland	mean, conf. interval	mean	yes
Galeriu/LINDOZ	Romania	mean, conf. interval	mean, conf. interval	yes
Carrasco/PRYMA	Spain	mean, conf. interval	mean	yes
Hinton/ECOSYS	Switzerland	mean	mean	yes
Tarrant/SPADE2	UK	mean	none	no
Napier/GENII	USA	mean	none	yes
Napier/HEDR	USA	mean, conf. interval	none	yes

TABLE 2. CHARACTERISTICS OF MODELS TESTED IN SCENARIO CB EXERCISE

Participant/MODEL	Calculational method[a]	Dynamic or quasi-steady state[b]	Best estimate or conservative estimate	Method used for uncertainty propagation
Sohier/DOSDIM	1	dynamic	best estimate	none/subjective[c]
Peterson/CHERPAC	1	dynamic	best estimate	Monte Carlo
Hu/HUMOD	2	quasi-steady state	conservative estimate	none
Horyna/SCHRAADLO-T	1 and 2	dynamic	best estimate	subjective[c]
Kliment/ENCONAN	1 and 2	dynamic	best estimate	none
Müller/ECOSYS	2	dynamic	best estimate	subjective[c]
Kanyar/TERNIRBU	1	dynamic	best estimate	Monte Carlo
Krajewski/CLRP	2	dynamic	best estimate	subjective[c]
Galeriu/LINDOZ	1	dynamic	best estimate	Monte Carlo/parameter perturbation/subjective[c]
Carrasco/PRYMA	1	dynamic	best estimate	subjective[c]
Hinton/ECOSYS	2	dynamic	best estimate	none
Tarrant/SPADE2	1	dynamic	best estimate	none
Napier/GENII	2	quasi-steady state	conservative estimate	Monte Carlo
Napier/HEDR	2	quasi-steady state	best estimate	Monte Carlo

[a] Calculational methods: (1) first-order differential equations requiring numerical solutions; (2) closed-form algebraic solutions.

[b] "Quasi-steady state" refers to a model which is steady-state among compartments, but which may still change with respect to time.

[c] No propagation of error was used. Uncertainty was assigned to the calculated results using individual judgment.

3. SUMMARY AND DISCUSSION OF RESULTS

The comparison of initial predictions and observations from the CB Scenario is summarized in this section by means of a series of composite graphs. These graphs represent the results for the primary starting points, midpoints, and endpoints of this study: the average deposition of ^{137}Cs on the ground surface; the average concentrations of ^{137}Cs in milk, beef, pork, and the human body; and the estimates of the internal and external effective dose equivalents. Composite graphs are presented for all 14 models at three selected time periods, and for the entire time sequence of observations for six models that submitted uncertainty estimates prior to the disclosure of the observed data. Results are also shown for three models that attempted a simulation of the variability of ^{137}Cs whole body concentrations among individuals.

In Section 3.2, some examples of model improvements are provided which resulted from individual evaluations of model predictions based on observed data.

Detailed information about the measured data, descriptions of participating models, model predictions and individual evaluations of model predictions are given in Appendices I-IV.

3.1. COMPARISON OF OBSERVED DATA TO INITIAL ("BLIND") PREDICTIONS

3.1.1. Total deposition

The arithmetic mean of the total deposition to bare soil was obtained from 152 bare soil measurements and derived from the assumption that the individual measurements are just a sample of an underlying lognormal distribution. The mean value for these soil measurements was estimated at 5570 Bq m^2 with a 95% confidence interval about the mean of 4050 to 7660 Bq m^{-2}.

Most model predictions of total deposition fell within the uncertainty bands for this estimated mean deposition of ^{137}Cs in soil (Figure 4). However, this is not surprising since extensive data on soil contamination approximating the total deposition were part of the input data. The one obvious

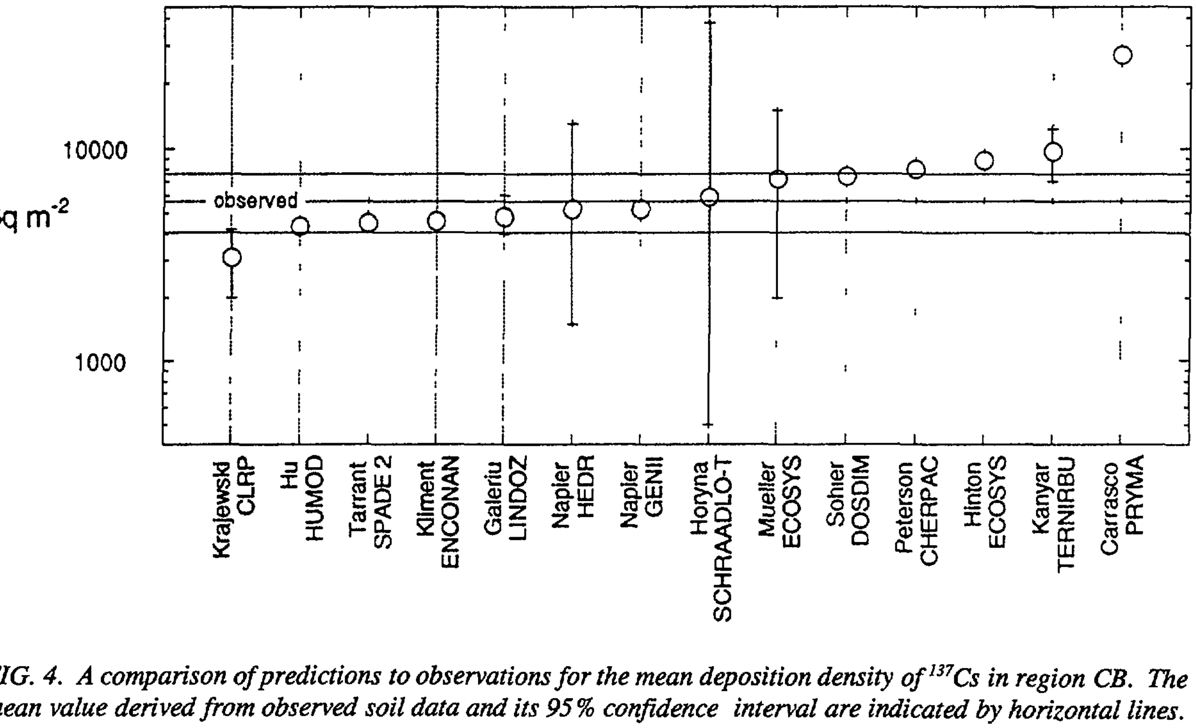

FIG. 4. A comparison of predictions to observations for the mean deposition density of ^{137}Cs in region CB. The mean value derived from observed soil data and its 95% confidence interval are indicated by horizontal lines. The predicted means are open circles with vertical bars indicating the 95% subjective confidence interval about the mean.

overestimation was mainly the consequence of an approach that relied entirely on the measured concentration in air and the average rainfall to estimate the amount of total deposition. The large differences in uncertainty estimates for model predictions reflect differences in investigator judgment about the representativeness of the measured data. The absence of uncertainty estimates indicates either lack of knowledge about the limits of confidence about the model predictions, lack of time for performing the uncertainty analysis, or lack of appropriate tools for propagating parameter uncertainty to obtain a measure of confidence in the model result.

Because measurements represent concentrations of ^{137}Cs in bare soil, excluding vegetation, the estimate of total deposition of ^{137}Cs (as requested by the modellers) is biased on the low side. This bias is alleviated somewhat by the fact that the total deposition of ^{137}Cs in the region CB was dominated by wet deposition, and bias resulting from using bare soil to estimate total deposition is most pronounced under conditions of dry deposition. In addition, in situ gamma spectrometric measurements at a few locations have confirmed that the amount of total deposition of ^{137}Cs indicated by the bare soil measurements is close to the average total deposition in the whole area.

3.1.2. Concentrations in milk

Mean values of measured concentrations of ^{137}Cs in milk from CB varied from 22.5 Bq L^{-1} in May of 1986 to about 0.22 Bq L^{-1} in early 1989. For 1986 and 1987, the mean milk concentrations are consistently overestimated by almost half of the 14 models participating in this study (Figure 5). A substantial underestimation is produced for the early part of 1987 by the quasi-steady state model, GENII. This model, which was constructed primarily for the evaluation of routine discharges, assumes that the concentration in milk is in continuous equilibrium with the concentration of ^{137}Cs in the diet. Thus, when cows are taken off of contaminated stored feed and put onto fresh pasture, the model calculates milk concentrations that are proportional to the lower concentrations in fresh forage, ignoring the ^{137}Cs that has accumulated in the muscle of the cow which functions as a secondary source of milk contamination. Other factors leading to misprediction were the assumption that the amount of surface soil ingested daily by a dairy cow would be 2 kg (Carrasco/PRYMA) and the assumption that pasture land would be subjected to deep plowing which in turn would reduce the amount of ^{137}Cs available to the animal's diet (Kanyar/TERNIRBU).

Two models, Galeriu/LINDOZ and Horyna/SCHRAADLO-T, consistently reproduce the average value estimated at specific time periods from measurements (Figure 6). The most critical factors influencing model predictions were assumptions made about the feeding regime of dairy cattle, the amount of stored feed obtained from materials harvested during the late spring and summer of 1986, and coefficients used for the diet-to-milk transfer of ^{137}Cs.

3.1.3. Concentrations in beef

Within the region CB, mean concentrations of ^{137}Cs in beef range from 96 Bq kg^{-1} during June of 1986 to a low of near 1 Bq kg^{-1} at the end of the first quarter of 1989. The results for beef (Figures 7 and 8) exhibit the largest discrepancy among model predictions for any of the test endpoints presented in this summary section. For specific time periods during 1986 and 1987, the ratio between the maximum and minimum predicted values is about three orders of magnitude. This discrepancy is influenced by assumptions about the actual diet of the animals, including the type of stored fodder actually consumed by beef cattle, the portion of the fodder that is contaminated, and assumptions about the retention of ^{137}Cs in the animal after the diet is changed to feed having a lower level of contamination. As with the predictions for milk, assumptions about the amount of surface soil consumed by beef cattle (Carrasco/PRYMA) and the effect of possible deep plowing of pastures (Kanyar/TERNIRBU) also affected the accuracy of model predictions for 1988 and 1989.

Most predictions, however, are within one order of magnitude of the average observed value for most time periods. The large differences among uncertainty estimates again reflect differences in judgment about the degree of confidence to be placed in the model prediction of ^{137}Cs in beef. The

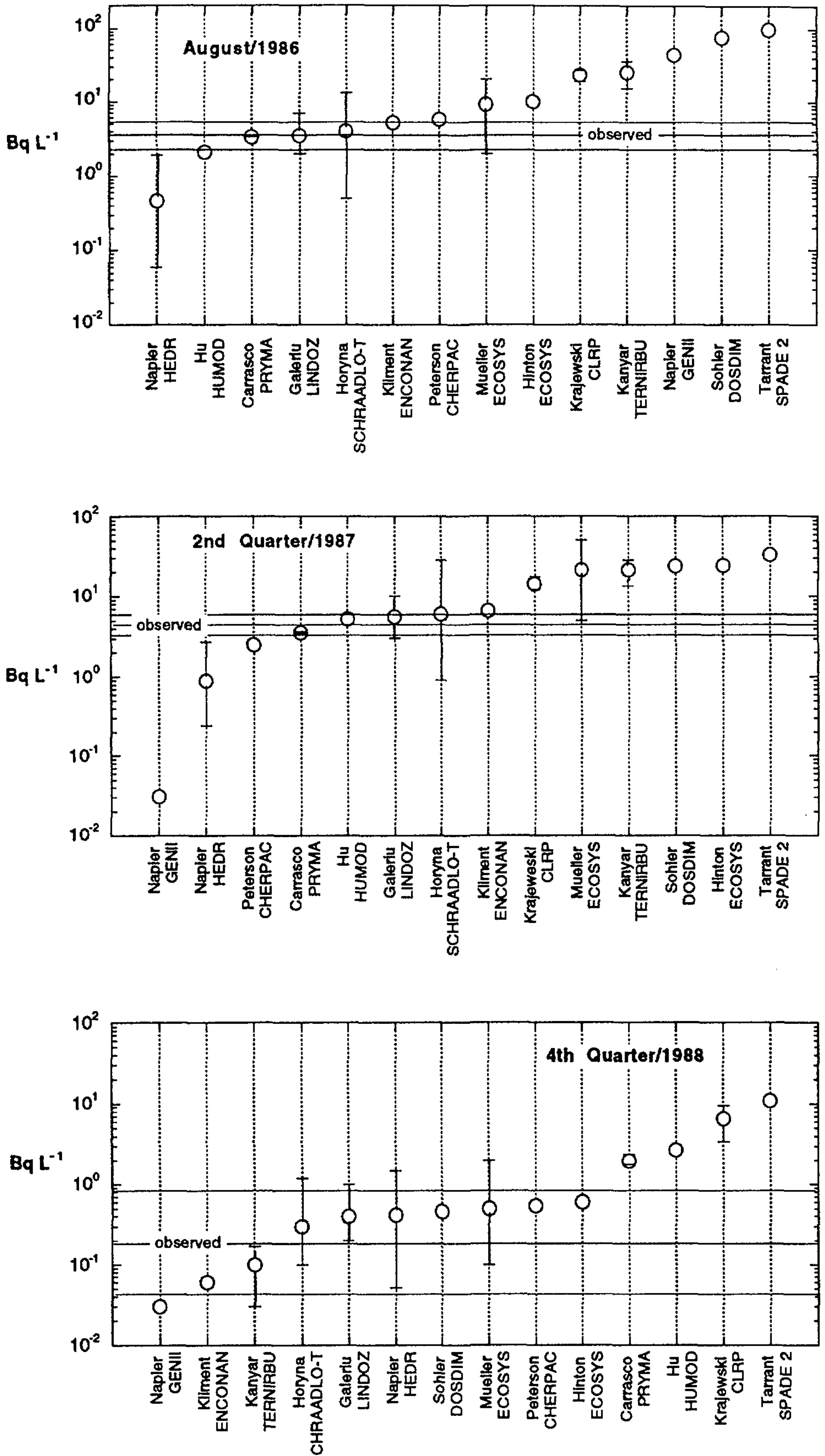

FIG. 5. A comparison of model predictions against observations for the average concentration of ^{137}Cs in milk in region CB at three different time periods. The mean value derived from observed data and its 95% confidence interval are indicated by horizontal lines. The predicted means are open circles with vertical bars indicating the 95% subjective confidence interval about the mean.

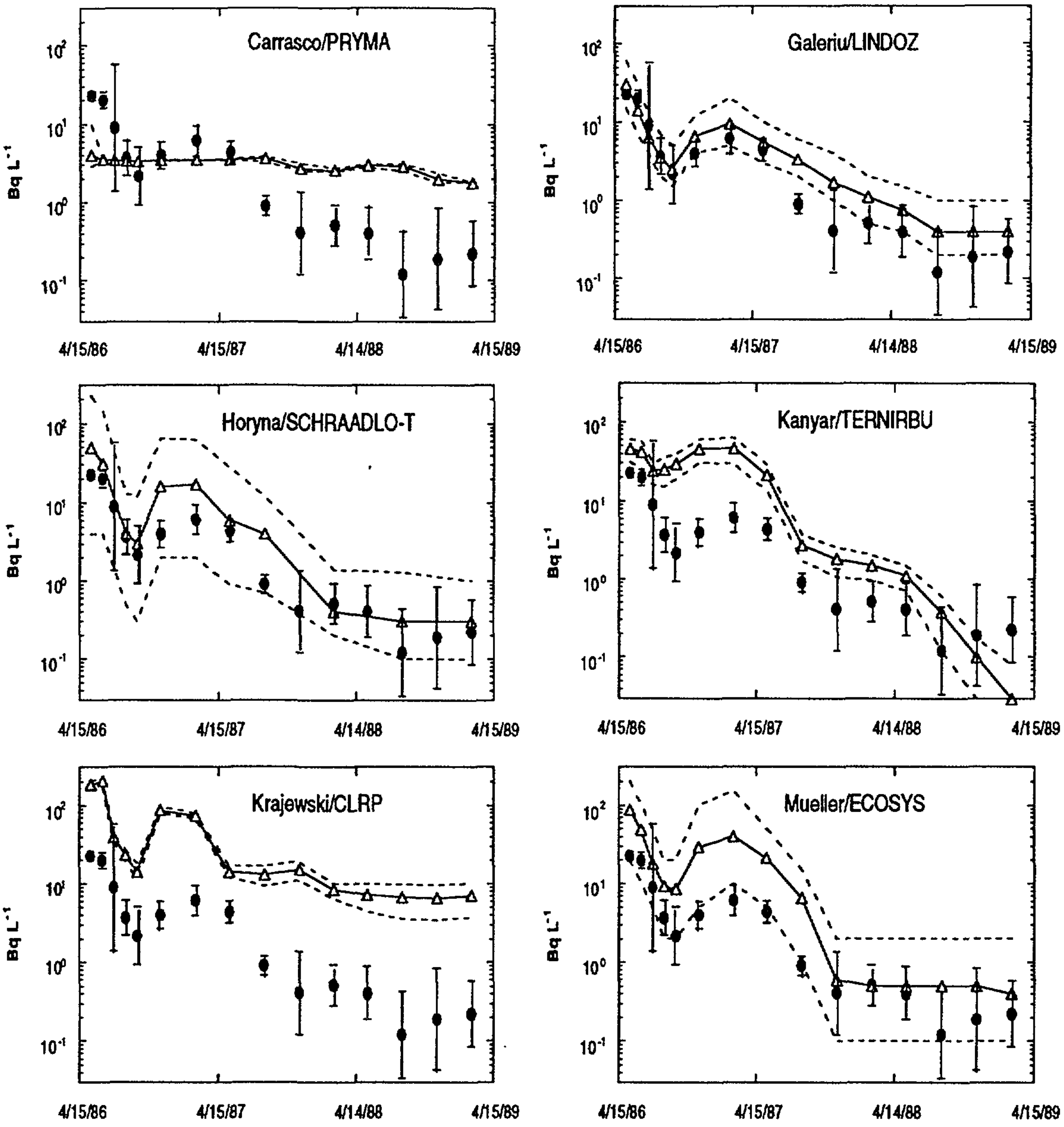

FIG. 6. Average concentrations of ^{137}Cs in milk: A comparison of selected model predictions with observations for region CB. Vertical bars indicate 95% confidence intervals on the mean value of observations (dark circles); dashed lines indicate the 95% subjective confidence interval about the mean prediction (solid line with triangles).

most accurate predictions were observed for Kliment/ENCONAN, Horyna/SCHRAADLO-T, Galeriu/LINDOZ, and Peterson/CHERPAC. The latter three participants had prior model validation experience with Chernobyl fallout data for ^{137}Cs [3]. The results for Kliment/ENCONAN cannot be considered a blind test, because Kliment assisted with the organization of the test data for the CB region and therefore had previous knowledge of the results for the endpoints of the scenario.

3.1.4. Concentrations in pork

Unlike the observed concentrations for beef, the mean concentrations observed for pork are relatively constant at about 10 to 20 Bq kg^{-1} for most of 1986 and 1987. A substantial and rapid decrease is observed during the winter of 1987-88, with the remaining concentrations occurring at about 1 Bq kg^{-1}. The limited extent of pork data obtained during the second quarter of 1988 accounts for the very large range of uncertainty about the estimated mean value, reducing the reliability of the data at this time period for model testing.

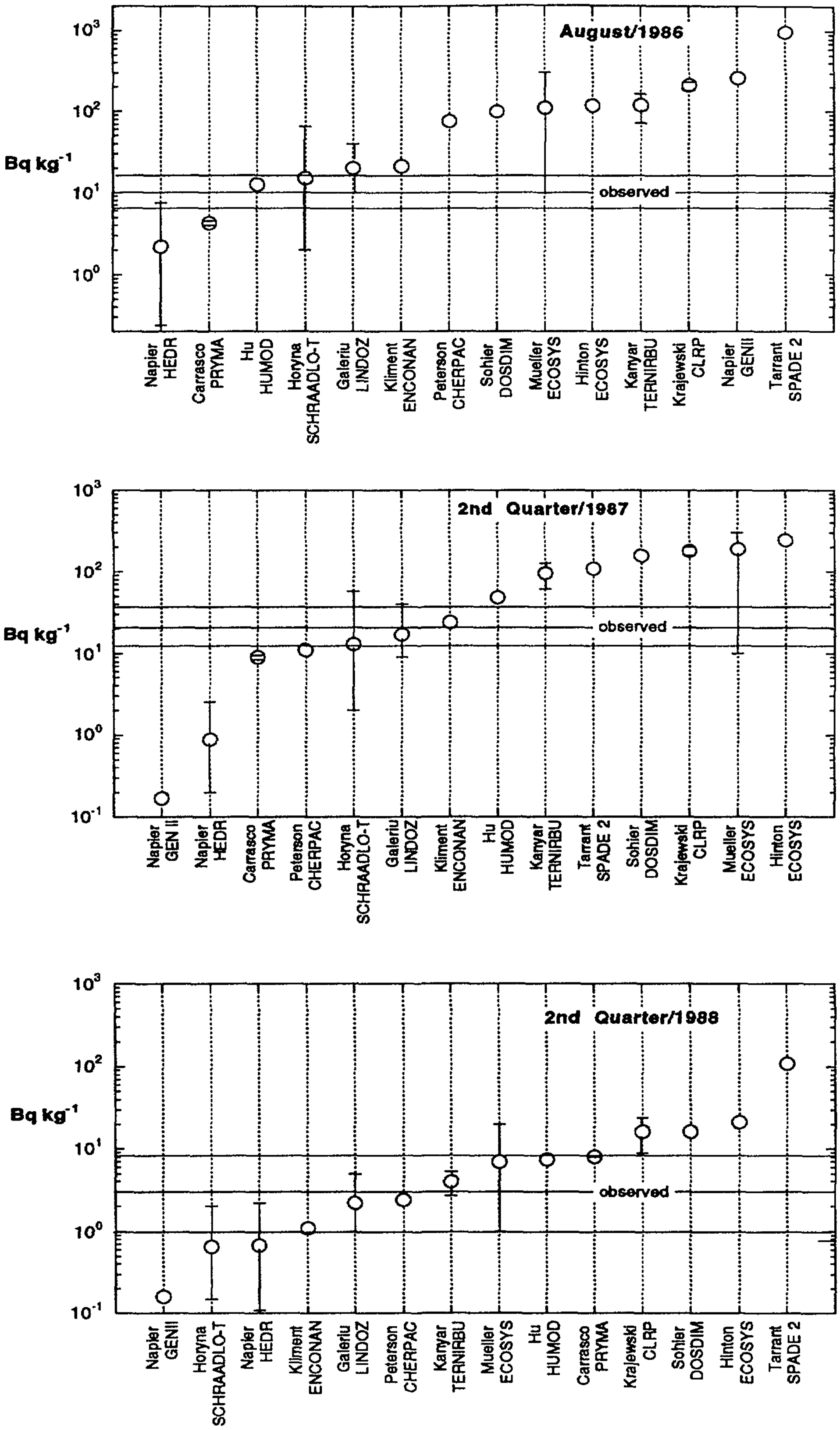

FIG. 7. A comparison of model predictions against observations for the average concentration of ^{137}Cs in beef in region CB at three different time periods. The mean value derived from observed data and its 95% confidence interval are indicated by horizontal lines. The predicted means are open circles with vertical bars indicating the 95% subjective confidence interval about the mean.

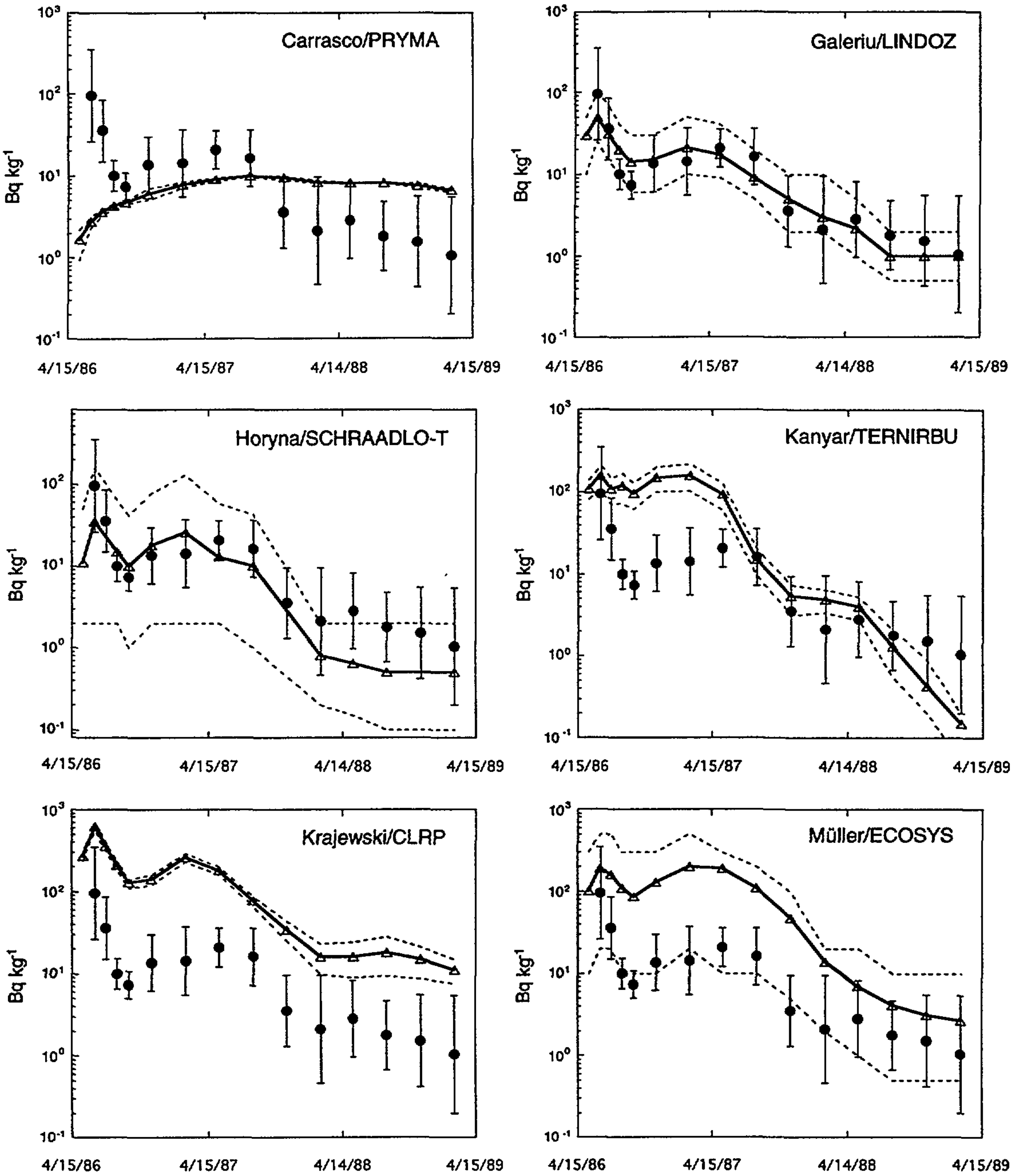

FIG. 8. Average concentrations of ^{137}Cs in beef: A comparison of selected model predictions with observations for region CB. Vertical bars indicate 95% confidence intervals on the mean value of observations (dark circles); dashed lines indicate the 95% subjective confidence interval about the mean prediction (solid line).

Only eleven sets of model predictions were submitted for the concentrations of ^{137}Cs in pork. Of these models, four consistently predicted the observed values to within a factor of two. Two of these sets of predictions were submitted by participants from the Czech Republic who had previous knowledge of the data for pork in the region CB.

For 1986, the predictions were generally within one order of magnitude of each other. This initial agreement among model predictions decreased with time (Figures 9 and 10). For 1989, this discrepancy had increased to about two orders of magnitude, but most models were always well within a factor of ten of the observed values.

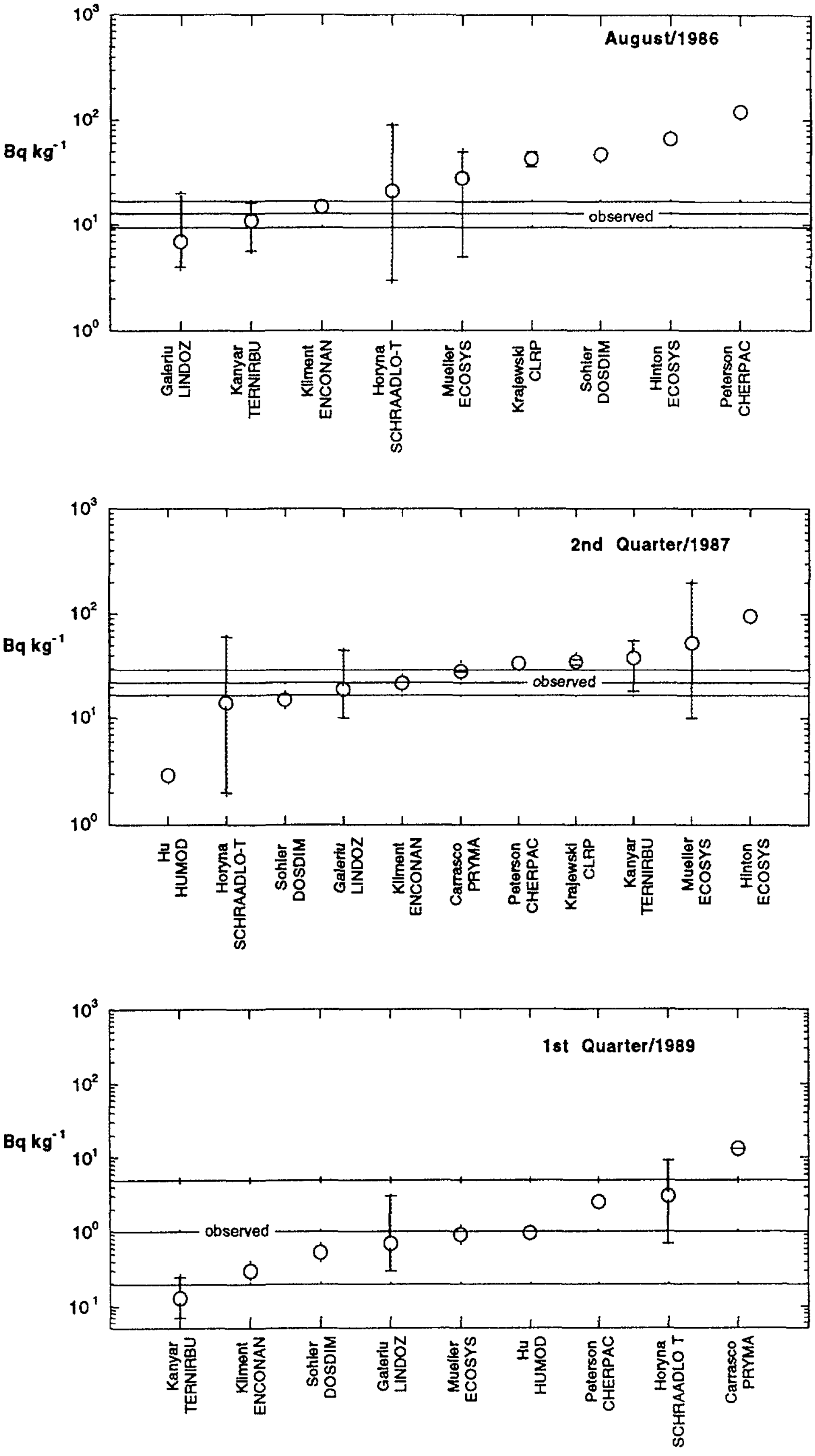

FIG 9 A comparison of model predictions against observations for the average concentration of ^{137}Cs in pork in region CB at three different time periods. The mean value derived from observed data and its 95% confidence interval are indicated by horizontal lines The predicted means are open circles with vertical bars indicating the 95% subjective confidence interval about the mean

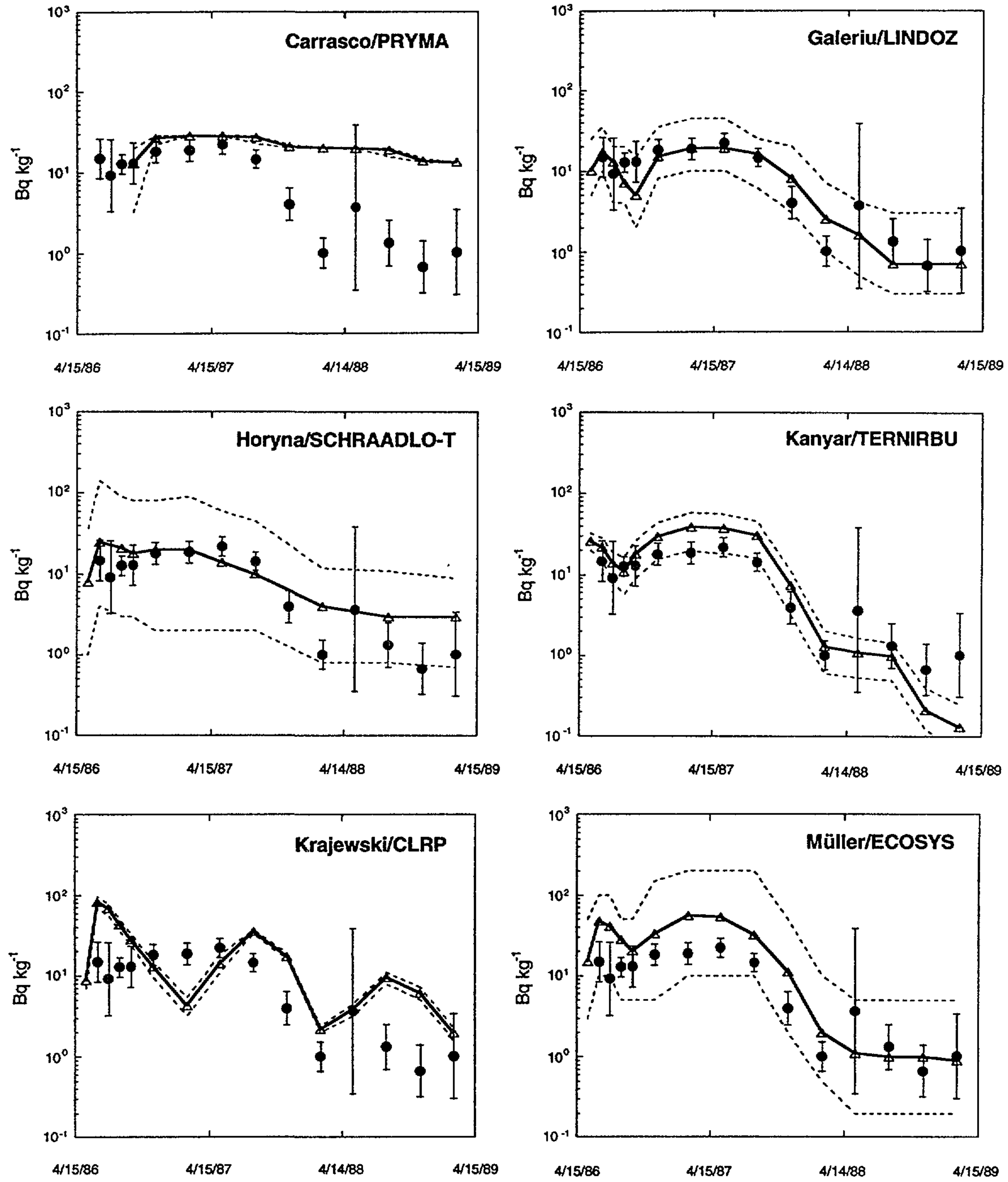

FIG. 10. Average concentrations of ^{137}Cs in pork: A comparison of selected model predictions with observations for region CB. Vertical bars indicate 95% confidence intervals on the mean value of observations (dark circles); dashed lines indicate the 95% subjective confidence interval about the mean prediction (solid line with triangles).

No consistency was seen in the trends among model results, due to dramatic differences in the predicted dynamics of pork concentrations. Differences among model predictions were due to respective capabilities for modelling the concentration of ^{137}Cs in milk whey, a major dietary constituent for pigs in this region, and the uptake and retention of ^{137}Cs in pig muscle.

3.1.5. Average concentrations in humans

The mean values of measured concentrations of ^{137}Cs in humans varied from about 3 Bq kg^{-1} for early May of 1986, reaching 11 Bq kg^{-1} for 1987, and returning to about 3 Bq kg^{-1} for early 1989.

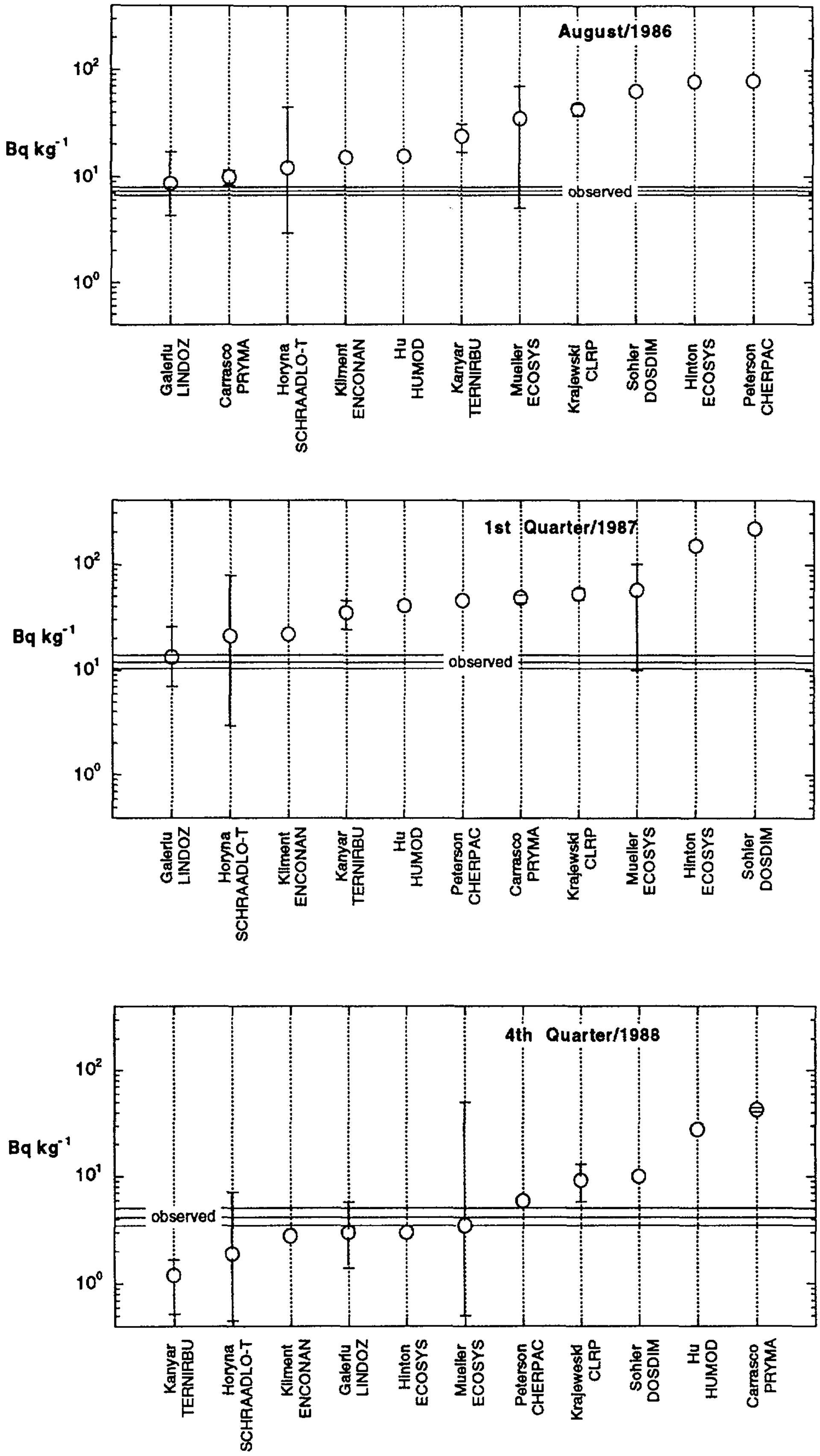

FIG. 11. A comparison of predictions against observations for the average concentration of ^{137}Cs in humans in region CB at three different time periods. The mean value derived from observed data and its 95% confidence interval are indicated by horizontal lines. The predicted means are open circles with vertical bars indicating the 95% subjective confidence interval about the mean.

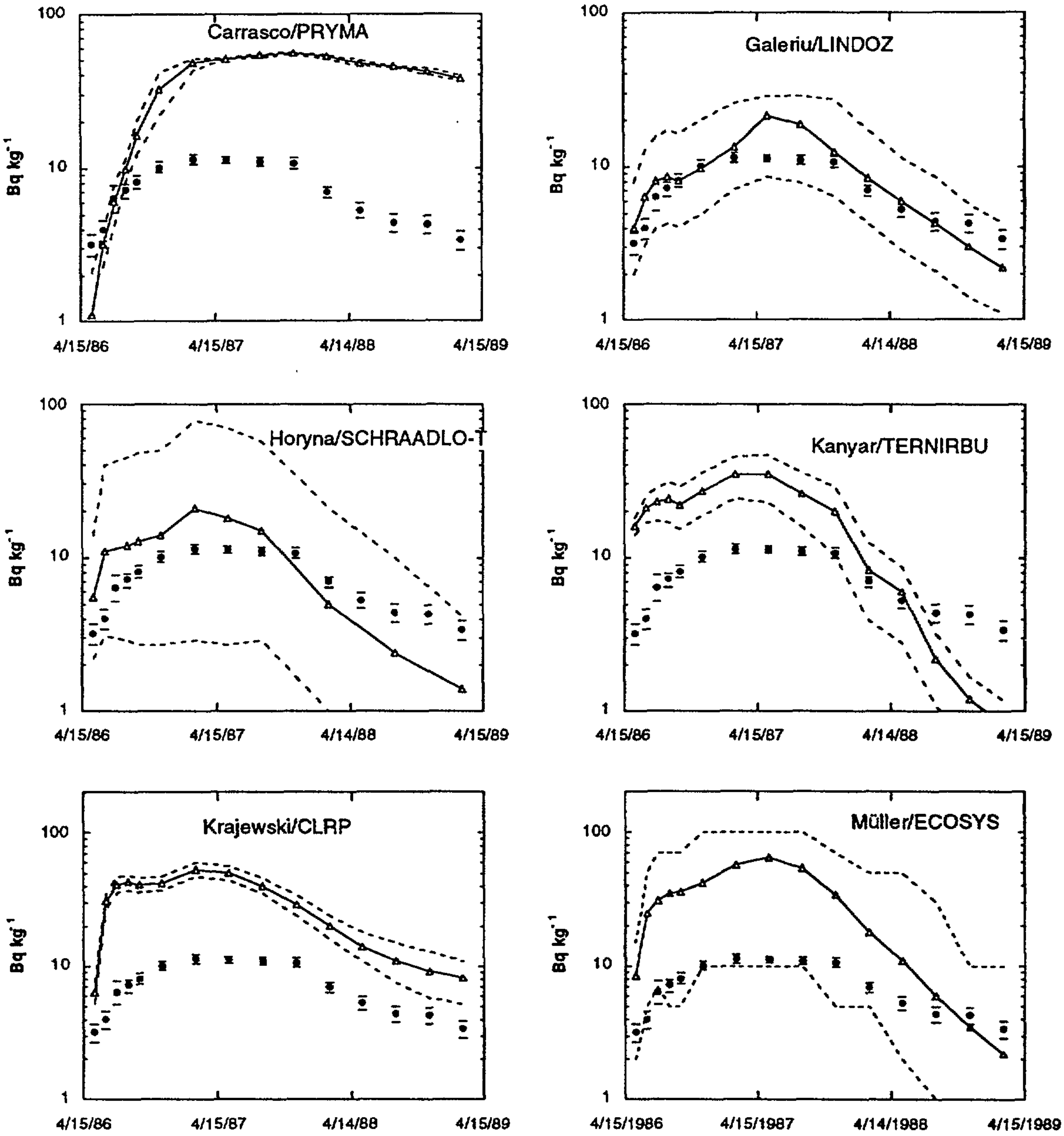

FIG. 12. Average concentrations of ^{137}Cs in humans: A comparison of selected model predictions with observations for region CB. Dark circles indicate the mean and horizontal bars the 95% confidence intervals of the mean of observations; dashed lines indicate the 95% subjective confidence interval about the mean prediction (solid line with triangles).

The confidence limits on these mean values are small because of the large number of measured individuals contained in the data base and the supplemental studies in Appendix I that indicate that these individuals are representative of the entire region of CB.

For 1986 and 1987, almost all model predictions are overestimates (Figures 11 and 12). These results are due primarily to overestimates of the amount of locally consumed fresh food products and the concentrations of ^{137}Cs in these foods, and not to errors associated with the internal metabolism of ^{137}Cs in humans. Primary sources of overestimation of ^{137}Cs in the human diet were overestimation of milk and meat concentrations due to inaccurate assumptions about feeding regimes, the overestimation of ^{137}Cs in fruit, limited bioavailability of Chernobyl cesium from surface-contaminated feed and food, as well as the failure to account for losses due to food preparation and processing.

The most accurate results were obtained by those modellers having firsthand experience with the situation in the region CB (Horyna/SCHRAADLO-T and Kliment/ENCONAN) and those whose local conditions at the time of Chernobyl fallout deposition were not unlike those in CB. Galeriu/LINDOZ, for example, assumed that the population of CB would have exhibited dietary patterns similar to the population surrounding Bucharest, Romania. Galeriu, like several other participants, also adjusted the assumed dietary intake for residents of CB after his analysis of the reported diet indicated an intake that was too high in calories.

Most participants tended to predict a faster decline of ^{137}Cs concentrations in the human body than was observed between 1988 and 1989. Plausible explanations for this slower rate of decline are the long-term storage of feed and food products harvested in 1986 and, to a certain extent, the consumption of food products obtained from the forest ecosystem. The changes in chemical form of Cs in soil resulting in progressive increasing of its leachability is a probable reason, too.

3.1.6. The variability of concentrations in humans

The most challenging test question faced by the participants was the request to simulate the variability of whole body ^{137}Cs concentrations among individuals in CB for the 2nd quarter of 1987 and the first quarter of 1989. The answer to this question requires the use of a probabilistic model. Only three modelling groups attempted to address this question prior to the disclosure of test results, and only two of these provided estimates of uncertainty about their predictions (Figure 13).

The variability of individual whole body ^{137}Cs concentrations is approximated by a lognormal distribution with a geometric mean of 10.6 Bq kg^{-1} and a geometric standard deviation (GSD) of 1.44 for the 2nd Quarter of 1987, and by a geometric mean of 2.7 Bq kg^{-1} and a GSD of 1.9 for the 1st Quarter of 1989. These distributions were reasonably well simulated by Horyna/SCHRAADLO-T and Galeriu/LINDOZ, but the latter substantially overestimated the GSD of the distribution of individual whole body concentrations for the 2nd Quarter of 1987, causing underestimates at the low end and overestimates at the high end of the observed individual whole body concentrations. Galeriu's estimates for the 1st Quarter of 1989 are nearly perfect, with all observed concentrations falling within the confidence intervals given for his predictions.

Kanyar/TERNIRBU overestimated individual whole body ^{137}Cs concentrations for the 2nd Quarter of 1987. For the 1st Quarter of 1989, Kanyar substantially underestimated the geometric mean of the distribution, but by overestimating the GSD, he reproduced the high end of the observed individual concentrations (which approximated 10 Bq kg^{-1}). The underestimation of whole body concentrations produced by Kanyar in 1988 and 1989 is influenced by his assumption that deep plowing of ^{137}Cs occurred for both pastures and agricultural crops.

3.1.7. Estimates of internal and external doses

No direct measurements were made of the effective doses for the period of April 1986 to April 1989, but independent analyses using the data from the CB scenario combined with other supplemental data sets (see Appendix I) estimated the mean committed effective dose due to ingestion at 5.2×10^{-2} mSv, the external effective dose from exposure to gamma radiation from the decay of ^{137}Cs deposited on the ground surface at 2.7×10^{-2} mSv, and the committed effective dose due to inhalation at 2.5×10^{-3} mSv. These dose estimates, along with their 95% confidence intervals, are presented and compared against the model predictions in Figure 14.

All but one participant (Galeriu/LINDOZ) significantly overestimated the committed dose from the ingestion of ^{137}Cs. This result is consistent with the overestimations made for the mean whole body concentrations of ^{137}Cs measured in 1986 and 1987. The time-integrated air concentration reported for the region was suspected by many of the participants to be biased high. Thus, there was a tendency for most participants to overestimate the independent evaluation of the inhalation committed dose. Several participants produced predictions that were significantly above the upper

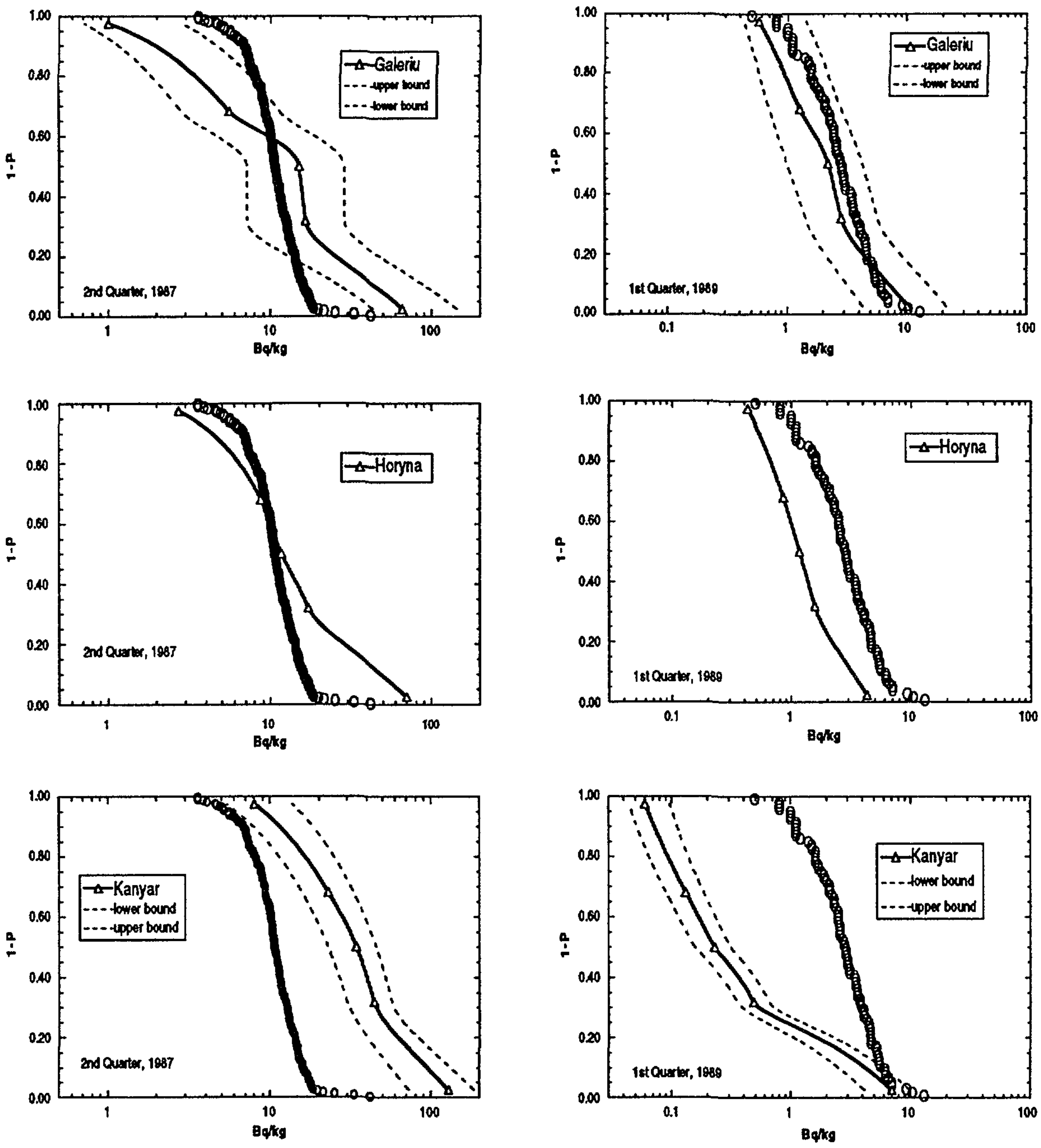

FIG. 13. Distribution of concentrations of ^{137}Cs in individual humans: A comparison of selected model predictions with observations for region CB. Observed values are indicated by open circles.

confidence bound of the mean inhalation dose estimate. The predictions for the dose from external ground exposure, however, were the most consistent ones, with only one or two participants producing predictions significantly above the estimate produced by independent analysis, and one, Carrasco/PRYMA (not shown in the figure), producing a substantial underestimate (almost two orders of magnitude). All other participants were within the confidence bounds of the ground dose estimate.

For all the dose estimates, the differences among model predictions were much smaller than for any of the previous endpoints. Most predictions were within a factor of three of each other. This is because the effective doses are directly related to time-integrated concentrations, which vary less than concentrations at specific time periods.

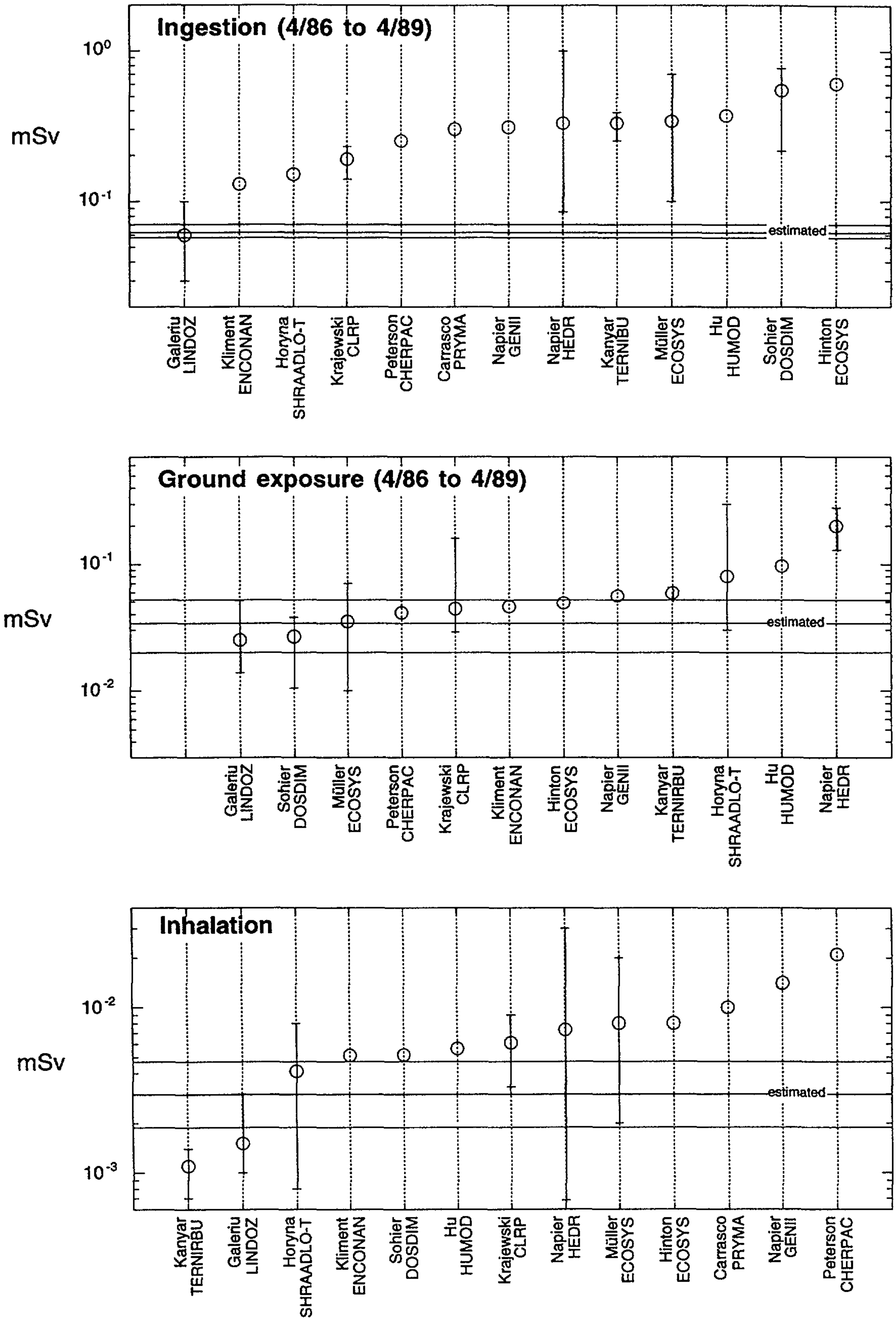

FIG. 14. A comparison of predicted versus estimated effective doses for ^{137}Cs deposited in Central Bohemia.

3.2. EXAMPLES OF IMPROVEMENTS TO MODELS

Once the test data were disclosed, the participants were asked to analyze their results and identify the major reasons for misprediction. They were then asked to make corrections to their models and produce revised sets of predictions. The following figures show the revised set of predictions submitted for the six models selected in the previous sections for comparison against the entire time series of test data (Figures 15 to 18). The following is a summary of the most common changes made to improve model predictions. Detailed descriptions of these modifications are described in Appendix III, which contains the individual evaluations of each model.

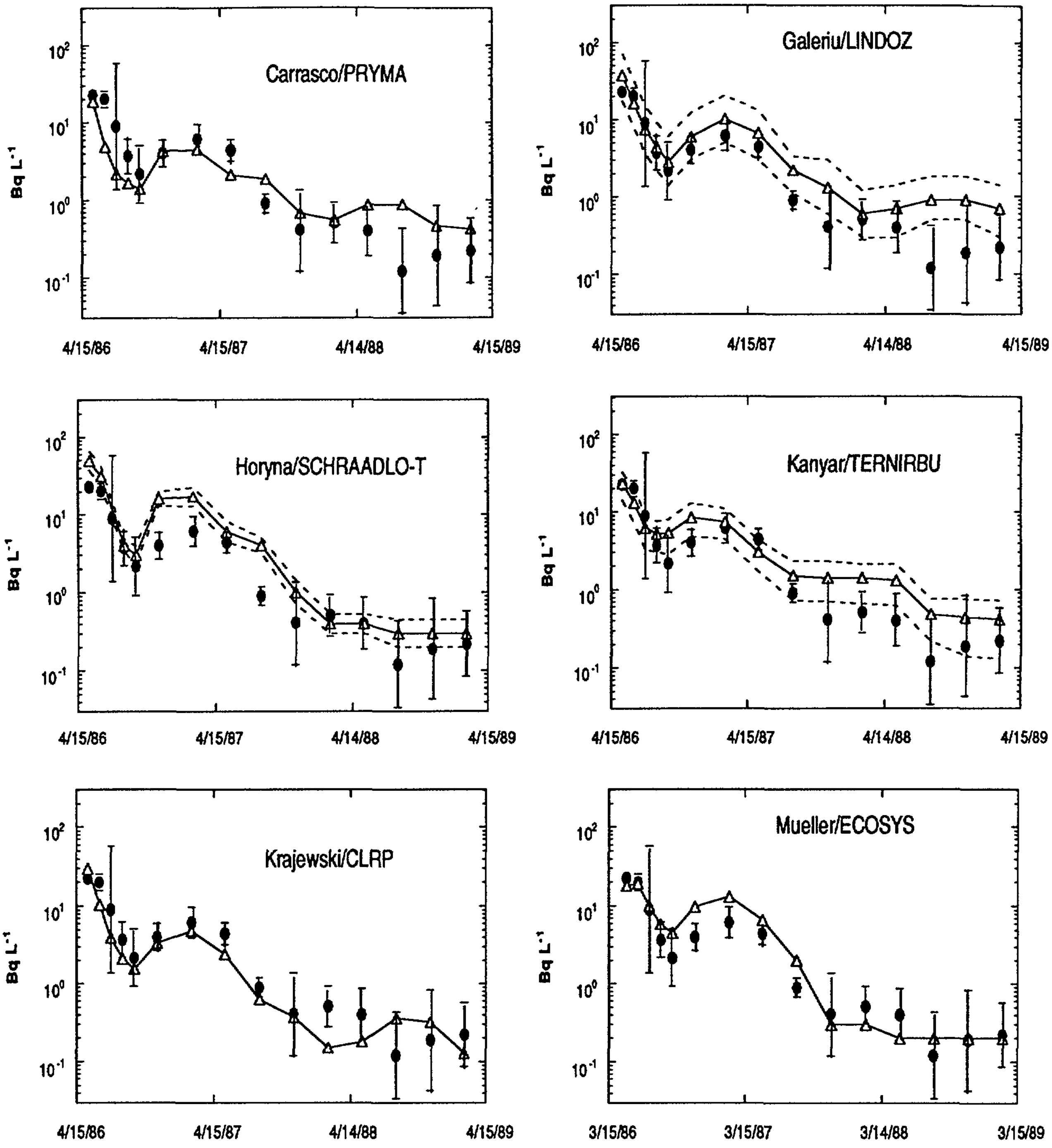

FIG. 15. Final predictions for ^{137}Cs in milk from Central Bohemia, adjusted after the observations were disclosed to the modellers.

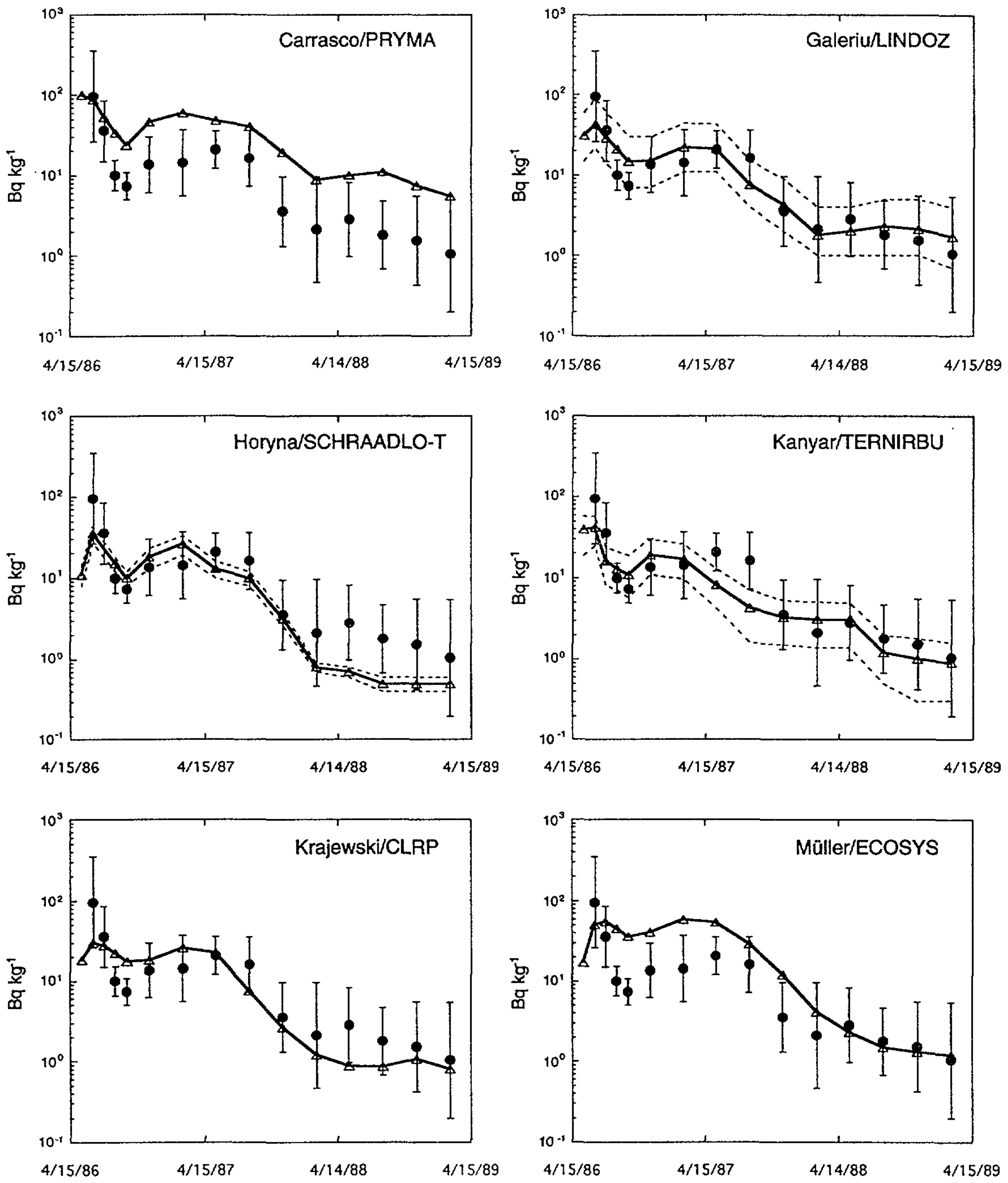

FIG. 16. Final predictions for ^{137}Cs in beef from Central Bohemia, adjusted after the observations were disclosed to the modellers.

Most changes involved adjustments to the assumed dietary intake by beef and dairy cattle as well as to the dietary intake by humans. In one case, major changes were made to the compartmental structure of the model used to simulate the metabolic transfer of ^{137}Cs into milk and meat, along with a reduction in the amount of surface soil ingested by animals on pasture (Carrasco/PRYMA). Another modeller changed the initial estimate of total deposition and assumptions about the deep plowing of pasture land and the uptake of ^{137}Cs by winter wheat (Kanyar/TERNIRBU). In another case, improvements were made by correcting an error found in the milk and meat transfer coefficients and adjusting assumptions about the amount and type of stored fodder consumed by farm animals (Krajewski/CLRP). Almost all modellers experienced problems with the predictions of ^{137}Cs in fruit, and adjustments to this pathway were necessary to bring about a more accurate simulation of the concentration of ^{137}Cs in humans over time (Müller/ECOSYS).

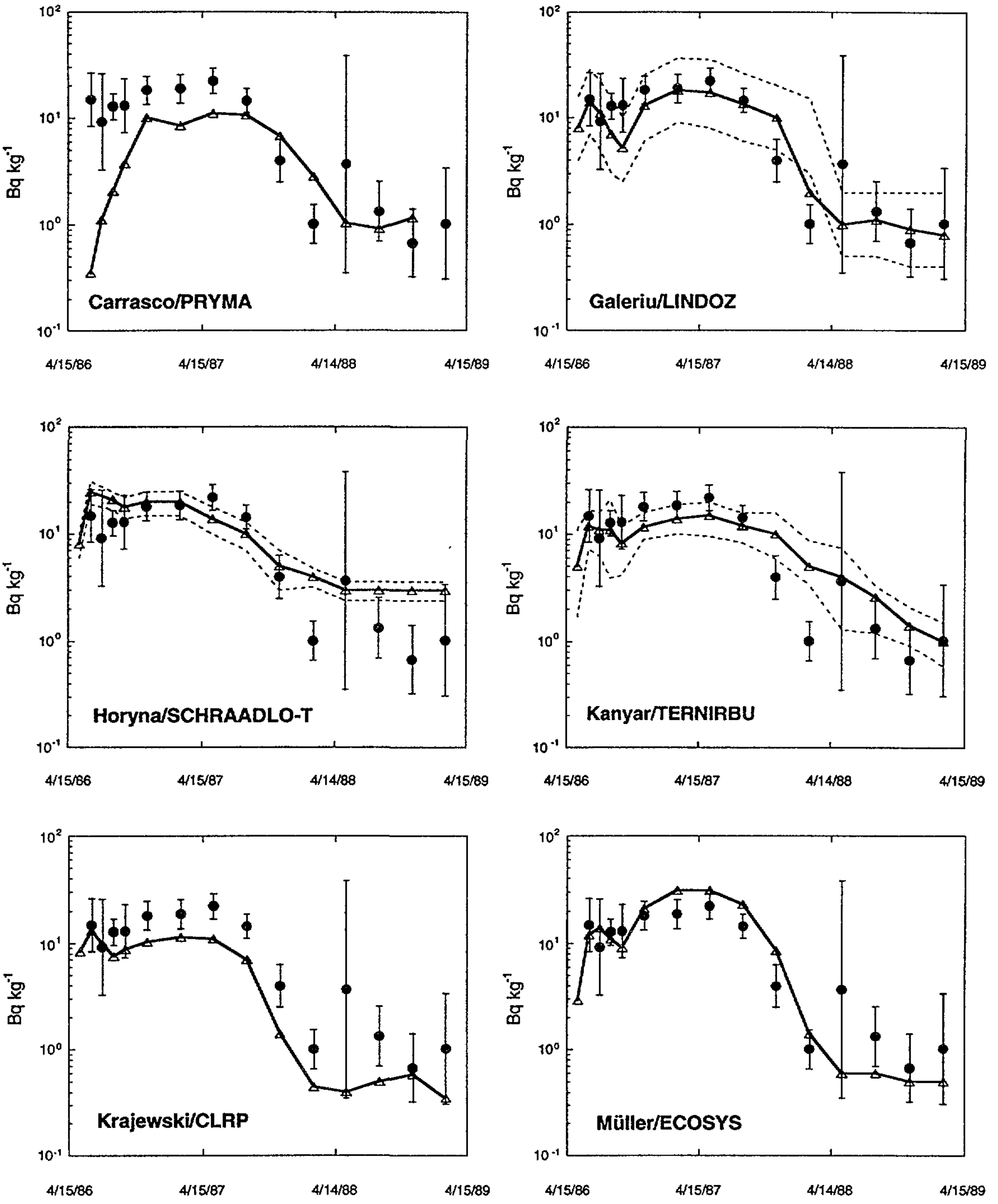

FIG. 17. Final predictions for ^{137}Cs in pork from Central Bohemia, adjusted after the observations were disclosed to the modellers.

Most participants did not try to make their models fit perfectly to the test data without first being able to explain the reasons for adjusting their parameter values and model structure. The final improved predictions made by Müller/ECOSYS, for example, still overestimate the whole body concentrations for 1987 and underestimate these concentrations for late 1988 and early 1989. Although Galeriu/LINDOZ consistently produced the most accurate set of initial results, further changes to the structure of the model were made to improve process-level understanding. These changes included accounting for reduced solubility of Chernobyl-derived ^{137}Cs in fresh fallout, differentiating between vegetation interception of wet- versus dry-deposited ^{137}Cs and adjusting vegetation interception according to different stages of plant growth, incorporation of a loss term for vegetation senescence, modification of the rate of fixation of ^{137}Cs in surface soil, and further

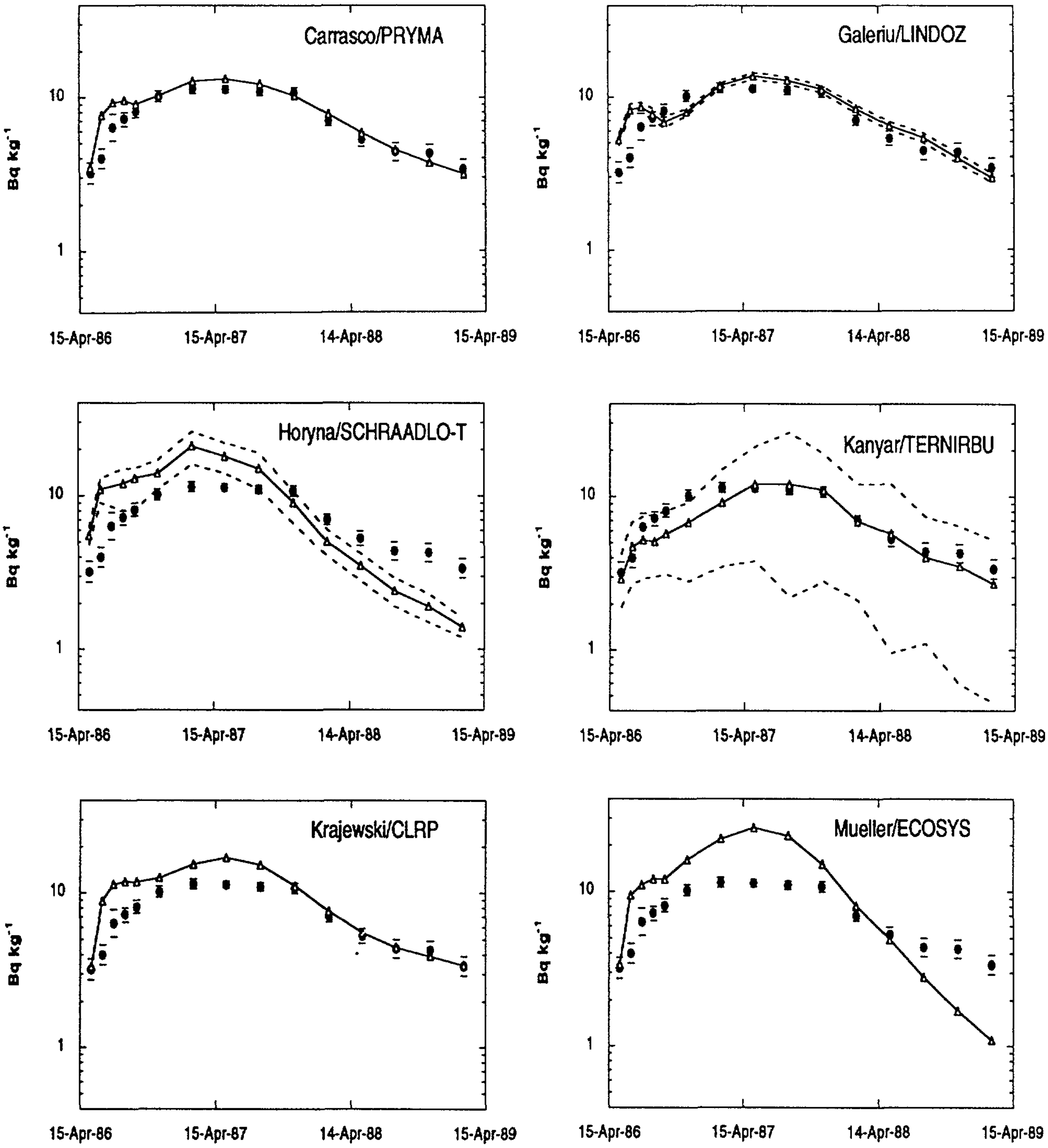

FIG. 18. Final predictions for whole body concentrations of ^{137}Cs in humans, in Central Bohemia, adjusted after the observations were disclosed to the modellers.

adjustments to the assumptions made for the animal and human diets. These adjustments were deemed necessary to correct for numerous sources of compensatory error which made the initial results better than they should have been.

After the test data were disclosed, the participants either reduced their uncertainty estimates or eliminated these estimates altogether. Among the six models depicted in Figures 15 to 18, only three presented estimates of uncertainty with their final predictions, and these were reduced from the original calculations to reflect a higher degree of confidence. A reason for elimination of uncertainty estimates was that personal judgement of uncertainties is strongly biased in the case of known "true" results. Kanyar/TERNIRBU, Napier/HEDR, and the revised estimates by Peterson/CHERPAC used Monte Carlo calculations to propagate estimates of parameter uncertainties through their models. Otherwise, all uncertainty estimates submitted in this study were made using investigator judgment about the confidence in the model prediction itself. Future changes recommended for these models will include the ability to run the codes in a Monte Carlo mode to account for individual estimates of parameter uncertainty and to properly translate this uncertainty into an estimate of uncertainty in the model result.

4. MAJOR EXPLANATIONS OF MISPREDICTIONS

The major explanations for misprediction by various models fall into three general categories: the user, the model, and the scenario (including the input data). A partial summary of this information is given in Table 3.

4.1. THE USER

In evaluating the performance of a model, one cannot separate the influence of the user from the performance of a model. The judgment required of a user in order to perform calculations with the model will affect the accuracy of the results. Predictive accuracy was best when the user of the model was personally familiar with conditions prevailing within the region CB, had experience with previous model validation exercises using Chernobyl fallout data, and employed a model with a structure suitable for calculating concentrations in various foodstuffs as a function of time. Of particular importance was the user's familiarity with the specific dietary and behavioral habits of the population of CB that may have differed from the generalized information presented in the original scenario description. For this reason, consistently accurate calculations were submitted by participants from the Czech Republic and Romania.

User inexperience with a given model was an important contributor to model misprediction, particularly for someone using a code developed by someone else. An inexperienced user may not fully understand the model and the model's capabilities and will be less likely to alter the code when that could be helpful. A flexible code structure was considered important so that the code can be readily adapted to a site-specific situation following an accidental release of radionuclides.

Misunderstanding or misinterpretation of input information on the part of the user was another reason for misprediction in some cases. To put it another way, modellers whose understanding or interpretation of the scenario was more nearly accurate, whether by means of experience, extra effort, firsthand knowledge, or providence (e.g. what they knew firsthand and therefore used, happened to be right), tended to predict more accurately.

Errors on the part of users at any level of experience were also a source of misprediction. These were primarily typographical errors in either the code or the input parameters, but also included such things as changing a piece of code in one part of the model but failing to make the same change in other parts of the model where it appeared.

4.2. THE MODEL

The majority of models exhibited a predominant tendency to overestimate observed values. For the CB test scenario, discrepancies among model predictions were smallest for time-integrated quantities. The endpoints of the CB test scenario representing time-integrated quantities were the total deposition on soil and the effective dose accumulated between April 1986 and April 1989 from ingestion of ^{137}Cs in food stuffs, inhalation of ^{137}Cs in air and external exposure to ^{137}Cs in soil. Somewhat larger discrepancies occurred for the prediction of the average individual whole body concentrations of ^{137}Cs at specific time periods. The largest discrepancies, however, occurred among predictions for concentrations of ^{137}Cs in specific food items at specific time periods.

Not surprisingly, an over- or underestimate in a donor compartment of a model generally led to corresponding over- or underestimates in receptor compartments, unless compensating errors occurred among the transfer coefficients; e.g. misprediction for vegetation (silage, wheat, pasture, etc.) led to misprediction for milk, meat, and man. An exception was misprediction for total deposition, which did not generally lead to mispredictions in the same direction for the subsequent components (different types of plants). The reason for this is compensation by misprediction of other

TABLE 3. A SUMMARY OF EXPLANATIONS FOR MISPREDICTION OF WHOLE BODY CONCENTRATION, BY SELECTED PARTICIPANTS IN SCENARIO CB

Explanation	Peterson/ CHERPAC[a]	Kliment/ ENCONAN	Horyna/ SCHRAADLO-T	Hinton/ ECOSYS	Müller/ ECOSYS	Kanyar/ TERNIRBU	Krajewski/ CLRP
User inexperience				+++[b]			
Air concentration biased high	+		+		+		
Deposition miscalculated				+		+	+
Mistiming of leafout	---[c]			+	+		
Cesium less biologically available		+					
True diet of farm animals unknown	+	+	+	+++	++	+	+
Fruit model needs work		+		++	++		++
Winter wheat overestimated						++	
Generic transfer coefficients	++		+	+	+	+	+,-
All soils assumed ploughed						+	
Storage of 1986 foodstuffs	-	+	-		+	+,--	+
Pork model improved	++						+
Effectiveness of counter-measures		+					+
True diet of humans unknown	+++	++	--	+	+	+	++
Losses via food preparation		+	-				+
Mistakes corrected after submission of initial results	--			++		+	++

[a] Uncertainty estimates on model predictions (submitted after deadline) are so large (factor of 10) that they preclude detailed analysis of the comparison of P/O ratios.

[b] + Bias towards overestimation; ++ may approach one order of magnitude; +++ exceeds one order of magnitude.

[c] - Bias towards underestimation; -- may approach one order of magnitude; --- exceeds one order of magnitude.

contributing effects such as interception and retention. The use of generic or nuclear weapons test-related rather than site-specific and Chernobyl-specific parameters and transfer factors also contributed to misprediction, and the direction of misprediction was predominantly towards overestimation.

Many participants overestimated the concentrations of ^{137}Cs in fruit trees and now conclude that models for predicting the contamination of fruit are in need of further improvement, particularly with respect to time and stages of leafing and transfer within the tree and the fruit.

Models developed for a specific purpose or type of situation often required alteration. In particular, models developed for chronic releases had to be adapted for use with an acute release. Also, one model developed for ^{131}I (short half-life) required alteration for use with ^{137}Cs (very long half-life), including the addition of resuspension and rainsplash terms and the consideration of the migration/fixation of ^{137}Cs in soil and of removal mechanisms (both soil and biological). Some of the large discrepancies for specific food items at specific time periods resulted from the misapplication of quasi-steady state models during the transitional period when winter feed is replaced by fresh pasture vegetation for the nutrition of livestock.

Many modellers found it necessary, especially after the actual observations were made available, to add compartments or terms or to adjust parameters in order to handle the scenario in sufficient detail. These changes required alterations to the code as well as to the parameter values.

There was a tendency for many models to overpredict concentrations of ^{137}Cs in humans, even when the predictions for various dietary components were good. The general tendency to overestimate ^{137}Cs in humans is consistent with comparisons made of model predictions against whole body measurements made within the former USSR [4] after the Chernobyl accident. Possible explanations include an overestimate of the total human diet; a failure in the scenario description or by the modeller to account for loss due to processing, spoilage, or feeding of animals; or a voluntary limitation or prolonged storage of contaminated foodstuffs by the people. Most participants overestimated the rate of decline of whole body concentrations during the latter part of 1988 and 1989. The slower than expected rate of decline might be partly due to long-term storage of food items produced during the late spring of 1986, progressive increase of the mobility of ^{137}Cs in soil, and to some extent also consumption of wild game and food items derived from the forest ecosystems. The potential importance of contaminated food products from the forest ecosystems to the average ^{137}Cs body burden of the residents of Central Bohemia is a topic that warrants further investigation.

4.3. THE SCENARIO

Perhaps the most prevalent explanation for misprediction given by the modellers themselves was the absence or insufficiency of site-specific information, particularly for agricultural practices, dates and times, and human dietary habits. Modellers whose assumptions for such things as feeding regimes for livestock most nearly resembled the actual practices tended to predict more accurately. To give one example, beef cattle in Central Bohemia region are stabled and fed stored feed for most of the year. Some modellers whose experience in North America was with beef cattle pastured year-round used an incorrect feeding regime for beef cattle in their models.

The exactness of the scenario description was an especially crucial point, because the Chernobyl accident and subsequent radionuclide deposition occured at the time of year when temporal changes of ecological conditions (e.g. development of vegetation, feeding regimes for domestic animals) are most pronounced. If a modeller assumes a situation which actually reflects conditions 1-2 weeks before or after the event, rather than the correct conditions for the date, considerable differences in the predicted model results will occur.

Several modellers questioned the representativeness of various data, including air concentration, soil samples, pasture data, human (whole body) data, and the dairy and beef samples. Concern was expressed that there were insufficient monitoring data (vegetation and/or deposition) from too few sites, and that there was inconsistency between the air concentration data and the deposition data. There appeared to have been uneven precipitation rates throughout the region of the scenario, and both the accuracy of the reported wet vs. dry deposition and the use of mean vs. instantaneous values were questioned.

5. CONCLUDING REMARKS

The following remarks summarize results and conclusions derived from the experience of the VAMP Multiple Pathways Assessment Working Group with Scenario CB.

- *In general, models tended to overestimate the effective doses for ingestion and inhalation, while most predictions for the effective dose from external ground exposure were within a factor of two.*
    - Most of the models that did not perform well for external ground exposure produced overestimates because of failure to adequately account for shielding by the ground surface or the indoor environment.
    - Overestimation of inhalation doses is suspected to have been caused by overestimation of the actual air concentrations of ^{137}Cs within the CB region.
    - Overestimation of ingestion doses is attributable partly to overestimation of the concentration of ^{137}Cs in foodstuffs and partly to overestimates of food consumption.

- *In general, the differences among model predictions were much smaller for the effective dose estimates than for any of the environmental concentrations used in the testing exercise.*
    - The required dose predictions are directly related to time-integrated concentrations, which are subject to less variability than concentrations measured at specific points in time.

- *Comparison of model predictions to a set of independent observations provided an opportunity to identify and correct errors in the models that otherwise would have been unrecognized, even though quality control of the results was a prerequisite for participation in the testing exercise.*

- *Several scenarios should be used to test models.*
    - Several modellers questioned the wisdom of making major changes to models or model parameters based on a single set of observations, especially if the model has given better performance for a previous set of observations. Therefore, the reported results on the performance of individual models should be considered as examples only. It must be expected that models will perform differently when applied to different scenarios.

- *For an ideal intercomparison of model predictions, a scenario should provide as much detail as possible so as to minimize user interpretation and the corresponding risk of misinterpretation.*
    - Under most actual situations, this level of information is seldom available.
    - It is almost always necessary for the users of models to make judgements about the data available to initialize calculations. The accuracy of the model prediction reflects the quality of these judgements.

- *Attempts should be made to have each compartment or term in a model as accurate and as site-specific as possible.*
    - When possible, each compartment or term should be tested against appropriate data sets. Otherwise, seemingly accurate predictions may be the result of compensatory errors.

- *When planning for the use of models in accident situations, it would be useful to have strategies in place to provide for the rapid collection of data in order to calibrate the models to the site-specific situation.*

    - To take advantage of such information, it should be possible to change both parameter values and model structure within the overall design of the computer code.

- *The experience and effort of the modeller are at least as important as the nature of the model.*

    - An experienced user can always make changes to a code if its structure is sufficiently flexible.

- *Critical assessment issues and questions should be independently addressed by more than one group.*

    - The accuracy of model predictions and the estimates of uncertainty about the model predictions are influenced by user judgment.
    - The resolution of discrepancies in initial results between groups of modellers will enhance the credibility of the final conclusions.

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Appendix I

DOCUMENTATION AND EVALUATION OF MODEL VALIDATION DATA USED IN SCENARIO CB

I.1. DESCRIPTION OF TEST SCENARIO CB

V. Kliment, I. Bučina, I. Malátová

I.1.1. GENERAL INFORMATION

The test region CB covers a territory of approximately 11500 km^2; its altitude varies from 180 to 850 m, with most parts lying between 200 and 450 m altitude. It administratively consists of the capital, Prague (AB) and twelve subregions (districts): Benešov (BN), Beroun (BE), Kladno (KL), Kolín (KO), Kutná Hora (KH), Mělník (ME), Mladá Boleslav (MB), Nymburk (NB), Prague-east (PH), Prague-west (PZ), Příbram (PB), Rakovník (RA).

In general it shows a structure typical for Central Europe with a mixture of dwellings, farming (covering approximately 6400 km^2), forest (approx. 2400 km^2) and industrial areas. CB has a temperate climate with a long-term annual average temperature of 9.7°C and an annual rainfall of 490 mm, measured in Prague. Monthly averages of temperature are in Table I.1. At the time of the Chernobyl accident there was no snow left and the vegetation period had already begun. Detailed data on wind and rain during the passage of the plume are given in Section I.1.2, information on vegetation in Section I.1.4.

I.1.2. RADIONUCLIDE CONCENTRATIONS IN GROUND-LEVEL AIR

The information on radionuclide concentrations in ground-level air is collated from measurements of aerosol samples collected by the Czech Hydrometeorological Institute and the by Centre of Radiation Hygiene (CHR) of the National Institute of Public Health (former Institute of Hygiene and Epidemiology). Both sampling sites are located in Prague approximately in the centre of the CB region. The distance between these sites is about 7 km. Data from these two sites supplement each other for a full coverage of the whole period after the accident. The data have been compared with observations from other sampling sites within and around CB [3] and, in general, radionuclide concentration in the ground-level air of similar quantities has been found (see Section I.2.2).

At both sites aerosols were collected on filters with high volume air samplers with flow control at a flow rate of 0.8 to 1.2 m^3 min^{-1}. The sampler of the Czech Hydrometeorological Institute (data in Table I.2) was placed in a meadow remote from buildings, at 1.5 m height. The sampler of CRH (data in Tables I.3 to I.6) was placed in a window of the attic (5th floor) of a building (see Figure I.1).

All filters were measured in the Laboratory of Gamma Spectrometry of CRH using well-shielded HPGe semiconductor detectors. For the evaluation of measured spectra, the application software Spectran F by Canberra Industries was used. Results given in the Report IHE [I.1] after the Chernobyl accident were obtained using the 90% confidence level for peak search. For VAMP the 68% confidence level for peak search was used in order to have the same confidence level for the whole time series of activity concentration of radionuclides in air. Otherwise it would be impossible to evaluate very low activity concentrations occurring nowadays, for which the respective peaks in the spectrum could be not found using higher confidence levels. There were, however, several reasons due to the algorithm used for computation which can cause the peak areas and consequently the computed activities of individual radionuclides to differ slightly for different confidence levels.

Table I.2 contains data on ^{137}Cs and ^{134}Cs concentrations in the ground-level air starting from April 30, 1986, up to and including May 12, 1986. Table I.3 for the rest of 1986, Table I.4 for 1987, Table I.5 for 1988, and Table I.6 for 1989 additionally list results of measurements of ^{7}Be concentrations in the air. In each table the date and time of commencement and end of an observation

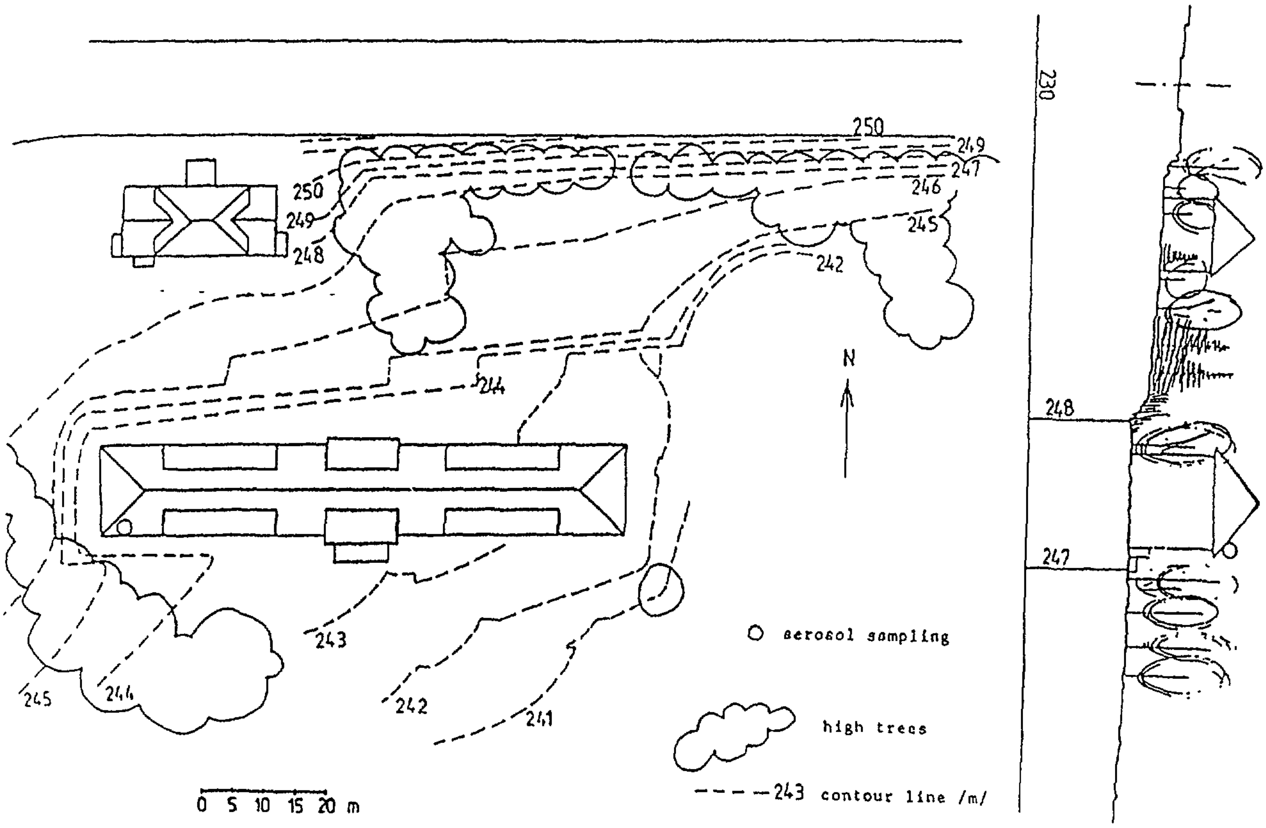

FIG. I.1. Plan of the air sampling station in Prague.

period is given, followed by the average radionuclide concentrations in that period in ground-level air in mBq m^{-3}. A radionuclide concentration of "0.0" denotes a value below the detection limit (approximately 2 mBq m^{-3} for ^{137}Cs and ^{134}Cs).

The Chernobyl plume arrived in CB on April 29, 1986, at approximately 8 p.m. Air measurement commenced on April 30, 1986, at 10 a.m. Since no guidance can be given on the ^{137}Cs and ^{134}Cs concentrations in air for the uncovered 14 h period, assumptions on its time course have to be made by each participant.

Measured ^{137}Cs/^{134}Cs ratios in ground-level air deviate sometimes from about 2 in the early period after the accident. This was caused by the complexity of the spectra with a predominance of ^{132}Te + ^{132}I interfering with the peak of ^{137}Cs at 661.2 keV.

The data in Table I.2 up to June 20, 1986, were gained by summing up the activity on the individual stages of a cascade impactor used for determining the particle size distribution (see Section I.2.5.1). This impactor was previously used for sampling in the ventilation stack of a Nuclear Power Plant and also for sampling in first days after the Chernobyl accident, which might have caused contamination. This is probably the reason for the difference in activity concentration in the end of Table I.2 and in the beginning of Table I.3, rather than real increase of its value.

Wind direction and wind speed [I.2] have also been observed and are listed in Table I.7. However, these data were obtained at a site located approx. 10 km away from those sites where ground-level air samples were taken. All three sites lie in Prague within an area of about 500 km^2.

For the same site and 13 others, daily measurements of rainfall [I.2] are given (Table I.8). The location of these sites is described in Table I.9 and shown in Figure I.2. Generally rainfall occurred locally with a duration of less than 1 hour.

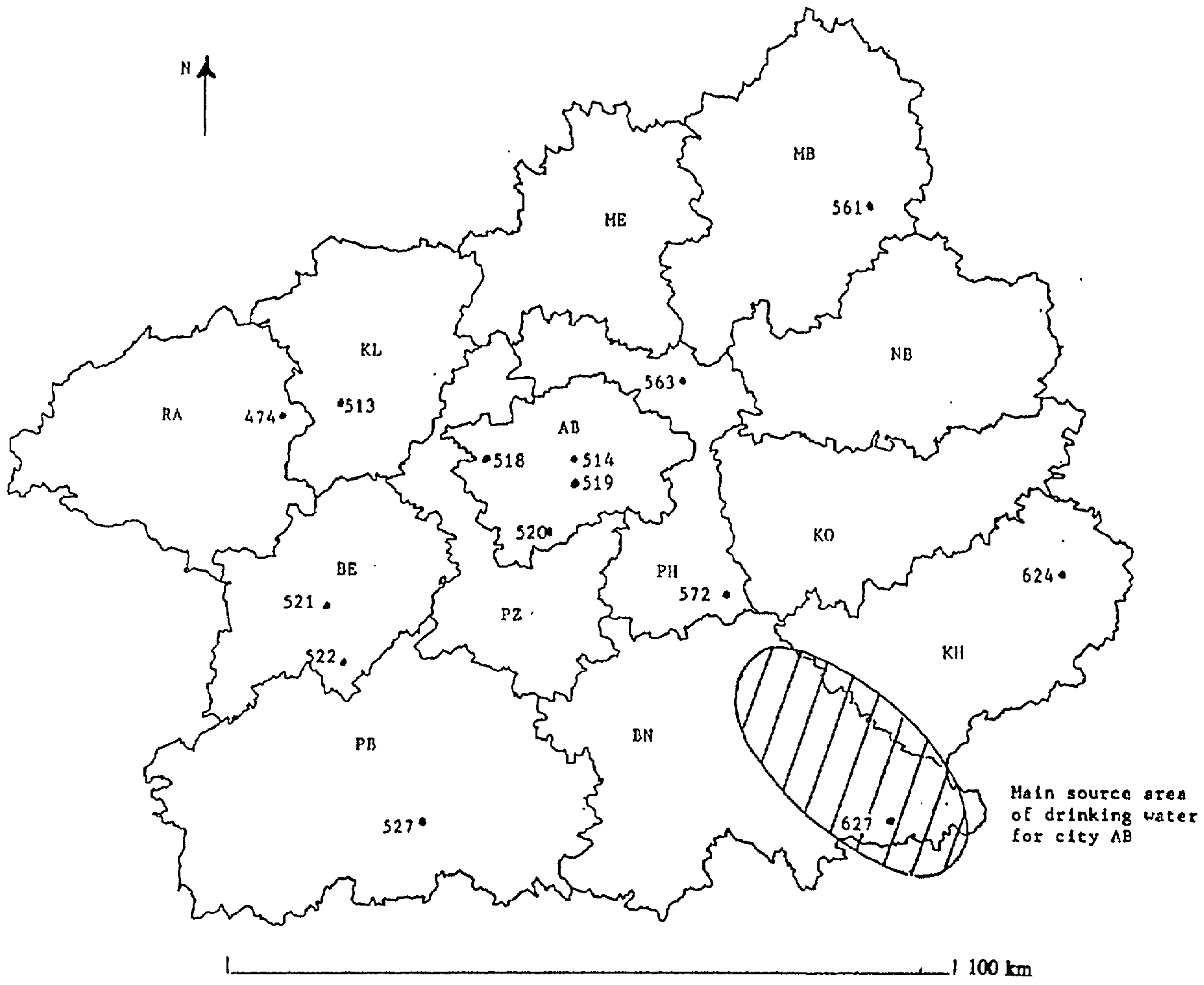

FIG. I.2. Location of rain sampling stations.

I.1.3. SOIL CONTAMINATION

As part of a nationwide study of fallout and soil contamination, samples of bare soil were collected between June 16 and 18, 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 April 26, 1986, on places with the slope less than 3°, principally not on sandy soil. Samples were taken as a rule from an area of 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 the semiconductor gamma spectrometry the samples were dried, stones greater than 2 cm in diameter and the roots of plants were removed, and then the samples were homogenized.

No data are available on ^{137}Cs contamination on soil from the nuclear weapons testing, and information of background contamination of food products is rather scarce. No observations on stable Cs are available, but some information on the K content in soils is given in Section I.1.4.

Results of measurements are listed in Table I.11. Observations are given for 13 subregions of CB. Each record is listed with a code describing the location of sampling in Figure I.3. Listed is the surface activity of ^{137}Cs, ^{134}Cs and ^{103}Ru in kBq m^{-2}. Four entities of soil characteristics, i.e, granularity, permeability, humus content and humus quality in the respective area, typical for the neighborhood of individual sampling sites are given, too. The abbreviations used are explained in Table I.10. Figure I.4 shows areas of different soil types relevant for plant production which are explained in Table I.12. Table I.13 gives ranges of pH values for these areas.

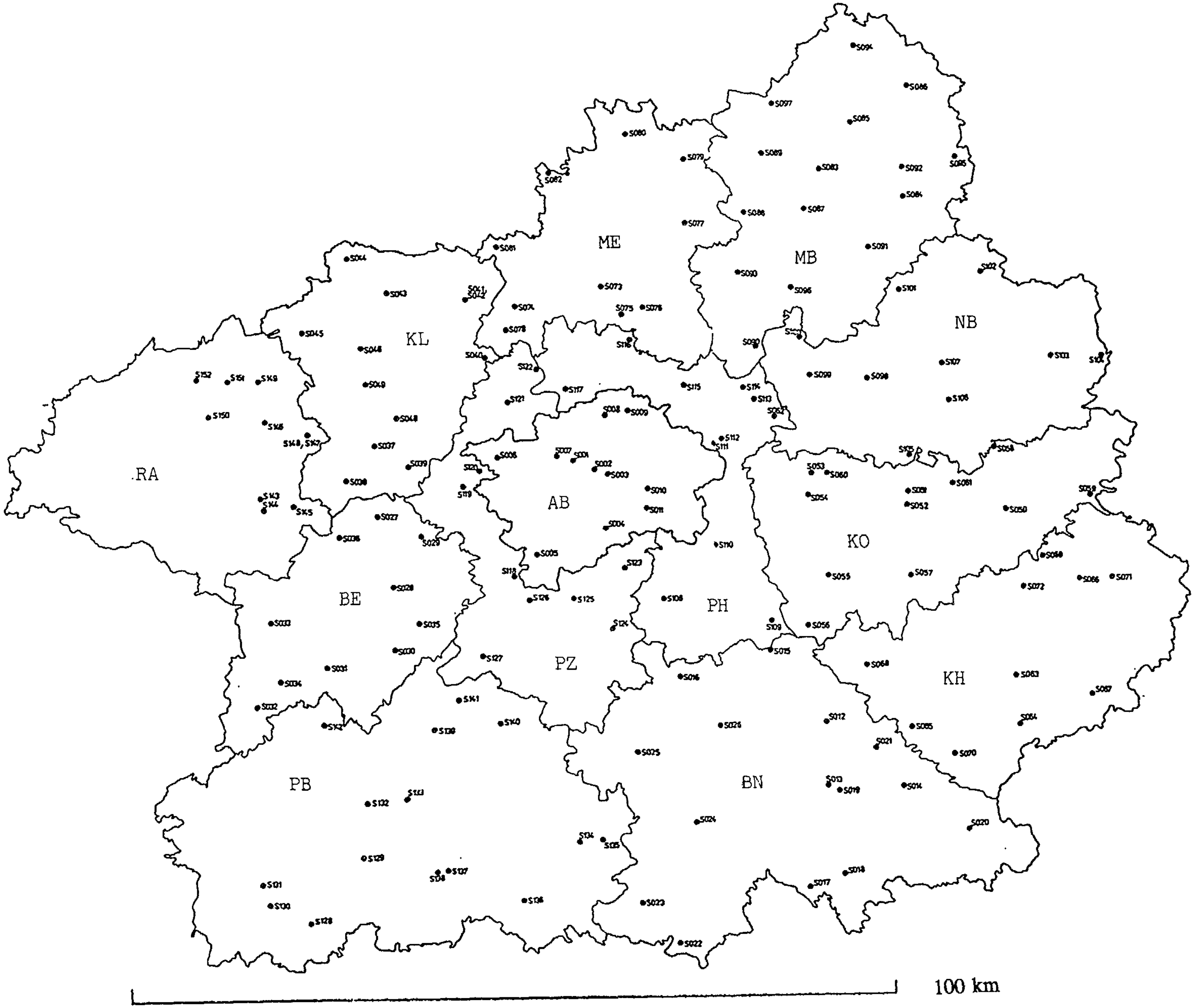

FIG. I.3. Location of soil sampling points.

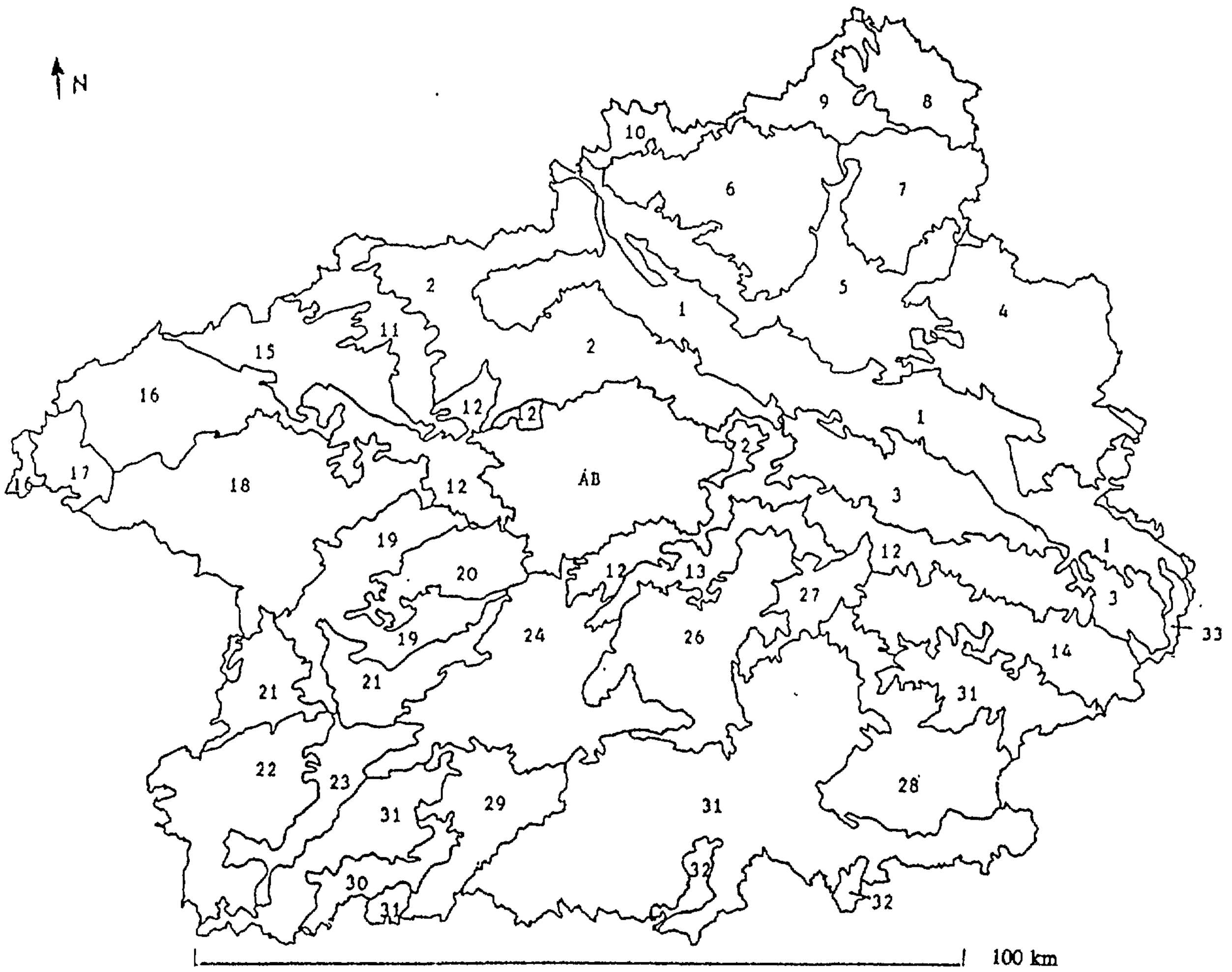

FIG. I.4. Soil types relevant for plant production.

I.1.4. AGRICULTURAL INFORMATION

Table I.14 lists the land used for production of different kinds of plants for each subregion of CB. The actual production yield of these plants is given in Table I.15, while Table I.16 summarizes information relevant for meat, milk, and egg production. All these tables contain values derived for 1986 [I.3], while the values for consecutive years are expected to be very similar, variation should not exceed 10 to 20%.

In Tables I.14 and I.15, the following explanations should be used for those products which are not self explanatory:

- pulses are those used for drying, processing, etc.;
- green beans and green peas mean those which are consumed fresh by humans;
- fodder root crops means beets etc. used for cattle feed;
- fodder arable 1y means fodder produced in a one year cycle, mostly maize, green oats and beans of which mostly the whole plants are ensilaged in fresh form;
- fodder arable xy is usually produced in a three year cycle, mostly clover (about 65% of production) and alfalfa (about 35% of production);
- technical products are other plants for animal feed, oilseeds (e.g. sunflower, rape) or plants used for industrial application (flax).

The vegetation period in CB starts about April 15 to 25. In 1986, the majority of cattle has not yet been let on pastures on May 1.

It is impossible to give detailed information on seeding and harvesting dates of different plants. However, Table I.17 contains general information of these dates for CB. The yield at harvesting can be calculated from the Tables I.14 and I.15. However, only little information is available of the yield at the time of deposition: clover had a mean yield of 2.6 kg fresh weight m^{-2}, with a range from 1.2 to 3.8 kg m^{-2} observed May 1 to 12; wheat had a mean yield of 0.25 kg dry weight m^{-2} with a range from 0.20 to 0.28 kg m^{-2} observed May 7 to 15. Average leaf area indices, expressed as area of leaves per ground area, for wheat, barley [I.4] and clover [I.5] are given in Table I.18. The growing period for clover starts about mid April and of alfalfa about beginning of April. Vegetation periods and shares of annual yield for clover and alfalfa are given in Table I.19. About 2/3 of the first, 1/3 of the second cut is used for conservation, and the rest for direct feeding. The dry matter contents of green fodder are estimated to be 18% and of hay 72%.

In general following amounts of industrial fertilizers are used in CB (annual average): N 88.7 kg ha^{-1}, P_2O_5 69.7 kg ha^{-1}, K_2O 74.2 kg ha^{-1}. The ploughing depth varies with modern farming practices from 5 to 32 cm. The first tillage after harvest of grain reaches 5 to 10 cm depth. Ploughing for winter grain in fall reaches 20 to 25 cm depth, for spring grain and other plants seeded or set in spring 25 to 32 cm, for maize about 20 cm and for clover and alfalfa about 25 cm.

Through the CB authorities directing agricultural production a recommendation was given after the Chernobyl accident to feed cattle on winter feeds and to delay feeding fresh forage as long as possible. It is not possible to assess the effect of this countermeasure, but an estimate of 40 to 60% uncontaminated fodder can be assumed for the first half of May 1986.

Table I.20 contains information of feeding practices in CB [I.3, I.6]. The summer period lasts approximately from May to October, the winter period from November to April. The feeding of cereals harvested in summer 1986 started approximately in November 1986.

The average gain of weight of growing animals is 0.65 to 0.72 kg living weight d^{-1} for cattle and 0.53 to 0.58 kg living weight d^{-1} for pigs. Relating the feed consumption to animal growth or products results in 0.20 to 0.23 kg d.w. feed consumption per litre milk yield, 1.87 to 2.36 kg d.w. per kg living weight gain of cattle, 3.28 to 3.54 kg d.w. per kg living weight gain of pigs and 2.27 to 2.65 kg d.w. per kg living weight gain of broiler. Cattle are usually kept in stalls, pigs are always kept in stalls. The mean lifetime of cattle is approximately 2 years, of pigs 6 months and of broilers 5 weeks. The mean milk yield is about 10 L d^{-1} and the mean egg yield is about 180 eggs a^{-1}.

I.1.5. DEMOGRAPHIC INFORMATION

Table I.21 gives information on the area and population of CB and its subregions [I.7]. Table I.22 shows the age distribution of the CB population.

52.2% of the CB's population is female and 47.8% male. About 68.4% are living in cities of more than 10 000 inhabitants. The total number of working people is about 1 534 000, of which 54.3% are employed in industry, 6.4% are construction workers, 37.8% are office workers and 1.5% are farmers. Naturally the office employees are working indoors only and the people employed in industry mostly work indoors, while construction workers mostly and farmers often work outdoors.

The population lives in typical Central European dwellings. Urban settlements consist mostly of concrete reinforced buildings of 4 to 5 floors, rural settlements of 1 to 2 floor houses. The air exchange can not be specified, but windows mostly consist of double glass panes in wooden frames. The times spent indoors and outdoors differ widely and can not be specified.

The food production in CB is sufficient to supply the needs of CB's population. Exchange with other regions of the country occurs, but as the entire country shows similar deposition levels of ^{137}Cs, bilateral food exchange does not lead to significantly different radionuclide intake. Certainly also foreign import occurs, but as this has negligible influence on the assessment question, food exchange balances are not reported.

For most "daily" food products (dairy products, bread, etc.) local producers exist in most subregions with a fairly uniform distribution network.

The annual consumption rates of food products are listed in Table I.23 [I.7]. This information originates from trade balance data and household surveys. The uncertainties involved can not be specified, but mainly are due to the household survey by questionnaires, deriving consumption of home-produced food, and estimation of food bought but not consumed due to molding, rotting or feeding to domestic animals. Food processing techniques cannot be specified in detail, but can be assumed to be typical of European practices.

I.1.6. INPUT INFORMATION AVAILABLE ON DISKETTE

The database contains information on ^{134}Cs and ^{137}Cs contamination in ground-level air, fallout, and soil, and a description of the agricultural, meteorological and demographic situation in CB region. It consists of **Subdirectories** and **files**:

AERO - Contamination of ground level air
- Aero-add.vap: Activity concentration in aerosols in ground level air from 1986/04/30 to 1986/05/12
- Aero86.vap: Activity concentration in aerosols in ground level air in rest of 1986
- Aero87.vap: Activity concentration in aerosols in ground level air in 1987
- Aero88.vap: Activity concentration in aerosols in ground level air in 1988
- Aero89.vap: Activity concentration in aerosols in ground level air in 1989

AGRO - Information on agricultural production
- Area.vap: Seeding area of plant products in 1986
- Harvest.vap: Plant production in 1986
- Animprod.vap: Animal production in 1986

METEO - Information on rainfalls and wind
- Precipit.vap: Rainfalls from April till August, 1986 (Information on wind direction and wind speed is at the end of this file)

POPULA - Information on population and food consumption
- Consumpt.vap: Information on consumption of main kinds of food stuffs for different age categories
- Populinf.vap: Information on population (number of inhabitants, age and profession structure)
- Babymilk.vap: Contamination of baby milk food - mean values for CSFR

SOIL - Contamination of soil surface
- Soil.vap: Specific activity in soil surface in 1986

I.1.7. ASSESSMENT TASKS FOR MODEL TESTING

For the items requested in this section, estimate the ^{137}Cs quantities· arithmetic mean of specific activity (Bq kg^{-1}) and/or activity concentration (Bq L^{-1}) for the time-periods specified and the entire region CB, and 95% confidence interval bounds about the arithmetic mean.

(1) Total deposition

Estimate the quantities for total deposition (wet and dry) in the entire region CB (Bq m^{-2}).

(2) ^{137}Cs Concentrations in food products

The quantities should be given for products prior to preparation for human consumption, averaged over the time-periods given and the entire region CB.

(a) Leafy vegetables

Estimate the quantities (Bq kg^{-1} f.w.) for the months May to September 1986, and the quarters II[1] and III of 1987 and 1988, averaged over entire CB.

(b) Cereals

Estimate the quantities in winter wheat (Bq kg^{-1} f.w.) for the harvests 1986, 1987, and 1988, averaged over entire CB.

(c) Fruit

Estimate the quantities in apples and pears (Bq kg^{-1} f.w.) for the harvests 1986, 1987, and 1988, averaged over entire CB.

(d) Milk

Estimate the quantities in milk (Bq L^{-1}) for the months May to September 1986, and the quarters IV 1986 to I 1989, averaged over entire CB.

(e) Beef

Estimate the quantities in beef (Bq kg^{-1}) for the months May to September 1986, and the quarters IV 1986 to I 1989, averaged over entire CB.

(f) Pork

Estimate the quantities in pork (Bq kg^{-1}) for the months May to September 1986, and the quarters IV 1986 to I 1989, averaged over entire CB.

(3) Human intake

Estimate the mean Cs-137 intake per day of an adult (Bq d^{-1}) for the months May to September 1986, and the quarters IV 1986 to I 1989, averaged over entire CB.

(4) Concentrations in animal feeds

(a) Pasture vegetation

Estimate the quantities in pasture vegetation (Bq kg^{-1} f.w.) for the harvest 1986, 1987, and 1988, averaged over entire CB.

(b) Alfalfa

Estimate the quantities in alfalfa (Bq kg^{-1} f.w.) for the 1st (approx. June) and 2nd (approx. August) cuts in 1986, 1987, and 1988, averaged over entire CB.

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[1] Quarters are noted I to IV for a year; i.e., I means January through March, II means April through June, III means July through September, and IV means October through December.

(c) Silage

Estimate the quantities in silage (Bq kg^{-1} f.w.) for the average annual harvests in 1986, 1987, and 1988, averaged over entire CB.

(d) Spring barley

Estimate the quantities in spring barley (Bq kg^{-1} f.w.) for the annual harvests 1986, 1987, and 1988, averaged over entire CB.

(5) Whole body content

Estimate the quantities in the body of an average adult (Bq kg^{-1}) in region CB for the months May to September 1986, and the quarters IV 1986 to I 1989.

(6) Distribution of whole body content

Estimate the distribution of individual adult whole body concentrations of ^{137}Cs (Bq kg^{-1}) as a complementary cumulative distribution function (CCDF) and a 95% confidence interval for this distribution for the quarters II 1987 and I 1989. Examples for CCDF functions can be found in IAEA publication SS 100 [I.8]. Note that the fractiles of a CCDF are equal to 1-p, where p is a fractile of the cumulative distribution function CDF.

(7) Multiple pathways dose assessment

Estimate the time-integrated dose equivalent (mSv) for an average adult (assumed to be of the age 20 at the time of the initial deposition of Cs-137 in region CB) for the following pathways and time-periods. It is understood that the average should be calculated for the time-periods specified and for the relevant adult population of the entire region CB.

(a) External dose

Estimate the quantities for dose to the adult from external exposure from the Chernobyl cloud (mSv). Estimate the same for dose from ^{137}Cs deposited onto ground and a 95% confidence interval thereof for the periods 0-1 a, 0-2 a, 0-3 a, and for the lifetime of the individual.

(b) Inhalation dose

Estimate the quantities for dose to the adult from inhalation from the Chernobyl cloud (mSv). Estimate the same for inhalation dose from resuspended ^{137}Cs for the time periods 0-1 a, 0-2 a, 0-3 a, and for the lifetime of the individual.

(c) Ingestion dose

Estimate the quantities for dose to the adult from ingestion (mSv) for the time periods 0-1 a, 0-2 a, 0-3 a and for the lifetime of the individual. For each time period show the percent contribution and the type of the top three food items contributing to the average ingestion dose.

(d) Total dose

Estimate the quantities for dose to the adult from all pathways (mSv) for the time periods 0-1 a, 0-2 a, 0-3 a, and for the lifetime of the individual. For each time period show the percent contribution of the top three exposure pathways contributing to the average dose.

If your model is not designed with a fixed set of dose conversion factors the use of the following factors for the dose predictions of adults is recommended:

Inhalation (Sv Bq^{-1}):	$8.6\ 10^{-9}$
Ingestion (Sv Bq^{-1}):	$1.4\ 10^{-8}$
External radiation	
- cloud (Sv m^3 h^{-1} Bq^{-1}):	$9.3\ 10^{-11}$
- deposition (Sv m^2 h^{-1} Bq^{-1}):	$1.3\ 10^{-12}$

I.2. MEASURED DATA ON Cs-137 CONTAMINATION OF CB ENVIRONMENT

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I.2.1. GENERAL INFORMATION

Monitoring of the radiation situation in ČSFR started immediately after the first passage of contaminated air masses from Chernobyl over the territory of the country on 30 April 1986.

The environmental samples and the samples of food stuffs and feed stuffs from CB region have been collected according the scheme elaborated by the Centre of Radiation Monitoring Network of ČSFR established at the Centre of Radiation Hygiene of the National Institute of Public Health, Prague (former name, Institute of Hygiene and Epidemiology). The scheme was valid for the whole of Czechoslovakia, the set of CB data was only a particular case. Gamma spectrometry of all samples collected in CB region as well as whole body counting of people was performed in the National Reference Laboratory for Internal Exposure of Czech Republic, which is a part of the Centre of Radiation Hygiene.

Samples were measured by semiconductor gamma spectrometry using well shielded HPGe detectors. The same equipment as for the measurement of air filters, soil samples and samples of fallout, results of which were used in the CB Scenario (Sections I.1.2 and I.1.3), was used. The difference in sensitivity of measurements (characterised by the minimum detectable activity - MDA) of the sets of samples of individual items varied with the counting time of the individual sample and the sample size. In the beginning of the monitoring period, the minimum detectable activity for ^{137}Cs and ^{134}Cs was influenced also by the presence of other short-lived radionuclides, especially by ^{132}I with ^{132}Te. Counting time and sample size were usually chosen according the technical possibilities in the given time. Especially in the beginning of the monitoring in May and June 1986, the demand on measurements was quite large, and quick response was expected. Therefore, measurement of some important samples (aerosol filters, soil samples) was repeated later with longer counting times.

The aim of the monitoring of the territory was in the first place protection of the population, so the schemes for collection of samples of individual items and the sensitivity of their measurements were chosen so as to fulfil this task.

Therefore, from the point of view of representativeness, the sets of measured data are of different quality. This is valid not only for CB, but also for the data sets from other regions used as additional sources of information when lack of data from CB occurred.

In principle, collection and measurements of individual sets of samples were done for several reasons:

- estimation of the contamination of the territory (soil samples);
- examination of possible extreme values of the dose to some groups of population, esp. from ^{131}I (milk sampling);
- prediction of the dose to the population (measurement of the food chain, incl. animal feed);
- certification of food stuffs for export;
- estimation of the dose and comparison with model predictions (whole-body counting of the reference group, measurement of daily intakes);
- estimation of the inhalation dose (whole-body counting of people coming to Prague from remote countries after 12 May 1986);

The **soil sampling** was planned as a nationwide survey with the aim of mapping of contamination of the whole territory of ČSFR. With additional studies of local variations of surface contamination and tests of quality of measurements, the set of soil contamination data can be taken as representative of the CB region. However, the method for the collection of soil included the condition that bare soil was sampled for guaranteeing reproducibility of the method all over the territory. Modellers had to take this fact into account.

Data about ^{137}Cs content in the **milk** came either from nation-wide surveys which included all large dairies in ČSFR (in CB region 15) and were performed on 15 May 1986, 11 June 1986, 1-5 Dec. 1986, 25-29 Mar. 1987, and 20-24 Jul. 1987, or from regular milk sampling performed on a smaller scale and covering especially the biggest dairies. Such regular checks were performed from the beginning of May 1986 till middle June daily, then weekly, later monthly. Samples of milk were taken either directly from storage tanks in dairies or from storage tanks in big milkproducing cooperative farms delivering milk to the corresponding dairy. Location of dairies together with their gathering regions are in a map (Figure I.5), and data about their production of milk in 1986 are in Table I.16. As the sampling was extensive over both the time interval and area of CB (altogether 454 samples for the time period followed - see Table I.28), it is possible to assume the concentration in milk to be representative for CB region. However, results of ^{137}Cs concentration in 139 milk samples from surrounding regions were supplied, too (Table I.30).

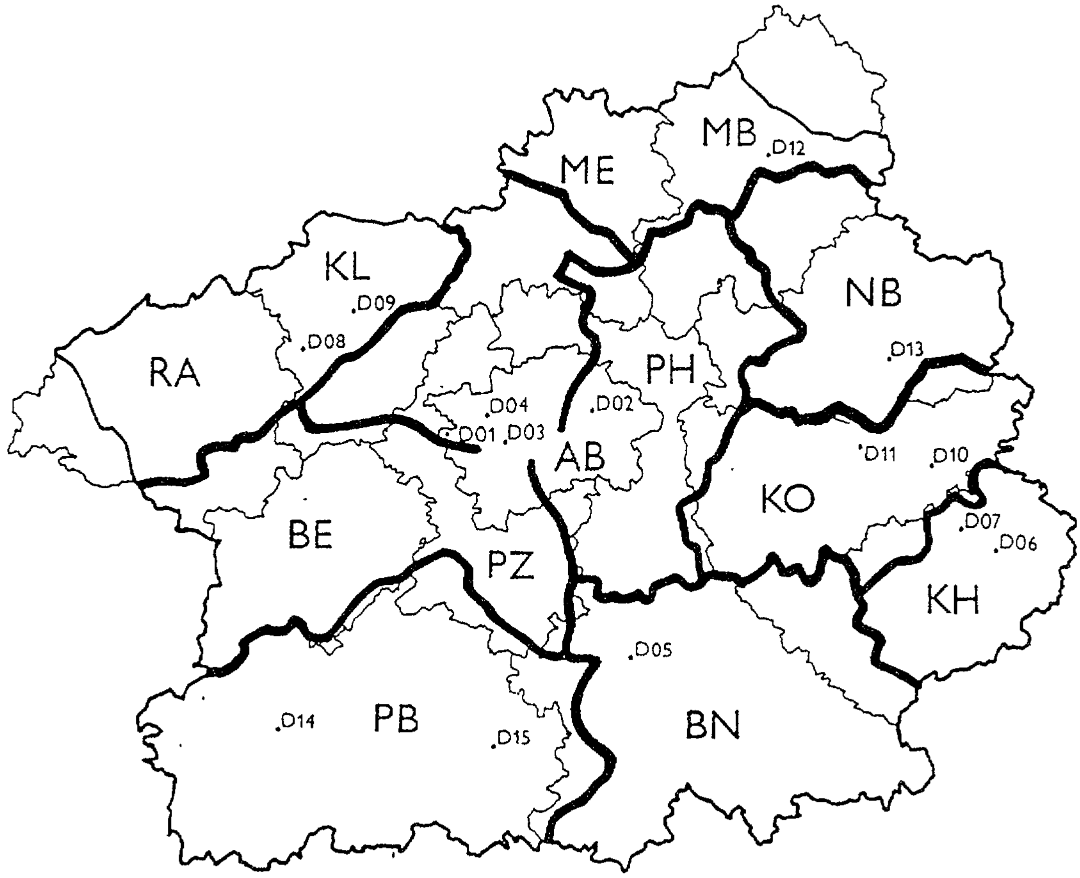


FIG. I.5. Location of dairies and their gathering regions.

Measurement of the milk samples was performed in native state and later, when volume activity of ^{137}Cs was less than 2 Bq L^{-1}, caesium concentration before measurement was used [I.9]. All samples were measured in the same laboratory by semiconductor gamma spectrometry. The samples from other regions were partly measured again in the National Reference Laboratory for Internal Exposure at Centre of Radiation Hygiene in Prague, partly in the local laboratories of hygienic service. All the local laboratories, equipped by semiconductor gamma spectrometry, took part in repeated intercomparison runs, which ensured good quality of the results [I.10].

Problems with representativeness arise when using ^{137}Cs content in samples of **meat**. The place of origin of the meat sample was given as the location of the slaughter-house, but it was not usually known where the animal came from. It is probable that they were not brought long distances, so the comparison of the results of meat contamination from CB (Tables I.31 and I.34) with results from neighbouring regions (Tables I.33 and I.36) is highly justified.

The interpretation of the measurement of contamination of **fruits and vegetables** is most complicated. From the very beginning, laboratory staff was instructed to measure samples of fruit and vegetables in the same way as they are usually consumed, i.e., washed, or for leafy vegetables, with the upper leaves removed, etc. Lots of samples of spinach were measured after deep freezing, which means that they were well washed, too. Later on, samples of fruits and vegetables were measured for export certification, and as some of them were exported just like they were harvested, it was necessary to measure them unwashed.

Sampling and measurement of **wheat** was planned well in advance. The whole CB region was covered, and production in subregions was also taken into account. Problems existed in connection with very low activity of ^{137}Cs in corn. There was not enough gamma spectrometry counting time and concentration methods were not ready in the summer 1986, so results of measurements of many samples were below the lower limit of detection. From this reason, the data from neighbouring regions were also supplied.

Also the collection and measurement of **animal feed** was planned well ahead, but for **silage**, it is nearly impossible to track the origin of plants.

All supplementary data on contamination of food stuffs and feed stuffs from neighbouring regions were statistically evaluated and are in tables in Section I.2.3. Data on individual samples from CB and neighbouring regions are on a diskette which is a part of the documentation, too.

Systematic study of **internal contamination of people** began also in the beginning of May, 1986. On a whole body counter equipped with a semiconductor detector, a reference group of approximately 35 volunteers living in Prague and its vicinity has been measured up to the present [I.11]. The monitoring interval was one month up to September, 1989, then it was extended to two months.

For the evaluation of ^{137}Cs and ^{134}Cs internal contamination of CB inhabitants, results gained during routine whole body counting of professionals for monitoring purposes were also used. (Tables I.25 and I.26). Possible interference by other sources of contamination was excluded by using the known ratio of ^{137}Cs to ^{134}Cs activity released from the Chernobyl reactor. The information from whole body counting was supplemented by data about internal contamination obtained from measurements of ^{137}Cs and ^{134}Cs in urine excreted in 24 hours [I.12]. The data from repeated nationwide surveys are in Section I.2.5, Information on Additional Measurements. The representativeness of the reference group for the whole of Czechoslovakia was repeatedly tested by comparing with results of whole body counting of people from other parts of the country [I.11]; significant differences were not found.

Daily intakes were measured only in June and July 1987, in order to find out some of the sources of disagreement of the model prediction and whole body counting. Volunteers, members of the reference group, were asked to collect the equivalent of their daily meal. ^{137}Cs activity was measured in homogenised samples by semiconductor gamma spectrometry.

I.2.2. ESTIMATION OF BASIC STATISTICAL CHARACTERISTICS OF PRESENTED DATA SETS

I.2.2.1. General methodology

Sets of data from environmental monitoring usually have wide distributions which are routinely approximated by logarithmic-normal distribution [I.13, I.14]. On the basis of the log-normal distribution, the geometric mean and geometric standard deviation are calculated. For balancing purposes and model predictions as well as for model validation purposes, however, the arithmetic mean is necessary. Since the distribution of data is supposed to be log-normal it is adequate to estimate the arithmetic mean from the mean of the log-normal distribution μ and its variance σ^2 as

$$\bar{x}_a = \exp\,(\mu + \frac{\sigma^2}{2})$$

The confidence interval bounds of $\bar{x}_a$ of a set of n data are obtained by multiplying $\bar{x}_a$ by

$$\exp\left[\pm t \left(\frac{\sigma^2}{n} + \frac{\sigma^4}{2(n-1)}\right)^{1/2}\right]$$

Sets of data may also contain some data which are recorded only as less than a specified value. As this value, rather than the minimum detectable value or detection limit, the minimum significant value (MSV) or decision limit or decision threshold should be used [I.15]. Distribution containing such a data is censored at the MSV, and the mean and the standard deviation can be estimated by plotting on a log-normal probability paper or by a linear regression computer code equivalent to it. With this procedure, just the number of results below the MSV is considered part of the total number of data forming the censored log-normal distribution, but the specified minimum significant value itself is not taken into account as being the censoring limit.

A more complicated situation arises if the set of data is a mixture of two or more subsets censored by two or more different MSV. In this case one must drop (censor) some significant data from sub-populations with MSV lower than the highest of the MSV, or use a more sophisticated solution. For this purpose a computer code using estimation by a maximum likelihood method which is based on information of Lawless [I.16] and Sampford and Taylor [I.17] was applied in CRH. The code allows for including all data from subsets, even with different MSV or censoring limits, and produces estimates of statistical parameters including the virtual number of data or degrees of freedom. In this case the confidence interval bounds about the arithmetic mean are to be calculated by a formula including, in addition to the standard error of the geometric mean m and the standard error of the geometric standard deviation σ, also a term incuding the covariance of these two parameters. Statistical parameters calculated by this computer code are presented in Tables I.24 to I.60 containing both the input data for models and the observation data intended for comparison with model predictions. A similar computer code [I.18] supported by SAS/STAT code [I.19] was developed in Oak Ridge. Some sets of data were evaluated by both the codes, with similar results.

I.2.2.2. Special cases

For most of the cases in which a sufficient number of data above the MSV was not available and/or the estimate of the geometric standard deviation was too high, N/A is given in the tables. For these cases an estimate using just the few data available and an enforced value of geometric standard deviation (GSD) was made, and by plotting on log-normal paper some very approximate estimates of geometric mean and by combining it with the GSD the arithmetic mean was also obtained. The resulting estimates are in Table I.61. The values of GSD used are mainly based on the analogy with the GSD=4 value found for the measured deposition. The value of GSD=2 is analogous to the GSD for barley 1987 and for apples/pears 1986. The value of GSD=4 used for beef III/88 and IV/88 can be considered also to be its approximate value in the neighbouring periods of monitoring. However, it has to be taken into account that these rough estimates based on an enforced value of the GSD and presented in Table I.61 therefore use only data which can be considered to be outliers, and the confidence of the estimates is very poor.

It was requested to provide for modellers also an estimate of the uncertainty of the data on activity concentration in the air. In CB region the air concentration was measured on two stations in parallel, both in Prague (AB) approx. 12 km each from the other (stations A7a and A7b - see Table 1.2.7. in [I.13]. The mean range of the logarithm of measured data in particular days (from 30 April to 9 May 1986) using the method of Studentized range gives an estimate of GSD of approx. 2.1 valid at least for the time of radionuclide cloud passage. Similarly for the whole ČSFR with 8 to 9 parallel stations active from 30.4. to 10.5., an estimate of GSD of approx. 2.8 was obtained. Since the area of CB is in log scale approx. in the middle between the area of AB and the ČSFR area, the log-mean of both GSDs can be used for CB, i.e., GSD approx. 2.4. From this GSD value we can estimate for CB an interval of quantiles (0.025 to 0.975) by dividing and multiplying the air concentration data in AB by approx. 6. However, to estimate the confidence interval of the air concentration time series measured in AB would be unrealistic.

I.2.3. TABLES OF OBSERVATION DATA

The final statistical characteristics of data sets concerning the results of measurement in soil and in individual items of the food chain are summarized in Tables I.24 to I.60 according to the commodities and time periods. In addition to evaluation of CB region data, the evaluation of B data from all regions of Bohemia is included as well as the evaluation OTH concerning regions neighbouring to CB only, i.e., North, East, South and West Behemian region. The aim of providing the evaluation of B and OTH data was to enable a comparison for any given commodity in cases where significant CB data were scarce. All these tables are available on diskette, too.

In some cases uncensored (significant) measurement results were scarce and large geometric standard deviations and consequently large values of confidence intervals are in Tables I.24 to I.60. For these data sets estimates of arithmetic means and their confidence intervals obtained by expert judgement based on enforced realistic values of the geometric standard deviation are provided in Table I.61, and the relevant procedure is discussed in more detail in Section I.2.2.2.

A map showing the locations of dairies and their gathering regions is provided in Figure I.5.

I.2.4. INFORMATION AVAILABLE ON DISKETTE

The database contains information on ^{137}Cs contamination as measured in individual samples of agricultural products, food stuffs, feed stuffs and on ^{137}Cs content in humans as measured in individual persons. It consists of **subdirectories** and **files**:

FEED - Contamination of feed stuffs in CB region
- Enscr86.obs: Specific activity in ensilaged crops in 1986
- Enscr87.obs: Specific activity in ensilaged crops in 1987
- Enshay86.obs: Specific activity in ensilaged hay in 1986
- Enshay87.obs: Specific activity in ensilaged hay in 1987
- Past-V86.obs: Specific activity in grass in May 1986, unmowed in 1986
- PastVI86.obs: Specific activity in grass in June 1986, unmowed in 1986
- Pas-V86.obs: Specific activity in grass in May 1986, mowed on April,30 1986
- Pas-VI86.obs: Specific activity in grass in June 1986, mowed on April,30 1986

FOOD - Contamination of food stuffs in CB region
- Milk86.obs: Activity concentration in consumed milk in 1986
- Milk87.obs: Activity concentration in consumed milk in 1987

- Milk88.obs: Activity concentration in consumed milk in 1988
- Beef.obs: Specific activity in beef in 1986 - 1989
- Pork.obs: Specific activity in pork in 1986 - 1989
- Poultry.obs: Specific activity in poultry in 1986 - 1989
- Meatoth.obs: Specific activity in other meat in 1986 - 1989
- Veg86.obs: Specific activity in different kinds of vegetable in 1986
- Veg87.obs: Specific activity in different kinds of vegetable in 1987
- Veg88.obs: Specific activity in different kinds of vegetable in 1988
- Applpear.obs: Specific activity in apple and/or pear in 1986 - 1988
- Fruit86.obs: Specific activity in different kinds of fruits in 1986
- Fruit87.obs: Specific activity in different kinds of fruits in 1987
- Fruit88.obs: Specific activity in different kinds of fruits in 1988

PRODUCTS - Contamination of agricultural products in CB region
- Barley.vap: Specific activity in barley in 1986 - 1989 (in most cases spring variety)
- Wheat.vap: Specific activity in winter wheat in 1986 - 1989
- Oats86.vap: Specific activity in oats in 1986
- Oats87.vap: Specific activity in oats in 1987
- Oats88.vap: Specific activity in oats in 1988
- Rye86.vap: Specific activity in rye in 1986
- Rye87.vap: Specific activity in rye in 1987
- Rye88.vap: Specific activity in rye in 1988

WBC - Information on whole body measurements and intake of humans
- Intake.obs : Daily intake in June and July 1987
- Wbc86.obs: Whole body content of adults in 1986
- Wbc87.obs: Whole body content of adults in 1987
- Wbc88.obs: Whole body content of adults in 1988
- Wbc89.obs: Whole body content of adults in 1989

OTHERS - Contamination of several food stuffs, feed stuffs and agricultural products in other regions of Bohemia (as additional information).
- Barley87.oth: Specific activity in barley in 1987
- Barley88.oth: Specific activity in barley in 1988
- Wheat87.oth: Specific activity in winter wheat in 1987
- Wheat88.oth: Specific activity in winter wheat in 1988
- Past5-86.oth: Specific activity in pasture grass in May, 1986
- Past6-86.oth: Specific activity in pasture grass in June, 1986
- Lvegma86.oth: Specific activity in leafy vegetable harvested in May 1986
- Lvegju86.oth: Specific activity in leafy vegetable harvested in June 1986
- Lvegjl86.oth: Specific activity in leafy vegetable harvested in July 1986
- Lvegsp87.oth: Specific activity in leafy vegetable harvested in Spring 1987
- Lvegsp88.oth: Specific activity in leafy vegetable harvested n Spring 1988
- Lefveg86.oth: Specific activity in leafy vegetable harvested in whole year 1986
- Lefveg87.oth: Specific activity in leafy vegetable harvested in whole year 1987
- Lefveg88.oth: Specific activity in leafy vegetable harvested in whole year 1988
- Enscr86.oth: Specific activity in ensilaged crops in 1986
- Enscr87.oth: Specific activity in ensilaged crops in 1987
- Enscr88.oth: Specific activity in ensilaged crops in 1988
- Enshay86.oth: Specific activity in ensilaged hay in 1986
- Enshay87.oth: Specific activity in ensilaged hay in 1987
- Enshay88.oth: Specific activity in ensilaged hay in 1988
- Fruit86.oth: Specific activity in fruit (apple/pear) in 1986
- Fruit87.oth: Specific activity in fruit (apple/pear) in 1987
- Fruit88.oth: Specific activity in fruit (apple/pear) in 1988

- Milk3-88.oth: Activity concentration in milk in 3. quarter of 1988
- Milk4-88.oth: Activity concentration in milk in 4. quarter of 1988
- Milk1-89.oth: Activity concentration in milk in 1. quarter of 1989
- Beef4-87.oth: Specific activity in beef in 4. quarter of 1987
- Beef1-88.oth: Specific activity in beef in 1. quarter of 1988
- Beef2-88.oth: Specific activity in beef in 2. quarter of 1988
- Beef3-88.oth: Specific activity in beef in 3. quarter of 1988
- Beef4-88.oth: Specific activity in beef in 4. quarter of 1988
- Beef1-89.oth: Specific activity in beef in 1. quarter of 1989
- Pork3-88.oth: Specific activity in pork in 3. quarter of 1988
- Pork4-88.oth: Specific activity in pork in 4. quarter of 1988
- Pork1-89.oth: Specific activity in pork in 1. quarter of 1989
- Codedist.oth: List of districts (subregions) in regions of Bohemia

I.2.5. INFORMATION ON ADDITIONAL MEASUREMENTS

This section contains data gained in some special measurements connected with the input data and with the data on internal contamination of people which were not included in the above sections but could be of some information value for the modellers.

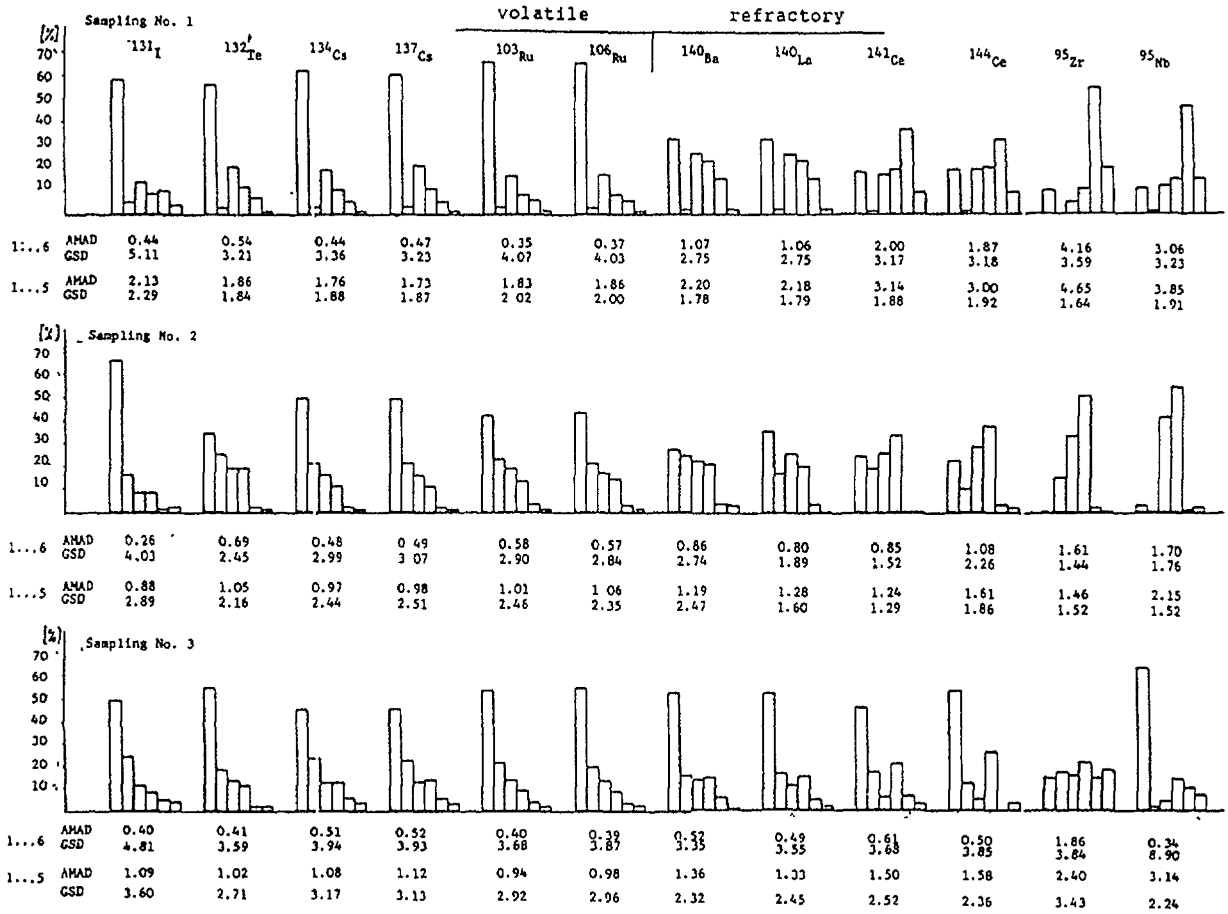
I.2.5.1. Aerosol particle size distribution [I.20]

After the Chernobyl accident 9 samplings of aerosols were carried out in Czechoslovakia in the period from 3 May to 20 June 1986 with a five stage cascade impactor (Type 235 Sierra Instruments) attached to a high volume air sampler with flow control. By means of semiconductor gamma spectrometry the activity of individual radionuclides was determined on slotted collection filters from individual stages of the impactor and on the back-up filter situated after the last stage.

Only 2 samplings were performed during the passage of contaminated air masses from Chernobyl over Czechoslovakia (first on 3 May to 4 May 86 and the second on 6 May 1986); unfortunately these samplings were made outside of Central Bohemia. For this reason the information was not included in the Scenario. However, it could contribute to an explanation of the behaviour of Chernobyl aerosol-particles. In Figure I.6, there are presented in differential form the size particle distribution of aerosol particles found for 12 radionuclides from two first samplings. The columns represent the percentage fractions on individual stages of the impactor of the total collected activity. Below the distributions the estimates of activity median aerodynamic diameter (AMAD in mm) and geometric standard deviation (GSD) determined from cumulative logarithmic-normal distributions are presented. In the first two lines are AMAD and GSD calculated from all values; in the second two, the AMAD and GSD are calculated omitting the back-up filter. These histograms indicate bimodal distributions with one part above approx. 0.5 mm and the second one below. Since the impactor gives no information on distributions below approx. 0.5 mm, it was possible only to estimate AMAD and GSD for the higher sub-distribution omitting the activity fraction on the back-up filter.

The aerosol particle size distributions of volatile radionuclides on the left and refractory ones on the right and their parameters on Figure I.6 differ significantly. The existence of greater relative contribution of larger particle subdistribution and resulting higher AMAD values for refractory radionuclides is evidence of two supposed distinct ways of origin of the aerosol particles; the condensation of volatile radionuclides and the dispersion of the nuclear fuel by explosion and fire. For ^{137}Cs both ways are to be considered.

These results support the assumption of lower leacheability of ^{137}Cs from some aerosol particles and thus its possible lower transferability in the environment and also lower absorbed fraction in the GI tract of humans and animals [I.21] than that usually assumed by the models [I.22]. This could contribute to an explanation for overestimation of ^{137}Cs body burdens calculated by individual models.



Sampling No. 1

		131I	132Te	134Cs	137Cs	103Ru	106Ru	140Ba	140La	141Ce	144Ce	95Zr	95Nb
1...6	AMAD	0.44	0.54	0.44	0.47	0.35	0.37	1.07	1.06	2.00	1.87	4.16	3.06
	GSD	5.11	3.21	3.36	3.23	4.07	4.03	2.75	2.75	3.17	3.18	3.59	3.23
1...5	AMAD	2.13	1.86	1.76	1.73	1.83	1.86	2.20	2.18	3.14	3.00	4.65	3.85
	GSD	2.29	1.84	1.88	1.87	2 02	2.00	1.78	1.79	1.88	1.92	1.64	1.91

Sampling No. 2

		131I	132Te	134Cs	137Cs	103Ru	106Ru	140Ba	140La	141Ce	144Ce	95Zr	95Nb
1...6	AMAD	0.26	0.69	0.48	0 49	0.58	0.57	0.86	0.80	0.85	1.08	1.61	1.70
	GSD	4.03	2.45	2.99	3 07	2.90	2.84	2.74	1.89	1.52	2.26	1.44	1.76
1...5	AMAD	0.88	1.05	0.97	0.98	1.01	1 06	1.19	1.28	1.24	1.61	1.46	2.15
	GSD	2.89	2.16	2.44	2.51	2.46	2.35	2.47	1.60	1.29	1.86	1.52	1.52

Sampling No. 3

		131I	132Te	134Cs	137Cs	103Ru	106Ru	140Ba	140La	141Ce	144Ce	95Zr	95Nb
1...6	AMAD	0.40	0.41	0.51	0.52	0.40	0.39	0.52	0.49	0.61	0.50	1.86	0.34
	GSD	4.81	3.59	3.94	3.93	3.68	3.87	3.35	3.55	3.68	3.85	3.84	8.90
1...5	AMAD	1.09	1.02	1.08	1.12	0.94	0.98	1.36	1.33	1.50	1.58	2.40	3.14
	GSD	3.60	2.71	3.17	3.13	2.92	2.96	2.32	2.45	2.52	2.36	3.43	2.24

FIG. I.6. Aerosol particle size distributions of individual radionuclides from post-Chernobyl samplings. From left to right are stages Nos (aerodynamic diameter in μm) 6(0.01), 5(0.45), 4(0.95), 3(1.5), 2(3.0), 1 (7.2).

The difference in estimation of inhalation intake from whole body counting [I.11] and from model calculation (Section I.3) could be explained also in this way.

I.2.5.2. Additional soil measurements

The first set of input data for VAMP CB Scenario contained 152 data on ^{137}Cs, ^{134}Cs, and ^{103}Ru deposition in CB region after the Chernobyl accident (see Table I.11). These data were gained by an extensive soil sampling program in June 1986. The sampling method is described in Section I.1.3. Due to the great variability of the deposition it was decided already in 1986 to do additional research with the aim being to verify and to analyse the variability of surface activity found. Part of this additional soil sampling on small areas was done simultaneously with the deposition survey in June 1986, part in September 1986, but the results of these measurements were not included in the Scenario. They are presented now so as to illustrate the extreme variability of Chernobyl deposition even on small areas. In Table I.62 there is an evaluation of the variability of deposition in CB; in Figure I.7 dependence of the geometric standard deviation of the ^{137}Cs deposition on the sampling area for the whole territory of ČSFR is presented. Also additional measurements using in situ gamma spectrometry and airborne measurements were performed. The aim of these measurements was mainly to verify the big variability in deposition in CB region as indicated by the bare soil sampling data; however, to a certain extent, the new in situ gamma spectrometry measurements include also the contribution on dry deposition by interception and impaction on vegetation during passage of the contaminated air in 1986.

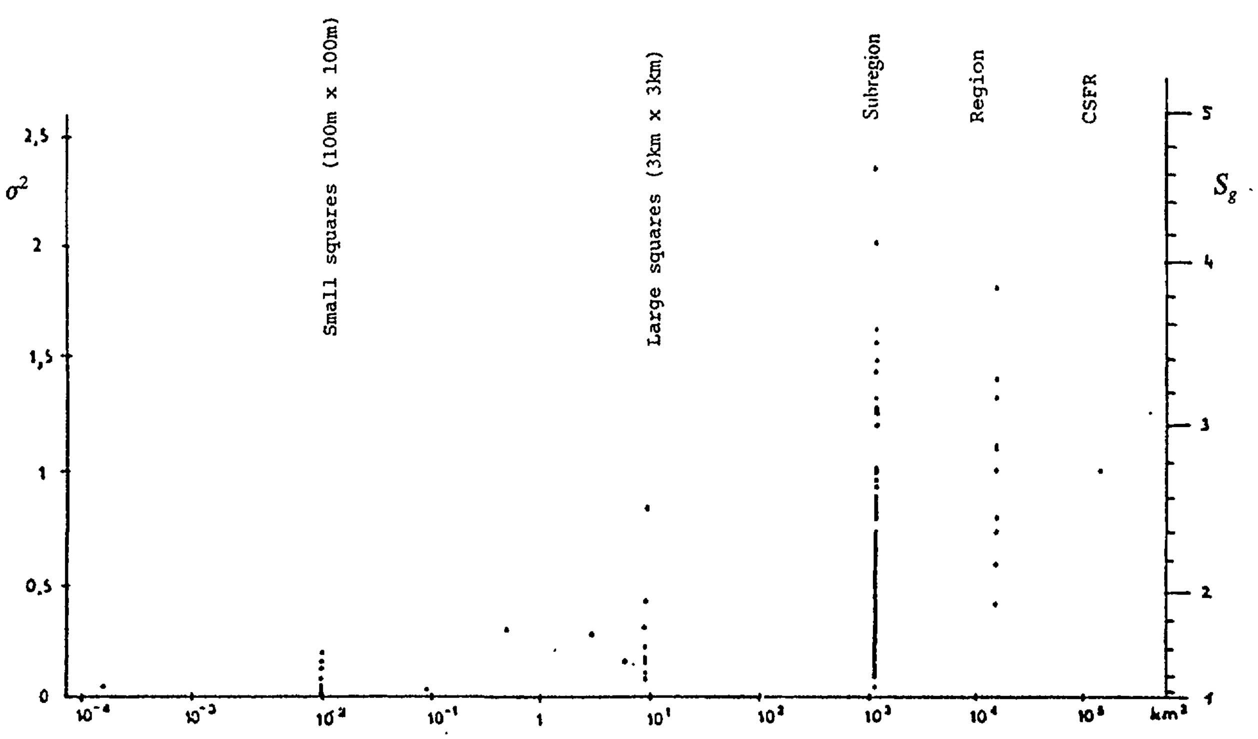


FIG. I.7. Dependence of variance of the logarithm naturalis σ^2 and the geometric standard deviation S_g of the superficial acitvity of Cs-137 on sampling area.

(a) Measurement of deposited ^{137}Cs and ^{134}Cs activity in large and small squares from soil sample collection in september 1986

The identification of the sampling sites corresponds (if possible) to that used in the CB Scenario Description (Section I.2.3).

For the evaluation of the significance of observed variations, some sets of up to 10 samples each were taken in squares of 0.1 × 0.1 km^2 and 3 × 3 km^2, as well as a set of samples along some profiles. This demonstrated the variability in soil contamination and enables deduction of the difficulties in distinguishing from each other the regional, intermediate and local variations [I.23, I.24] (Figure I.7). In CB region the sets of such samples were taken in two places and the results are summarised in Tables I.63 and I.64.

(b) Additional soil contamination data gained by in situ gamma spectrometry

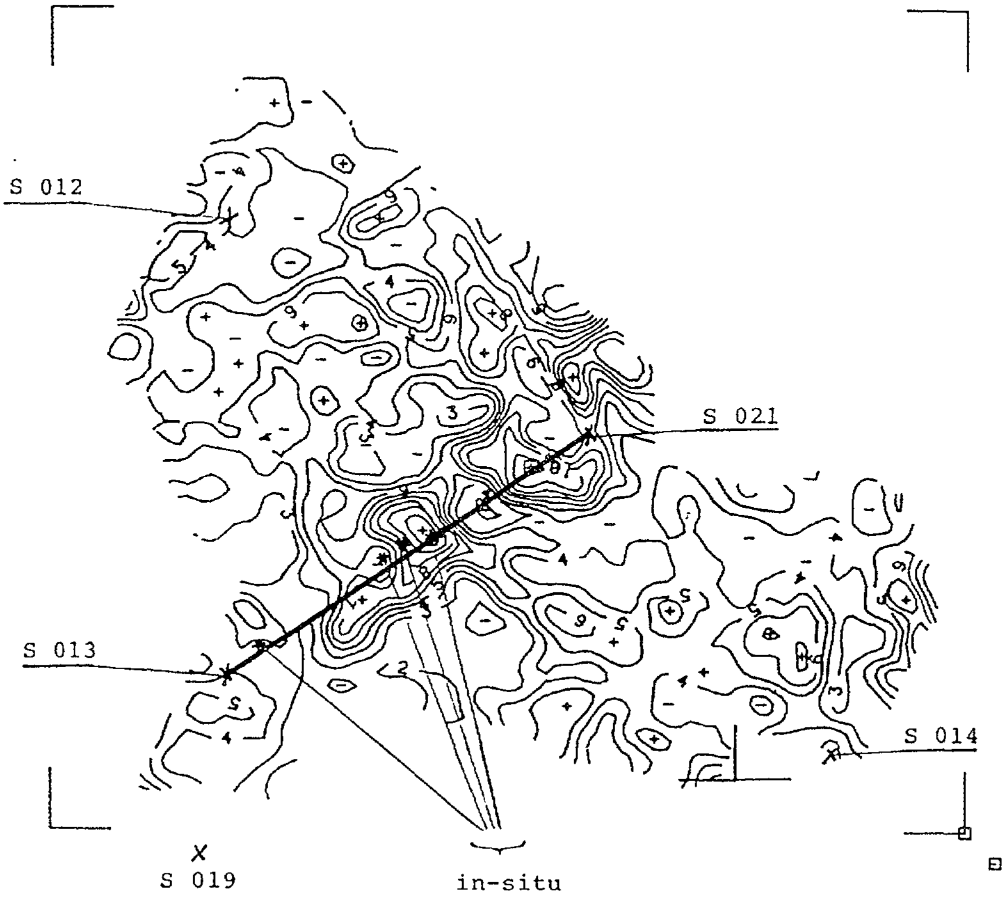
The in situ gamma spectrometry was performed by NRL for Internal Contamination of Centre of Radiation Hygiene. Evaluation of the measurement was performed according to Ref. [I.25]. For the measurements on arable land the assumption of homogeneous distribution of ^{137}Cs in soil was used, and the specific activity of this radionuclide was determined; for nonarable land the exponential depth distribution was assumed with relaxation depth (relaxation depth is a conventionally used quantity expressing the depth in which the activity concentration decreases on 1/e its original value) of 3 cm, and the surface activity (or deposition) was determined. Measurements were performed on places with rather high and very low Chernobyl deposition of ^{137}Cs in Central Bohemia (CB). The places were chosen on the basis of a detailed survey carried out by soil sampling in 1986, the deposition data provided by this survey being also the most important input data for VAMP CB scenario. Data on the deposition of ^{137}Cs gained by in situ gamma spectrometry are summarised in table I. 65.

Some of the in situ measurements were again verified by soil sampling with the following results:

Date	Sampling site	^{137}Cs concentration	
		in situ	sample
29-Aug-91	BN S013 (arable)	36.2 Bq kg^{-1}	41.8 Bq kg^{-1}
29-Aug-91	BN S013 (meadow)	13.71 kBq m^{-2}	13.5 kBq m^{-2}
30-Aug-91	KL S038	1.89 kBq m^{-2}	1.6 kBq m^{-2}

When the exact place of sampling was known and the surface was not disturbed, the agreement between the results of soil sample measurement in 1986 and insitu measurement is very good (see in the above table results from places in AB). In places where identification was rather difficult the differences were greater. When the collection of soil samples was done on arable land, the evaluation of in situ measurements could be done only in Bq kg^{-1}. Comparison with original values from the year 1986 in Bq m^{-2} was done using an assumption of homogeneous distribution of ^{137}Cs in soil down to 25 cm and soil density 1600 kg m^{-3}. The deposition was calculated by multiplying the specific activity on soil by the factor of 400.

To study in more detail the very uneven deposition pattern found in the soil contamination survey in 1986, the aerial survey of ground contamination in BN subregion was carried out in 1992 on area of approx. 100 km^2 (15 × 7 km^2). The chosen area included sampling points S012, SO13, S014, SO19, S021. The deposition of ^{137}Cs on this area ranged from approx. 2 kBq/m^2 to approx. 40 kBq/m^2 (Figure I.8). These results were again confirmed by insitu spectrometry carried out on 3 places chosen according to a map of contamination levels resulting from the aerial survey.



Note: Values of individual isoplets of deposition should be multiplied by a factor of about 3 as the calibration of the spectrometer was performed with assumed plane distribution of ^{137}Cs on soil instead of using the more realistic exponential depth distribution as in the case of in-situ measurements.

FIG. I.8. Map of deposition of ^{137}Cs (kBq m^{-2}) in part of BN subregion according to aerial survey.

(c) Depth distribution of caesium radioisotopes determined on two places in CB region

This measurement was performed so as to verify assumptions under which activity of ^{137}Cs from in situ measurements were calculated (see Table I.66).

I.2.5.3. Nationwide survey of internal contamination of people by ^{137}Cs through measurement of its daily excretion in urine

The original purpose of this nationwide survey was to find extreme values of internal contamination for some groups of inhabitants and also to find out if there is a correlation between internal contamination of people and fallout level. The effort to bring people for whole body counting from all parts of Czechoslovakia began in May 1986 [I.11]. However, it was not possible to include homogeneous groups of inhabitants from the whole territory and from different social environments. Therefore, it was decided to measure internal contamination by caesium radionuclides through samples of daily urine [I.12]. Collection of samples across the Czechoslovakia was organized by Departments of Radiation Hygiene of Regional Hygienic Service. They were asked to collect each year 30 samples from 30 persons per region, with 5 to 6 samples per subregion; always they had to include the subregion with the highest fallout. Recommendation to find people with different nutritional habits, esp. self-suppliers, was also given. In CB region subregions BN, KH, MB, PV and NB were included. The selection of subregions with higher fallout might cause, rather biased estimation, however. Samples of urine were measured by semiconductor gamma spectrometry, in the years 1987 and 1988, in native state; later a caesium concentration method was used. Samples from CB region were measured in NRL for Internal Exposure at Centre of Radiation Hygiene in Prague. Correlation between results of whole body counting (retention of the ^{137}Cs in the body) and excreted ^{137}Cs in 24-hour samples was established using altogether 185 pair values. It was found that daily excretion was 0.62% of the retention which does not differ significantly from the value 0.64%, calculated from a retention function according to Recommendation ICRP 30 [I.26] and $f_u=0.9$.

According to the original aim, each year the possible difference for the average body content of ^{137}Cs in the reference group against average body content of ^{137}Cs, calculated from excretion rate of ^{137}Cs, was examined [I.11, I.12]. No significant differences were found in any of the time periods. For the CB scenario, however, the results of this research have only informative value as the so called reference group is not fully identical with the group of people whose results from whole-body counting were used for CB Scenario evaluation (Table I.25); also, representativeness was tested for the whole country, not for CB region only.

Therefore, results of body content of ^{137}Cs for CB region as measured by whole-body counter and calculated from excretion rate of ^{137}Cs by urine, summarized in the Table I.67, were statistically tested, too. Neither of the differences is significant according to the t-test applied to the logarithms of the geometric means and standard deviations.

I.3. ESTIMATION OF MEAN EXPOSURE IN REGION CB

I. Bučina, Z. Prouza, H. Müller, I. Malátová

Radiation exposure of people via the different pathways (external exposure from cloud and ground, internal exposure from inhalation and ingestion) has been an endpoint of the model calculations in scenario CB for which no direct measurements exist. Therefore this part of the exercise can not be regarded as a model validation exercise, but a model intercomparison exercise only.

However, some additional information has been made available which was given to the modellers in the CB scenario. Based on all information available at present, a best estimate of radiation exposure from ^{137}Cs in CB is given in this section. Due to the assessment tasks, this estimation considers the effective dose equivalent for adult persons (age 20 years at time of deposition), averaged over the whole region CB.

I.3.1. INHALATION DOSE

The average 50-year committed effective dose equivalent from inhalation $H_{E,inh}$ for the CB region can be estimated in a common way from the time integrated activity concentration of radionuclides in the air:

$$H_{E,inh} = C_{air} \cdot I \cdot f_{inh} \cdot g_{inh}$$

with

C_{air} time-integrated activity concentration of ^{137}Cs in air ($Bq \cdot h \cdot m^{-3}$),
I inhalation rate ($m^3 \cdot h^{-1}$),
f_{inh} reduction factor considering reduced activity concentration in buildings, and
g_{inh} dose conversion factor ($Sv \cdot Bq^{-1}$) for inhalation.

In the CB scenario, ^{137}Cs concentration in air had been given for two sites within subregion AB only (see Section I.2.5.1), with a time-integrated concentration of about 610 $Bq \cdot h \cdot m^{-3}$. For the time period before 10:00 on 30 April 1986 no data had been given, but it is known that the cloud had arrived already at about 20:00 on 29 April 1986. Assuming a linear increase of activity concentration in air during this time interval, another 160 $Bq \cdot h \cdot m^{-3}$ must be added to the value given above (as advised already in the CB scenario), but it has to be stressed that there is a very large uncertainty about this estimate. Due to the very small number of sampling sites there is an additional large uncertainty on the average air concentration in the whole region CB. Taking into account (see also Section I.2.2.2) additional published data on ^{137}Cs concentration in air [I.13, I.26] and a previous inhalation intake estimate [I.11], a mean value of 600 $Bq \cdot h \cdot m^{-3}$ for average C_{air} in the whole CB region is estimated by expert judgment, with a 95% confidence interval from 400 to 900 $Bq \cdot h \cdot m^{-3}$.

The average inhalation rate I for adults is estimated to be 1 $m^3 \cdot h^{-1}$ with an uncertainty interval given by a factor of $1.25^{\pm 1}$.

The reduction factor f_{inh} considering lower activity concentrations in indoor air can be estimated from

$$f_{inh} = 1 - F_o + F_o \cdot f_b$$

with

F_o indoor occupancy factor, and
f_b filtering factor of buildings.

Using the demographic information given in the CB scenario, a mean indoor occupancy factor of 0.83 with an uncertainty interval given by a factor $1.12^{\pm 1}$ has been estimated. The filtering factor for buildings is assumed to be 0.7 with uncertainty factor $1.14^{\pm 1}$. This results in a mean reduction factor f_{inh} of 0.75 with confidence bounds 0.67 to 0.83.

The dose conversion factor for inhalation of ^{137}Cs, $g_{inh} = 8.6 \cdot 10^{-9}$ Sv·Bq^{-1}, as given in the CB scenario description, is based on the model of ICRP publication 30 [I.25]. This value is based on the assumption that caesium deposited in the lung has a rentention factor of 1.0, i.e. that it is totally absorbed in the respiratory or gastrointestinal tract. This assumption might give some overestimation of the inhalation dose in the case of caesium from the Chernobyl fallout. Experiments on rats with dust collected in an air conditioning system in subregion AB during the first days of May 1986 resulted in an average fraction of Cs absorbed in the gastrointestinal tract of 56% [I.21]. The particles applied in this experiment were mainly rather big aerosol particles: their count median aerodynamic diameter was 1.55 μm and mass median, 12 μm. Approximately 50% of the Cs in the Chernobyl fallout was bound on aerosol particles with aerodynamic diameter less than 0.5 μm (see Figure I.6 in Section I.2.5.1) which can be supposed to be rather soluble and fully absorbable in the pulmonary region of the lung. The other 50% is mainly deposited in the nasopharingeal and tracheobronchial regions, from where the non-absorbable fraction is transported very fast to the gastrointestional tract and excreted from there. Thus it is estimated that for Chernobyl caesium in CB the effective absorbable fraction is about 0.75 with confidence bounds 0.66 to 0.85. The dose conversion factor as given above is reduced by this factor.

Taking into account the estimated mean values and their uncertainty intervals of all factors discussed above, a mean inhalation dose $H_{E,inh}$ for region CB of 2.9 μSv with a confidence interval from 1.8 to 4.6 μSv results. This corresponds to a mean activity intake by inhalation of 450 Bq from which only about 200 Bq is not excreted fast (in approx. two days) and so can be detected by whole body measurements (see Section I.3.2).

A more direct way for estimating the dose due to inhalation is to infer it from the whole body measurements performed at the end of and shortly after the time of passage of the main part of the radioactive cloud from the Chernobyl accident. Up to that time intake of radionuclides by ingestion is assumed to be still rather low in the CB region as compared to intake by inhalation.

Data on retention of ^{137}Cs for 34 persons who stayed mainly in subregion AB have been measured from 4 May to 9 May 1986 (these data are given in the diskette mentioned in Section I.2.4, file WBC86.OBS in subdirectory WBC). The ^{137}Cs activity concentration in air dropped steeply after 8 May, and so inhalation intake after 9 May 1986 can be considered to be negligible for the total inhalation dose. The arithmetic mean of ^{137}Cs retention was about 215 Bq with 95% confidence bounds 183 to 254 Bq. The contribution of ingestion to this intake can be estimated only very roughly: it is assumed that the ingestion intake rate from 1 May to 8 May was at the most the same as the mean rate in the period 8 May to 15 June. From the retention data given in Table I.25 a whole body content of 283 Bq can be estimated for 15 June. Assuming a half-life of 110 d for Cs in the human body, an intake of about 120 Bq between 9 May and 15 June can be estimated, i.e., a mean intake rate of about 3.2 Bq per day. This rough guess of the intake rate seams to be reasonable: measured milk contaminations in CB during these first days were on the order of a few up to about 10 Bq·kg^{-1}, and vegetables were not yet ready for harvest. If this intake rate is also applied to the period before 9 May, a contribution of ingestion of about 20 Bq to the body burdens measured in that time period results. Subtracting this value from the measured body content, a contribution of inhalation of about 195 Bq with 95% confidence bounds from 165 to 220 Bq is estimated. Using the dose conversion factor of $1.4 \cdot 10^{-8}$ Sv·Bq^{-1} [I.25] as for ingestion (i.e., rounded $8.6 \cdot 10^{-9}$ Sv·Bq^{-1}/0.63) the resulting 50-year committed effective dose equivalent is 2.7 μSv with approximate 95% confidence bounds of 2.3 μSv and 3.2 μSv.

The first estimate of the inhalation exposure based on activity concentration in the air fits well within the bounds of the estimate based on the whole body measurement. It is obvious, however, that the deduction from the body content is more confident. This is because this estimate does not need the rather uncertain assumptions on activity concentration in the air before the measurements started, the occupancy and filtering factors and on inhalation rate or the knowledge of the aerosol solubility and resulting fraction of ^{137}Cs absorbed in the body. Although the measured persons were mainly from subregion AB (Prague), their residence and working places covered a much wider area than represented by just two aerosol sampling stations. It should be added that the variability of the air concentration within CB (see Section I.2.2.2) is supposed to be significantly smaller than the variability of the deposition on bare soil caused by non-uniform rain conditions during the passage of the Chernobyl cloud [I.13].

For the use in Sections I.3.3 and I.3.4, the integrated activity concentration in the air can be calculated back from the body content, which results in 550 $\mathrm{Bq \cdot h \cdot m^{-3}}$ with 95% confidence bounds from 380 $\mathrm{Bq \cdot h \cdot m^{-3}}$ to 800 $\mathrm{Bq \cdot h \cdot m^{-3}}$.

I.3.2. INGESTION DOSE

The most realistic estimation of ingestion dose is derived from whole body counting of CB inhabitants, because in comparison with calculation from measured food stuff contaminations it needs no additional assumptions except the estimate of the inhalation intake. It reflects properly all specificity of the CB region as well as of the Chernobyl origin of the contaminant.

Ingestion intakes (Table I.68) were calculated from mean body ^{137}Cs retention (Table I.25) measured by a whole body counter. For each time interval the apparent average daily intakes were calculated assuming single ingestion intake in the middle of each interval. The contributions from previous intakes were subtracted using the retention function according to ICRP 30 [I.25].

In Section I.3.1, a contribution to measured body content due to inhalation was estimated as 195 Bq (the inhalation intake of soluble and fully absorbable caesium is then about 310 Bq since only 63% of inhalation intake of a standard aerosol is supposed in the ICRP model to be deposited in respiratory tract). This equivalent of inhalation intake was subtracted from the total intake in May 1986.

Comparison with directly measured content of ^{137}Cs in daily meals shows good agreement of the arithmetic mean, 5.7 Bq (Table I.27) from measurement of samples from June and July 1987 with derived values for the 2nd and 3rd quarters of 1987 in Table I.68. The total ingestion intake of ^{137}Cs until the end of the 1st quarter of 1989 is about 4400 Bq; using ICRP 30 dose conversion factor $1.4 \cdot 10^{-8}$ $\mathrm{Sv \cdot Bq^{-1}}$ the 50 year committed effective dose equivalent for ingestion in this time interval is 62 μSv.

The 95% confidence interval bounds of this value can be supposed to be proportional to the bounds about the arithmetic mean of the total ^{137}Cs intake to the human body which were estimated by propagation of error from the bounds of the original data on retention given in Table I.25 and the almost negligible estimate of bounds about the subtracted equivalent of inhalation intake. However, the influence of individual variations and local differences from the values used in the ICRP model of retention on the relation of intake to the resulting retention and dose is neglected. The representativeness of the whole body counting results was not ensured by random selection of people. Measured people came mainly from AB (Prague). Therefore, the representativeness of this group for the whole CB region was examined by comparison of the body contents as measured by whole body counter with the calculated values from the excretion rate of ^{137}Cs in urine collected from inhabitants of CB, excluding AB (see Section I.2.5.3). The differences found were not significant and therefore it is possible to suppose the results from whole body counting to be representative for CB. Thus the approximate bounds about the estimated value 62 μSv as evaluated by propagation of error are 58 μSv and 70 μSv.

I.3.3. EXTERNAL DOSE FROM GROUND

The external dose from ground-deposited ^{137}Cs was calculated as

$$H_{E,eg}(\Delta T) = D(T_o) \cdot h_{E,eg}(\Delta T) \cdot f_{eg}$$

with

$H_{E,eg}(\Delta T)$	effective dose equivalent (Sv) due to external exposure from ground deposited ^{137}Cs within time interval ΔT after time T_o,
$D(T_o)$	surface activity ($Bq \cdot m^{-2}$) deposited at time T_o onto a lawn,
$h_{E,eg}(\Delta T)$	effective dose equivalent ($Sv \cdot m^2 \cdot Bq^{-1}$) due to external exposure within time interval ΔT after deposition of 1 $Bq \cdot m^{-2}$ ^{137}Cs on a lawn at time T_o, and
f_{eg}	correction factor for residence at different environments (it considers different deposition patterns and shielding by different types of buildings).

The mean deposition $D(T_o)$ of ^{137}Cs in CB region onto lawns was estimated from the mean deposition onto bare soil and an estimated additional dry deposition onto grass. The reason for that is that wet deposition, which was the dominant part of Cs deposition from Chernobyl fallout in CB, is independent of the type of surface while dry deposition depends on the type of plant canopy. On the basis of a log-normal distribution the mean total deposition on bare soil in CB was estimated (see Table I.11) as 5530 $Bq \cdot m^{-2}$ with a 95% confidence interval from 4000 to 7600 $Bq \cdot m^{-2}$.

The mean time-integrated concentration of ^{137}Cs in near-ground air in CB was estimated in Section I.3.1 to be 550 $Bq \cdot h \cdot m^{-3}$ with a 95% confidence interval from 380 to 80 $Bq \cdot h \cdot m^{-3}$. Assuming a dry deposition velocity of 0.7×10^{-3} $m \cdot s^{-1}$ (uncertainty factor $1.42^{\pm 1}$) the mean dry deposition of ^{137}Cs onto grass is 1400 $Bq \cdot m^{-2}$ with a confidence interval from 860 to 2300 $Bq \cdot m^{-2}$.

Using these values, the mean total ^{137}Cs deposition $D(T_o)$ onto a lawn of the CB region is 6900 $Bq \cdot m^{-2}$ with a 95% confidence interval 5300 to 8800 $Bq \cdot m^{-2}$.

The effective dose equivalent $h_{E,eg}(\Delta T)$ due to external exposure during the time period ΔT after deposition of 1 $Bq \cdot m^{-2}$ ^{137}Cs onto a lawn was calculated based on the time dependency of the gamma dose rate over the lawn measured after the Chernobyl accident [I.27, I.28]:

$$h_{E,eg}(\Delta T) = g_{E,eg} \cdot \int_0^{\Delta T} e^{-\lambda_r \cdot t} \cdot y(t) \cdot dt$$

with

$g_{E,eg}$	effective dose equivalent rate ($Sv \cdot m^2 \cdot Bq^{-1} \cdot h^{-1}$) for gamma radiation from unit ^{137}Cs deposition on ground (This factor is valid for an infinite plane source on a ground surface with a roughness corresponding to an effective depth of 3 mm of the source in soil.);
λ_r	physical decay constant ($2.3 \cdot 10^{-2}$ a^{-1} for ^{137}Cs); and
$y(t)$	correction function for shielding due to leaching of the radionuclides in the soil.

The value $g_{E,eg} = 1.3 \cdot 10^{-12}$ $Sv \cdot m^2 \cdot Bq^{-1} \cdot h^{-1}$ is taken from [I.28]. Though there is certainly some uncertainty about this factor and also some variability amongst individuals, this is not further treated here.

According to the findings of extensive measurements after the Chernobyl accident [I.29] the following correction function for leaching is used:

$$y(t) = p_1 \cdot e^{-p_2 \cdot t} + p_3$$

with

$p_1 = 0.54 \pm 0.04$,
$p_2 = 0.37 \pm 0.06$, and
$p_3 = 0.46 \pm 0.03$ ($p_1 + p_3 = 1$, since initial shielding is considered already in $g_{E,eg}$).

Using these data, the integral in the above equation for $h_{E,eg}(\Delta T)$ for the time interval $\Delta T = 3$ a equals 2.3 a. Its uncertainty is estimated to be given by a factor of $1.2^{\pm 1}$.

Finally, $h_{E,eg}(\Delta T)$ has the value 26 $nSv \cdot m^2 \cdot Bq^{-1}$ (estimated confidence interval 22 to 31 $nSv \cdot m^2 \cdot Bq^{-1}$) for $\Delta T = 3$ a.

The correction factor for residence at different environments f_{eg} which considers differences of the deposition pattern and shielding by different types of buildings can be calculated by

$$f_{eg} = \sum_{i=1}^{4} f_i \cdot c_{g,i}$$

where f_i are fractions of time which people spend at location i:

$f_1 = (1 - F_o) \cdot (1 - F_p)$ outdoors, rural or subrural area;
$f_2 = (1-F_o) \cdot F_p$ outdoors, urban area;
$f_3 = F_o \cdot (1 - F_p)$ indoors, rural or subrural area;
$f_4 = F_o \cdot F_p$ indoors, urban area;

with

F_o	indoor occupancy factor,
F_p	the urban fraction of a country's population.

Using the demographic information given in the CB scenario and the occupancy factors later developed in the Czech Republic, the mean indoor occupancy factor was calculated. The mean value $F_o = 0.83$ was obtained; the uncertainty is assumed to be given by a factor of $1.12^{\pm 1}$. For the urban fraction the value presented in the CB scenario ($F_p = 0.68$) was used assuming an uncertainty factor $1.07^{\pm 1}$. $c_{g,i}$ are the correction factors for the locations i as given above: they are defined as the ratio of gamma effective dose equivalent rate from ground in environment i to that in open areas. For $c_{g,i}$ the following confidence intervals have been estimated from the location factors given by [I.30] considering that in the CB scenario mostly wet deposition occured:

$c_{g,1} = 0.9\text{-}1.0$ outdoors, rural or subrural area;
$c_{g,2} = 0.3\text{-}0.7$ outdoors, urban area;
$c_{g,3} = 0.05\text{-}0.3$ indoors, rural or subrural area;
$c_{g,4} = 0.01\text{-}0.1$ indoors, urban area.

Using these ranges of occupancy, urban, and location correction factors, a Monte-Carlo calculation results in a mean total correction factor f_{eg} of 0.19 with an uncertainty interval given by a factor of $1.3^{\pm 1}$.

The calculation of the external dose $H_{E,eg}$ from ground-deposited ^{137}Cs within 3 years after deposition using the ranges of parameter uncertainty as given above resulted in a mean effective dose equivalent of 34 μSv with a 95% confidence interval from 20 to 52 μSv.

I.3.4. EXTERNAL DOSE FROM CLOUD

The mean external effective dose equivalent from radionuclides in air is given by

$$H_{E,ec} = C_{air} \cdot g_{ec} \cdot f_{ec}$$

with

$H_{E,ec}$	external effective dose equivalent from cloud (Sv),
C_{air}	time-integrated activity concentration in outdoor air ($Bq \cdot h \cdot m^{-3}$),
g_{ec}	dose conversion factor for gamma radiation from cloud ($Sv \cdot m^2 \cdot Bq^{-1} \cdot h^{-1}$),
f_{ec}	shielding correction factor for residence at different environments.

The mean time-integrated air concentration of ^{137}Cs in Region CB is assumed to be 550 $Bq \cdot h \cdot m^{-3}$ with 95% confidence bounds from 380 to 800 $Bq \cdot h \cdot m^{-3}$ as estimated in Section I.3.1.

The dose conversion factor g_{ec} for gamma radiation from ^{137}Cs in the cloud is assumed to be $9.3 \cdot 10^{-11}$ $Sv \cdot m^3 \cdot Bq^{-1} \cdot h^{-1}$ as given in the CB scenario description. No uncertainty has been considered for this quantity.

The modification of the radiation dose due to shielding for different environments can be expressed by

$$f_{ec} = \sum_{i=1}^{4} f_i \cdot c_{c,i}$$

with

f_i fraction of time people spend at environment i (see Section I.3.3),
$c_{c,i}$ correction factor for location i (gamma dose rate from the cloud relative to that outdoors in open areas, i.e., without houses).

As in Section I.3.3, the mean indoor occupancy factor is assumed to be 0.83 with uncertainty bounds given by a factor $1.12^{\pm 1}$, and the urban fraction 0.68 with uncertainty factor $1.07^{\pm 1}$. This results in the same factors f_i as used for calculating exposure from ground. $c_{c,i}$ are the correction factors for the different environments: they are defined as the ratio of gamma effective dose equivalent rate from cloud in environment i to that in open areas. The following confidence intervals (based on [I.27]) have been assumed for $c_{c,i}$:

$c_{c,1}$ = 0.9-1.0 outdoors, rural or subrural area;
$c_{c,2}$ = 0.4-0.8 outdoors, urban area;
$c_{c,3}$ = 0.1-0.6 indoors, rural or subrural area;
$c_{c,4}$ = 0.05-0.2 indoors, urban area.

The Monte-Carlo calculation using the given ranges of residence habits and correction factors results in a mean shielding factor f_s of 0.28 with a 95% confidence interval given by a factor of $1.3^{\pm 1}$. The mean external effective dose equivalent $H_{E,ec}$ is 14 nSv with a 95% confidence interval from 9.2 to 22 nSv. This means that external dose from the cloud is negligible in the CB scenario as compared with the other exposure pathways.

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TABLE I.1. MONTHLY AVERAGES OF TEMPERATURE AND RAINFALL IN PRAGUE

Month	Temperature (°C)	Precipitation (mm month^{-1})
January	-0.8	20
February	0.3	22
March	4.2	22
April	9.5	34
May	14.7	57
June	18.2	65
July	19.9	77
August	19.2	68
September	15.3	38
October	9.6	39
November	4.0	24
December	1.0	25

TABLE I.2. ^{137}Cs AND ^{134}Cs CONCENTRATIONS IN GROUND-LEVEL AIR IN PRAGUE FROM APRIL 30 TO MAY 12, 1986

Start of sampling		End of sampling Cs-134		^{137}Cs	^{134}Cs
Date	Time	Date	Time	(μBq m^{-3})	
30-Apr-86	10:00	30-Apr-86	13:00	2.3E+07	1.4E+07
30-Apr-86	13:00	30-Apr-86	17:00	2.0E+07	1.2E+07
30-Apr-86	17:00	30-Apr-86	23:30	2.3E+07	1.0E+07
30-Apr-86	23:30	01-May-86	05:00	9.7E+06	4.8E+06
01-May-86	05:00	01-May-86	16:00	1.7E+06	9.0E+05
01-May-86	16:00	02-May-86	05:00	1.0E+06	5.0E+05
02-May-86	05:00	02-May-86	16:30	1.5E+05	6.0E+04
02-May-86	16:30	03-May-86	05:30	6.0E+04	3.0E+04
03-May-86	05:30	03-May-86	16:30	1.2E+06	7.0E+05
03-May-86	16:30	04-May-86	05:30	7.9E+06	3.5E+06
04-May-86	05:30	04-May-86	16:30	3.6E+06	1.8E+06
04-May-86	16:30	05-May-86	05:30	1.4E+06	7.0E+05
05-May-86	05:30	05-May-86	16:30	9.0E+05	4.0E+05
05-May-86	16:30	06-May-86	05:30	8.0E+05	3.0E+05
06-May-86	05:30	06-May-86	16:30	2.0E+05	9.0E+04
06-May-86	16:30	07-May-86	05:30	8.0E+05	4.0E+05
07-May-86	05:30	07-May-86	17:10	8.0E+05	4.0E+05
07-May-86	17:10	08-May-86	05:20	7.0E+05	3.0E+05
08-May-86	05:20	09-May-86	07:00	5.0E+04	3.0E+04
09-May-86	07:00	10-May-86	07:00	3.0E+03	1.0E+03
10-May-86	07:00	11-May-86	07:00	1.0E+03	1.0E+03
11-May-86	07:00	12-May-86	07:00	1.0E+03	1.0E+03

TABLE I.3. ^{137}Cs AND ^{134}Cs CONCENTRATIONS IN GROUND-LEVEL AIR IN PRAGUE FROM MAY 12, 1986 TO DECEMBER, 1986

Start of sampling		End of sampling		^{137}Cs	^{134}Cs	^{7}Be
Date	Time	Date	Time	(μBq m^{-3})		
12-May-86	17:13	14-May-86	16:00	21700	9930	2730
16-May-86	20:30	19-May-86	15:00	5270	2390	2760
19-May-86	15:55	23-May-86	15:00	4250	1990	3530
23-May-86	15:30	28-May-86	15:30	4670	2180	3730
28-May-86	16:00	05-Jun-86	13:30	2490	1210	1450
06-Jun-86	15:40	13-Jun-86	13:00	520	267	2760
13-Jun-86	14:00	20-Jun-86	14:00	1260	574	4180
02-Jul-86	15:00	08-Jul-86	10:00	470	210	6200
08-Jul-86	10:05	16-Jul-86	16:00	186	67.2	3920
16-Jul-86	14:30	23-Jul-86	09:45	144	92.7	4540
23-Jul-86	09:50	25-Jul-86	11:40	6430	2880	6150
25-Jul-86	11:45	26-Jul-86	14:55	613	276	4430
26-Jul-86	14:55	29-Jul-86	08:47	311	93.6	3610
29-Jul-86	09:15	30-Jul-86	15:15	510	184	5240
30-Jul-86	15:25	07-Aug-86	08:10	307	140	4280
07-Aug-86	08:38	15-Aug-86	08:00	500	207	5660
19-Aug-86	09:05	25-Aug-86	10:30	1810	750	2770
25-Aug-86	10:30	01-Sep-86	08:30	139	58.5	3380
01-Sep-86	08:34	08-Sep-86	12:30	107	51	3730
08-Sep-86	14:40	12-Sep-86	13:40	175	49.6	3890
12-Sep-86	13:45	19-Sep-86	13:45	103	38.5	2630
19-Sep-86	13:50	26-Sep-86	13:30	84.3	45.6	4050
26-Sep-86	14:00	03-Oct-86	13:10	100	36.4	3630
06-Oct-86	10:30	10-Oct-86	14:30	131	49.8	3860
28-Oct-86	15:40	03-Nov-86	13:40	63.5	21.6	2910
03-Nov-86	14:00	07-Nov-86	14:30	61.8	28.5	5190
10-Nov-86	13:40	14-Nov-86	14:50	119	51.5	5020
14-Nov-86	14:50	22-Nov-86	14:00	94.4	36.5	2130
22-Nov-86	14:00	28-Nov-86	13:30	84.2	31.9	1480
28-Nov-86	13:35	05-Dec-86	14:00	127	52.5	2870
05-Dec-86	15:00	12-Dec-86	07:30	95.7	34.8	3170
15-Dec-86	12:15	19-Dec-86	14:50	543	203	2260

TABLE I.4. ^{137}Cs AND ^{134} Cs CONCENTRATIONS IN GROUND-LEVEL AIR IN PRAGUE IN 1987

Start of sampling		End of sampling		^{137}Cs	^{134}Cs	^{7}Be
Date	Time	Date	Time	(μBq m^{-3})		
19-Jan-87	14:00	23-Jan-87	14:00	360	118	1510
27-Jan-87	10:00	30-Jan-87	15:50	251	99.8	1730
30-Jan-87	16:00	03-Feb-87	10:00	215	85.9	1930
03-Feb-87	12:15	06-Feb-87	15:30	516	192	3420
06-Feb-87	15:30	13-Feb-87	15:50	153	65.8	1790
13-Feb-87	15:50	20-Feb-87	14:20	271	105	1050
20-Feb-87	14:25	27-Feb-87	13:30	189	48	3260
09-Mar-87	14:40	13-Mar-87	16:00	187	62.4	5440
13-Mar-87	16:00	20-Mar-87	16:00	216	79.9	4110
20-Mar-87	16:00	27-Mar-87	14:00	136	54	859
06-Apr-87	10:00	10-Apr-87	14:00	183	70.5	4400
10-Apr-87	14:30	17-Apr-87	09:30	109	38.9	2320
21-Apr-87	10:45	24-Apr-87	13:00	211	81.6	1720
27-Apr-87	14:50	30-Apr-87	11:20	114	34.5	3190
30-Apr-87	14:00	04-May-87	08:00	103	28.2	2320
06-May-87	14:50	08-May-87	14:00	135	45.4	3120
08-May-87	14:00	15-May-87	13:45	94.4	29.8	4350
15-May-87	14:00	22-May-87	13:15	33.1	8.9	2650
22-May-87	13:15	29-May-87	15:30	29.4	11.6	5550
29-May-87	15:30	05-Jun-87	13:30	20.1	5.9	3820
05-Jun-87	13:40	12-Jun-87	13:20	14.3	6.8	3160
12-Jun-87	13:30	19-Jun-87	14:00	26.5	10.9	2980
19-Jun-87	14:05	26-Jun-87	14:05	11.4	2.8	2550
26-Jun-87	14:10	03-Jul-87	10:35	18	8.4	3340
03-Jul-87	13:50	10-Jul-87	13:20	15	4.3	4280
10-Jul-87	13:30	17-Jul-87	11:25	7.9	5.5	4420
17-Jul-87	13:45	24-Jul-87	12:35	20.7	8.2	4450
24-Jul-87	12:40	31-Jul-87	10:40	27	7.2	2420
31-Jul-87	10:45	14-Aug-87	08:35	12.2	4.4	2660
14-Aug-87	08:35	21-Aug-87	11:50	13.9	4.3	2900
21-Aug-87	11:55	31-Aug-87	09:00	18.6	7	4680
31-Aug-87	09:00	11-Sep-87	13:45	16.5	6.4	2920
11-Sep-87	14:00	18-Sep-87	14:40	44.4	14.5	3450
18-Sep-87	14:45	25-Sep-87	10:10	27.4	7.3	3650
25-Sep-87	10:30	05-Oct-87	15:15	16	5.5	2220
05-Oct-87	14:15	16-Oct-87	09:45	31.5	11.6	3490
16-Oct-87	09:45	26-Oct-87	12:00	16.9	5	3240
26-Oct-87	14:00	03-Nov-87	16:40	47.1	13.5	4880
03-Nov-87	16:40	20-Nov-87	14:30	24.1	7.5	2980
20-Nov-87	14:30	04-Dec-87	14:40	14.8	4.8	1520
04-Dec-87	13:55	18-Dec-87	13:40	21	6.5	2780
18-Dec-87	13:45	27-Dec-87	11:05	12.5	4.6	2230
27-Dec-87	11:10	03-Jan-88	09:15	25	9.5	3550

TABLE I.5. ^{137}Cs AND ^{134}Cs-CONCENTRATIONS IN GROUND-LEVEL AIR IN PRAGUE IN 1988

Start of sampling		End of sampling		^{137}Cs	^{134}Cs	^{7}Be
Date	Time	Date	Time	(μBq m^{3})		
03-Jan-88	09 20	11-Jan 88	09 50	25 9	7 9	2240
11-Jan-88	09 50	19-Jan-88	13 40	19 1	4 8	2720
19 Jan 88	13 45	27-Jan-88	15 30	61 7	12 3	1850
27-Jan-88	15 30	03-Feb-88	09 45	14 1	7.0	2500
03-Feb-88	09 45	05-Feb 88	13 45	20 9	4 0	1830
05-Feb-88	13 45	12-Feb-88	13 05	19 6	4 0	2980
12-Feb-88	13 10	18-Feb 88	17 00	16 3	4 9	2790
18-Feb-88	17 00	25-Feb-88	17 15	18 8	0 0*	2340
25-Feb 88	17 15	03-Mar-88	16 45	53 7	12 4	1290
03-Mar-88	16 50	11-Mar-88	12 40	18 1	6 1	1830
11-Mar-88	12 45	17-Mar-88	17 00	19 2	5 9	2020
17-Mar-88	17 00	24-Mar-88	17 00	5 1	0 0	2420
24 Mar 88	17 00	31-Mar-88	16 55	8 9	0 0	1640
31-Mar-88	16 55	06 Apr 88	14 30	4 8	0 0	2130
06-Apr-88	14 30	13 Apr 88	13 00	23 3	5 1	3380
13-Apr-88	13 00	20-Apr-88	16 40	19 3	6 9	4000
20-Apr-88	16 40	27-Apr-88	14 55	16 2	3 0	4100
27-Apr-88	14 55	04-May-88	13 50	19 2	5 6	4040
04-May-88	13 55	11-May-88	14 50	20 6	5 1	4950
11-May-88	14 55	18-May-88	16 40	58 6	13 2	6790
18 May 88	16 45	25-May-88	14 10	4 3	0 0	1730
25-May-88	14 15	01 Jun-88	10 45	31 3	6 0	4620
01-Jun-88	10 50	08 Jun 88	11 50	22 4	6 7	2660
08-Jun-88	11 55	15-Jun-88	11 55	17 1	4 0	5480
15-Jun-88	12 00	20-Jun-88	09 00	39 5	9 0	5940
20-Jun 88	09 05	29-Jun-88	13 30	11 7	7 0	4490
06-Jul-88	15 15	13 Jul 88	15 10	52 7	11 3	6840
13-Jul-88	15 15	20 Jul 88	15 00	7 8	0 0	2430
20-Jul-88	15 00	28 Jul-88	09 25	66 3	18 0	4880
28-Jul-88	09 25	03-Aug-88	13 40	9 3	3 6	5880
03-Aug-88	13 45	10 Aug 88	12 50	12 8	8 0	4460
10-Aug 88	12 55	17-Aug-88	11 55	18 9	4 9	5350
17-Aug-88	12 00	24-Aug-88	11 55	8 8	4 3	4130
24-Aug-88	12.00	31-Aug-88	11 55	7 7	4 5	3890
31-Aug-88	11 55	07-Sep-88	09 30	7 3	3 0	4210
07-Sep-88	09.30	14-Sep-88	10 00	10 4	3 2	4590
14-Sep-88	10 00	21-Sept-88	10 25	8 9	5 6	2640
21-Sep-88	10 25	28 Sep-88	11 00	13 4	0 0	4220
28-Sep-88	11 10	05 Oct-88	11 00	6 8	0 0	4220
05-Oct 88	11 00	12-Oct-88	10 30	17 9	5 7	4130
12-Oct-88	10 30	19 Oct-88	14 50	10 7	3 3	3490
19-Oct-88	14 50	26 Oct-88	14 20	4 5	0 0	3130
26 Oct 88	14 25	02-Nov 88	14 15	11 8	0 0	2690
02-Nov-88	14 15	09 Nov 88	13 05	11 9	3 6	3160
09 Nov 88	13 05	16 Nov 88	16 40	11 8	2 7	2440
16 Nov 88	13 40	23 Nov 88	13 10	5 0	0 0	1590
23 Nov 88	13 15	24 Nov-88	13 00	3 0	0 0	1670
24-Nov 88	13 05	25-Nov 88	07 45	8 2	0 0	945
25 Nov 88	07 45	28 Nov-88	08 30	21 2	4 5	1740
28 Nov 88	08 30	02 Dec 88	10 50	19 9	3 9	2890
02 Dec 88	10 50	12 Dec 88	10 45	8 6	3 4	1630
12-Dec 88	10 50	15 Dec 88	16 15	36 5	8 5	2060
15-Dec 88	16 15	22 Dec 88	16 20	13 1	3 1	1590
22-Dec 88	16 20	29-Dec 88	17 30	13 1	6 1	1620
29 Dec 88	17 30	05 Jan 89	11 10	14 0	2 8	2310

* The value "0 0" denotes a value below the detection limit of 2 μBq m^{3} for ^{134}Cs.

TABLE I.6. ^{137}Cs AND ^{134}Cs CONCENTRATIONS IN GROUND-LEVEL AIR IN PRAGUE IN 1989

Start of sampling		End of sampling		^{137}Cs	^{134}Cs	^{7}Be
Date	Time	Date	Time	(μBq m^{-3})		
05-Jan-89	18:30	12-Jan-89	09:05	14	2.5	1260
12-Jan-89	17:35	18-Jan-89	09:40	12.4	2.4	2510
18-Jan-89	09:45	23-Jan-89	15:15	21.7	5.1	2450
23-Jan-89	15:20	31-Jan-89	11:15	14.2	4.3	3400
31-Jan-89	11:30	02-Feb-89	10:30	15.3	3.4	2130
02-Feb-89	10:30	15-Feb-89	11:45	16.3	3	2500
15-Feb-89	11:45	22-Feb-89	11:50	11	3.2	2530
22-Feb-89	11:50	01-Mar-89	10:00	18.7	4.3	1970
01-Mar-89	10:00	08-Mar-89	10:50	11.6	2.8	2170
08-Mar-89	10:50	15-Mar-89	10:30	16.5	3.2	2550
15-Mar-89	10:30	22-Mar-89	13:15	19.1	4.8	2490
22-Mar-89	13:15	29-Mar-89	10:25	23.5	6.3	4230
29-Mar-89	10:25	05-Apr-89	11:40	13.9	4.3	2690
05-Apr-89	11:50	12-Apr-89	12:15	13.8	3.1	2650
12-Apr-89	12:15	18-Apr-89	14:00	23.2	5.8	3090
18-Apr-89	14:00	26-Apr-89	15:40	11.4	3.2	2860
26-Apr-89	15:40	03-May-89	16:40	6.5	2.7	2850

TABLE I.7. WIND PARAMETERS IN PRAGUE (STATION 518) OF THE GROUND-LAYER ATMOSPHERE (10 m ABOVE GROUND) DURING THE PASSAGE OF THE PLUME*

Date	7 a.m.		2 p.m.		9 p.m.	
	Direction (degree)	Speed (m s^{-1})	Direction (degree)	Speed (m s^{-1})	Direction (degree)	Speed (m s^{-1})
29-Apr-86	340	4	30	6	350	4
30-Apr-86	330	7	310	8	350	8
01-May-86	360	6	60	5	90	2
02-May-86	80	2	90	6	120	5
03-May-86	90	3	100	5	130	5
04-May-86	90	2	130	8	130	4
05-May-86	100	5	130	6	130	5
06-May-86	100	3	130	9	140	6
07-May-86	120	3	210	6	70	2
08-May-86	280	6	300	8	230	5
09-May-86	250	6	290	8	90	2
10-May-86	230	4	240	5	230	7
11-May-86	210	2	240	9	330	9

* A direction of 90 degrees means a wind from east.

TABLE I.8. ACCUMULATED DAILY PRECIPITATION IN 1986 (mm d^{-1})

Date	Location*													
	474	513	514	518	519	520	521	522	527	561	563	624	572	627
29-Apr-86														
30-Apr-86			2.9	0.0	2.0	0.6				0.4	0.4	0.0		1.6
01-May-86														
02-May-86														
03-May-86														
04-May-86														
05-May-86														
06-May-86														
07-May-86	2.6	2.2	0.4	1.9	0.6	0.4	0.7	0.5		1.0	1.1		4.2	0.0
08-May-86	1.8	1.7	2.9	1.6	2.9	3.1	1.4	0.7	0.0	6.1	2.1	8.3	4.6	3.8
09-May-86	2.2	2.8	3.0	2.3	4.2	3.8	10.1	0.0	0.0	6.6	14.6	2.0	6.0	0.9
10-May-86		0.4	0.3	0.1	0.2	0.3	1.0	0.1	0.0	0.6	0.1	0.8	0.2	1.3
11-May-86	1.3	0.4	0.2	0.5	0.3	0.3		0.5		1.4	5.7	0.8	0.2	0.2
12-May-86														
13-May-86	2.2	1.0	1.5	1.3	3.9	10.1	1.5	7.9	10.9	10.0	4.7	3.9	4.4	4.2
14-May-86	3.4	2.9	1.0	0.9	0.8	0.6	1.3	1.7	11.2	0.8	0.4	3.5	1.1	5.2
15-May-86	0.2	0.9	0.1	0.2	0.3	7.9	1.4	0.2	0.4	2.8	1.5	0.1	0.1	0.4
16-May-86	1.8	1.8	0.9	0.4	1.5	2.5		1.9	3.4	3.1	1.8	4.2	4.3	10.9
17-May-86												0.0		
18-May-86	0.2	0.2	0.2	0.2	0.1	0.5	0.0	0.0	0.0	7.8	1.0	2.6	0.7	
19-May-86	9.3	7.6	0.3	5.5	4.1	4.5	12.0	13.8	21.9	3.3	4.2	5.0	12.5	17.9
20-May-86	2.1	0.2	0.1	0.3	0.1	0.8	0.2	0.5	2.4	0.1	0.1	9.0	4.6	2.9
21-May-86	27.8	19.5	10.2	18.0	8.5	8.3	17.7	20.6	8.9	4.3	6.5	3.1	3.3	4.9
22-May-86												0.0		
23-May-86				0.0										
24-May-86	3.6	1.1	3.2	1.3	1.8	0.4	2.2	4.4	0.3	1.2	1.0	5.4	17.1	6.1
25-May-86														
26-May-86														
27-May-86	24.7	36.6	15.9	61.2	23.2	10.2	30.4	13.1	13.7	8.6	11.2	1.7	15.5	
28-May-86	12.8	10.2	15.5	13.4	12.7	15.8	23.1	23.0	30.3	6.2	11.4	5.3	10.8	6.9
29-May-86	32.8	33.8	1.8	28.8	16.5	16.9	25.1	30.1	27.1	11.6	19.1	17.4	16.4	22.8
30-May-86	21.6	23.8	13.9	20.5	11.5	18.2	13.9	19.3	17.0	10.1	11.7	5.6	16.4	10.1
31-May-86	1.7	2.6	1.6	3.8	1.2	2.8	3.8	3.8	4.3	1.1	4.6	0.0	1.2	3.4
01-Jun-86	0.0		0.2	0.0			3.8	0.8	0.3				0.0	
02-Jun-86	2.7	4.6	3.7	3.1	5.6	3.0	2.1	0.4	0.8	0.7	0.9	0.0	0.0	0.6
03-Jun-86	1.8	0.8	2.9	8.2	0.4	0.5	0.4	0.0	0.0	1.4	0.1	0.2	6.6	4.2
04-Jun-86	3.8	3.1	1.4	1.9	1.4	2.6	2.7	1.7	2.7	9.4	4.8	3.1	5.2	3.4
05-Jun-86		0.3	0.2	0.0	0.4	0.2		0.0	0.3	1.0	0.2	4.9	0.8	2.0
06-Jun-86	0.3	0.2		0.0		0.0				0.2			0.0	
07-Jun-86	0.2	0.2	0.0	0.0	0.0	0.0		0.0		0.2	0.3		0.1	0.5
08-Jun-86				0.0							0.0			
09-Jun-86														
10-Jun-86														

TABLE I.8 (cont.)

Date	Location*													
	474	513	514	518	519	520	521	522	527	561	563	624	572	627
11-Jun-86	0 1			0 0			1 0	1 9	0 0			0 0	0 0	
12-Jun-86	0 9	1 8	3 3	1 1	3 2	3 0	1 5	6 4	17 3	12 2	10 0	6 5	5 3	13 9
13-Jun-86	5 7	6 7	3 2	4 8	4 4	3 3		2 3	4 2	0 0	0 2		0 6	1 3
14-Jun-86														
15-Jun-86								0 3						
16-Jun-86														
17-Jun-86								0 3	0 0					
18-Jun-86	5 4	1 2	0 3	0 5	7 3		1 0	0 0					1 8	19 7
19-Jun-86	13 6	7 2	14 1	14 5		0 2	25 2	2 7	10 0	2 6	68 6	2 3	0 1	1 3
20 Jun-86				0 0		8 2		6 4		2 0				
21-Jun-86														
22-Jun-86														
23-Jun-86														
24-Jun-86								0 8						
25-Jun-86														
26-Jun-86														
27-Jun-86														
28-Jun-86														
29-Jun-86				0 0		0 0					0 0	0 0	0 6	0 8
30-Jun-86														
01-Jul-86														
02-Jul-86						0 0				0 7		0 0		
03-Jul-86				0 0					0 3					
04-Jul-86	0 2		0 7	0 0	1 9	0 0				8 7		0 0		
05-Jul-86	1 0	0 0	1 0	1 0	0 1	0 2		0 6		0 3	0 3			
06-Jul-86	8 2	11 8	5 9	9 9	6 7	9 3	12 1	13 0	8 2	5 4	7 5	6 2	6 3	8 9
07-Jul-86	16 3	18 0	12 6	16 0	6 1	11 2	12 0	10 5	11 1	8 9	21 1	10 4	12 7	10 3
08-Jul-86		0 6	0 2	0 2	0 0	1 0	2 5	4 3	3 1	0 9	0 4	0 3	0 4	2 5
09 Jul-86	8 3	8 2	1 4	3 2	5 2	4 0	12 1	1 3	1 9	3 0	3 9	1 3	4 8	5 1
10-Jul-86	2 3	1 1	0 4	0 1	0 1	0 2	1 5	3 0	5 5	3 3	0 8	0 0	2 6	9 4
11-Jul-86				0 0				0 1	0 2	1 8		0 0	0 1	
12-Jul-86														
13-Jul-86														
14-Jul-86				0 0										
15-Jul-86														
16-Jul-86														
17-Jul-86										0 2				
18-Jul-86			0 0	0 0	0 0		0 0	0 0	1 2	4 8	0 0	12 8	8 2	16 3
19-Jul-86	1 4	2 9	4 4	5 3	5 5	0 4	1 1	3 1	4 4	5 3	8 5	17 3	12 2	19 3
20-Jul-86						6 9				0 2		0 0		0 2
21-Jul-86														
22-Jul 86														
23-Jul 86	3 3	3 7	4 5	3 7	4 6		2 4	3 0	8 1	15 7	8 6	2 6	7 5	8 2
24-Jul-86	2 7	4 2	0 9	0 9	0 6	13 3	2 2	1 6	1 5	1 9	1 3	0 0	2 2	4 2
25-Jul 86	2 7	1 9	1 6	2 0	1 7	1 6		0 5		2 0	2 6	0 2	4 2	0 4

TABLE I.8 (cont.)

Date	Location*													
	474	513	514	518	519	520	521	522	527	561	563	624	572	627
26-Jul-86				0.0		1.7			0.7	0.4	0.0	1.4	0.2	0.2
27-Jul-86						0.4								
28-Jul-86														
29-Jul-86								0.0						
30-Jul-86														
31-Jul-86	2.3	0.5	2.4	1.0	1.8	3.4	2.8	12.5	4.8	8.8	6.6	14.7	12.5	22.0
01-Aug-86	1.8	4.6	1.1	1.3	1.2	1.8	2.0	2.2	0.8	1.8	0.5	1.2	0.6	1.2
02-Aug-86				0.0										
03-Aug-86														
04-Aug-86	9.2	17.2	30.4	18.2	40.2	35.7	10.8	21.8	3.4	12.3	10.5	7.3	21.3	5.9
05-Aug-86	0.8	0.2	0.0	0.4	0.0	0.3	0.0	0.7	1.6	0.8	0.2	1.2	1.3	0.3
06-Aug-86														
07-Aug-86														
08-Aug-86	1.1	0.9	2.8	0.6	4.6	3.7	0.6	1.7	8.5	0.5	2.7	8.9	1.2	6.9
09-Aug-86														0.2
10-Aug-86			2.0	0.3	2.6	0.8		3.3	4.2	0.0	2.0	0.2	19.7	7.9
11-Aug-86			0.1		0.1	0.0			0.6	3.7	0.0	4.0	2.1	0.2
12-Aug-86	11.2	11.1	4.3	6.2	13.8	7.1	11.7	10.0	3.5	29.8	5.9	18.2	15.3	8.0
13-Aug-86	1.4		2.1	0.0	10.2	0.0		0.3	0.3	0.1	0.0	1.5	2.1	3.4
14-Aug-86														
15-Aug-86	3.2	5.1	4.6	3.2	2.2	1.4		1.6	2.0	2.2	3.6	0.0	0.0	0.3
16-Aug-86	0.2	4.0	9.2	10.7	2.2	0.5	3.5	0.4		2.4	4.4	7.6	4.8	2.5
17-Aug-86	5.8	3.2	6.3	7.6	8.8	12.9	7.5	1.0	0.8	15.2	8.1	2.9	16.9	1.9
18-Aug-86	2.1	5.8	9.0	3.1	3.0	0.9	4.2	14.2	0.3	0.1	7.7	4.0	1.0	1.0
19-Aug-86	12.6	13.6	11.4	31.6	9.8	8.7	31.0	20.2	1.4	5.6	15.3	6.0	10.8	6.7
20-Aug-86	3.7	0.4	1.1	1.2	0.7	1.0	2.0	1.1	0.0	3.2	1.4	1.0	1.0	2.0
21-Aug-86				0.0						0.1				
22-Aug-86		3.6	3.5	1.9	2.4	0.5	0.0	1.0		2.0	2.0		0.0	
23-Aug-86	6.9	4.8	6.8	7.2	7.1	7.3	14.3	4.4	7.3	7.8	9.3	6.0	9.1	5.6
24-Aug-86	10.8	11.2	9.1	13.9	12.0	12.3	13.8	4.1	5.2	8.3	15.1	4.0	3.3	1.3
25-Aug-86		0.0	0.0	0.0	0.1	0.0	0.3	1.1	1.5				0.0	0.3
26-Aug-86	4.4	5.1	3.5	4.6	3.1	3.4	7.8	4.7	1.9	3.6	3.5	0.3	3.0	1.1
27-Aug-86	0.3	0.0	0.1	0.0	0.3	0.2		0.1	1.7	0.5		3.2	1.5	4.2
28-Aug-86	7.2	1.5	6.6	6.4	6.7	9.3	10.2	9.1	7.7	10.0	12.1	10.6	13.2	11,6
29-Aug-86	1.4	0.2	0.9	1.1	0.7	1.8		0.1	1.9	1.8	1.5	2.5	1.7	2.0
30-Aug-86	0.3	0.2	0.0	0.0						0.2		0.0	0.0	
31-Aug-86	5.6	10.5	7.3	8.0	4.1	4.2	0.0	0.5		0.7	4.5	1.6	4.2	1.0

* Locations are marked in Figure I.2. The value "0.0" indicates a precipitation of less than 0.1 mm.

TABLE I.9. PRINCIPAL GEOGRAPHIC DATA OF RAINFALL-GAUGE STATIONS IN CENTRAL BOHEMIA

Code	Name	N lat.	E long.	Sea level (m)
474	Lany [RA]	50°07	13°57	447
513	Kladno [KL]	50°10	14°07	293
514	Praha-Klementinum	50°05	14°25	191
518	Praha-Ruzyne	50°06	14°17	376
519	Praha-Karlov	50°04	14°26	232
520	Praha-Libus	50°00	14°24	305
521	Beroun [BE]	49°57	14°02	260
522	Neumetely [BE]	49°51	14°02	322
527	Solenice [PB]	49°37	14°11	357
561	Semcice [MB]	50°22	15°00	234
563	Brandys n.L. [PH]	50°11	14°40	179
572	Ondrejov	49°58	14°45	320
624	Chotusice	49°59	15°12	315
627	Cechtice	49°37	15°03	490

TABLE I.10. INFORMATION ON SOIL CHARACTERISTICS

Code	Granularity	Permeability	Humus Content	Humus Quality
0	No evaluation has been performed			
1	Less than 20% of particles with diameter smaller than 0.01 mm	High	Less than 2%	High
2	Between 20% and 45% of particles with diameter smaller than 0.01 mm.	Good	From 2% to 2.9%	Intermediate
3	More than 45% of particles with diameter smaller than 0.01 mm.	Reduced	More than 2.9%	Low
4		Poor		

TABLE I.11. SURFACE ACTIVITY (kBq m^{-2})

Code	^{137}Cs	^{134}Cs	^{103}Ru	Granularity	Permeability	Humus content	Humus quality
Prague (AB):							
S001	7.63	3.88	2.21	0	0	0	0
S002	6.97	3.35	1.74	0	0	0	0
S003	8.58	4.13	2.55	0	0	0	0
S004	3.51	1.71	1.14	0	0	0	0
S005	2.66	1.33	0.94	0	0	0	0
S006	0.62	0.32	0.20	0	0	0	0
S007	9.42	4.67	2.63	0	0	0	0
S008	9.02	4.40	2.77	0	0	0	0
S009	2.25	0.96	1.04	0	0	0	0
S010	4.34	2.18	1.55	0	0	0	0
S011	4.34	2.14	1.67	0	0	0	0
Benesov (BN):							
S012	36.5	19.91	25.76	2	2	2	3
S013	38.2	20.11	23.87	2	4	2	2
S014	39.8	19.92	25.5	2	2	2	3
S015	7.75	3.39	6.26	1	1	3	2
S016	4.16	1.80	3.58	1	1	3	2
S017	31.6	16.71	20.72	2	2	2	3
S018	21.6	11.39	12.81	2	4	2	2
S019	21.71	11.49	12.46	0	0	0	0
S020	8.44	3.94	6.00	2	4	2	3
S021	24.7	12.56	14.48	2	2	2	3
S022	38.6	19.31	20.07	2	2	2	3
S023	3.12	1.29	1.57	1	1	3	2
S024	2.32	1.00	1.50	1	1	3	2
S025	4.00	2.13	3.68	1	1	3	2
S026	2.77	1.46	2.76	0	0	0	0
Beroun (BE):							
S027	1.25	0.72	1.02	2	3	3	2
S028	0.85	0.39	0.53	2	3	3	2
S029	7.31	3.73	3.87	2	2	2	2
S030	0.91	0.45	0.75	2	2	2	3
S031	1.18	0.47	0.89	2	2	2	2
S032	0.59	0.08	0.19	2	3	1	3
S033	1.02	0.42	0.55	2	3	2	2
S034	0.66	0.23	<0.02	0	0	0	0
S035	3.96	1.85	2.59	2	2	2	3
S036	0.52	<0.02	<0.02	2	2	2	2

TABLE I.11 (cont.)

Code	^{137}Cs	^{134}Cs	^{103}Ru	Granularity	Permeability	Humus content	Humus quality
Kladno (KL):							
S037	0.63	0.37	0.43	2	3	3	2
S038	0.26	0.15	0.18	2	3	3	2
S039	0.09	0.06	0.06	2	3	3	2
S040	0.22	0.13	0.11	2	2	2	2
S041	0.39	0.22	0.27	2	2	2	1
S042	0.12	0.07	0.10	2	2	2	1
S043	<0.02	<0.02	<0.02	2	2	2	2
S044	0.05	0.03	0.07	2	2	2	1
S045	0.40	0.23	0.34	2	2	2	1
S046	0.06	0.04	0.04	2	2	2	1
S047	0.09	0.05	0.05	2	3	3	2
S048	0.10	0.06	0.07	0	0	0	0
S049	0.26	0.14	0.20	1	2	2	2
Kolin (KO):							
S050	1.29	0.61	1.82	2	2	2	2
S051	1.93	0.91	1.52	2	3	2	1
S052	2.84	1.47	2.21	2	3	2	1
S053	1.42	0.65	1.20	0	0	0	0
S054	0.90	0.43	0.72	2	3	3	2
S055	1.31	0.54	0.89	2	2	2	2
S056	0.18	<0.02	<0.02	2	2	3	2
S057	1.64	0.74	1.08	2	3	3	2
S058	2.11	0.98	1.67	2	3	1	1
S059	3.86	1.77	2.81	1	1	3	2
S060	0.16	<0.02	0.13	2	2	2	1
S061	3.27	1.47	<0.02	2	2	2	1
Kutna Hora (KH):							
S063	8.87	4.60	5.94	2	4	2	3
S064	23.1	11.02	15.8	2	2	2	3
S065	5.19	2.59	3.68	2	2	2	2
S066	11.76	5.80	8.95	2	2	2	2
S067	4.25	1.97	2.26	2	3	3	2
S068	11.34	5.27	6.72	2	2	2	2
S069	12.23	5.96	7.54	2	3	3	2
S070	8.93	4.57	6.17	2	2	2	2
S071	1.59	0.58	0.72	2	3	3	2
S072	1.45	0.62	1.09	2	3	3	2

TABLE I.11 (cont.)

Code	^{137}Cs	^{134}Cs	^{103}Ru	Granularity	Permeability	Humus content	Humus quality
Melnik (ME):							
S073	4.05	1.75	4.11	1	1	2	1
S074	1.32	0.62	1.60	2	2	2	2
S075	0.77	0.27	0.67	1	1	2	1
S076	5.54	2.29	6.23	1	1	3	2
S077	2.03	2.15	2.05	2	2	2	1
S078	1.06	0.59	1.06	2	2	2	2
S079	0.88	0.24	0.54	2	3	3	2
S080	5.94	2.53	5.00	2	3	3	2
S081	1.1	0.44	1.39	2	1	2	1
S082	2.11	1.01	1.61	2	2	2	2
Mlada Boleslav (MB):							
S083	2.93	1.29	3.02	2	2	2	2
S084	3.54	1.67	3.44	2	4	2	3
S085	2.89	1.30	3.05	1	1	3	3
S086	2.60	1.26	2.69	2	2	3	1
S087	1.79	0.75	1.62	2	2	2	1
S088	4.36	1.99	4.28	2	2	2	2
S089	3.10	1.47	3.47	3	2	2	2
S090	2.00	0.92	1.98	1	1	3	3
S091	5.53	2.77	4.19	3	3	1	1
S092	3.75	1.48	3.31	2	2	1	1
S093	2.56	1.30	2.26	2	2	2	2
S094	3.33	1.56	3.33	2	3	3	2
S095	4.31	1.83	3.98	2	4	2	3
S096	1.17	0.46	0.80	2	2	2	2
S097	2.46	1.06	2.15	1	1	3	3
Nymburk (NB):							
S098	3.44	1.68	3.46	2	3	1	1
S099	8.98	4.04	6.66	2	3	1	1
S100	6.70	3.31	4.56	2	2	2	2
S101	8.83	4.75	7.14	1	1	3	2
S102	5.04	2.17	4.87	2	3	1	1
S103	1.28	0.48	1.37	2	2	2	2
S104	2.57	1.19	2.24	3	3	1	1
S105	2.16	0.98	1.87	3	3	1	1
S106	1.12	0.56	1.26	2	2	2	1
S107	1.38	0.53	1.29	0	0	0	0

TABLE I.11 (cont.)

Code	^{137}Cs	^{134}Cs	^{103}Ru	Granularity	Permeability	Humus content	Humus quality
Prague-east (PH):							
S062	8.01	3.87	6.49	2	2	2	1
S108	6.89	3.34	6.31	2	3	3	2
S109	4.79	2.22	3.81	1	1	3	2
S110	3.37	1.00	2.61	2	3	3	2
S111	4.63	2.29	3.75	2	3	3	2
S112	4.74	2.31	3.45	2	3	3	2
S113	9.85	4.78	7.56	1	1	3	2
S114	2.04	0.98	1.38	2	2	2	2
S115	12.32	5.77	6.91	2	2	2	1
S116	6.74	3.26	6.63	2	2	2	1
S117	12.76	7.05	7.72	2	2	2	1
Prague-west (PZ):							
S118	1.40	0.66	0.83	2	2	2	2
S119	6.01	3.36	3.84	2	2	2	2
S120	0.97	0.45	0.76	2	3	3	2
S121	0.78	0.46	0.60	2	2	2	1
S122	0.77	0.38	0.65	2	2	2	2
S123	6.06	3.12	3.78	2	2	3	2
S124	1.14	0.33	0.70	2	3	3	2
S125	3.19	1.54	1.39	2	2	3	2
S126	2.80	1.34	1.26	2	2	2	3
S127	3.18	1.58	1.55	2	2	2	3
Pribram (PB):							
S128	0.76	<0.02	<0.02	0	0	0	0
S129	1.18	0.35	0.49	1	1	2	2
S130	0.79	0.23	0.34	2	3	1	3
S131	0.47	<0.02	<0.02	2	3	2	3
S132	0.22	<0.02	<0.02	2	2	3	3
S133	0.32	0.14	0.15	1	1	2	3
S134	0.85	0.44	0.59	1	1	2	3
S135	1.43	0.56	0.94	1	1	2	3
S136	1.27	0.44	0.50	2	2	2	3
S137	0.34	<0.02	<0.02	2	2	2	3
S138	1.33	<0.02	<0.02	2	2	2	3
S139	0.99	0.44	0.52	2	2	3	2
S140	0.51	<0.02	0.25	1	1	3	2
S141	1.70	0.53	0.60	2	2	3	2
S142	0.87	<0.02	0.43	2	4	2	3

TABLE I.11 (cont.)

Code	^{137}Cs	^{134}Cs	^{103}Ru	Granularity	Permeability	Humus content	Humus quality
Rakovnik (RA):							
S143	2.56	1.19	2.09	2	3	1	2
S144	1.20	1.19	2.09	2	3	1	2
S145	0.79	<0.02	<0.02	2	3	3	2
S146	0.50	<0.02	<0.02	2	3	3	2
S147	3.33	0.62	0.78	2	2	2	2
S148	2.15	0.96	1.87	2	2	2	2
S149	0.99	<0.02	0.44	2	2	2	2
S150	0.56	0.41	0.60	2	2	2	2
S151	1.71	0.68	1.22	2	2	2	2
S152	1.67	0.64	0.92	2	2	2	2

TABLE I.12. SOIL TYPES RELEVANT FOR PLANT PRODUCTION

Area	Soil type
1	Fluctuating level of ground water in meadow soils with temporary wetted localities, mostly soils of good agricultural qualities, strong dependence of water regime on precipitation owing to light granularity of substratum, low absorbing capacity.
2	Good soils in flat ground, in dry season suffering from lack of water.
3	Black earth in flat ground.
4	Heavier, at some places extremely heavy soils on marl, seasonally wetted, higher content of humus.
5	Heterogeneous soil cover, higher structure, sloping lands; soils on sandstone, their water regime is fully dependent on precipitation
6	Flat ground with deep valleys, intermediate soils able to bind nutrients and water.
7	Strongly heterogeneous soil cover, articulated relief, heavy or extremely heavy soils with reduced internal drainage, surface or ground water overwetting.
8	Good agronomic soils in a more broken relief and humid region than 6 and 12.
9	Large forest areas; deep soils without structure; acid, light soils.
10	Like 6 but with large forest areas.
11	Strongly heterogeneous soil cover, differing structure, broken relief, shortage of precipitation.
12	Brown earth in good climatic conditions, flat or moderately undulating ground.
13	Mostly deep soils on slopes, possibility of seasonal surface wetting and occurrence of places with higher structure; more broken relief than 12.
14	Mostly soils with worse internal drainage, strong surface wetting.

TABLE I.12 (cont.)

Area	Soil type
15	Intermediately deep, structured soils on argillite and lighter soils (in texture) on permacarbon; slightly undulating ground.
16	Strong heterogeneity of soils in texture and depth of soils, on some places higher structure.
17	Mostly lighter soils (in texture) with higher content structure, broken relief, danger of erosion.
18	Heterogeneous soil cover, prevalence of strong structured soils, broken or very broken relief.
19	Mostly heavier soils (in texture) with reduced internal drainage, frequent surface wetting.
20	The area of karst; strongly heterogeneous soil cover in profile depth and content structure; danger of erosion.
21	Deep soils on slopes, surface wetting and shallow soils with high content structure, bad chemical qualities, broken relief, humid climate.
22	Like 21, seldom used for agricultural purposes, forest areas.
23	Mostly soils with worse internal drainage; possibility of surface wetting in humid climate.
24	Like 18.
25	Lighter brown earth on sandstone with higher permeability and low absorbability and heavy brown earth on slate with poor internal drainage predisposed to surface wetting; flat or slightly broken relief in good climate.
26	Lighter brown earth on granite with different content structure, even stony, on slopes endangered by erosion, good chemical properties (slightly acid reaction, slight saturation by absorption); broken relief.
27	Heterogeneous cover of lighter soils (in texture) with differing content structure in broken relief.
28	Intermediately heavy brown earth with strong variations in profile depth and content structure; slightly acid and slightly saturated soils alternate with acid and unsaturated soils; local occurrence of deep soils with strong surface wetting; slightly broken relief.
29	Like 26, in addition to it brown soils with limited depth of profile and higher structure.
30	Mostly light or intermediately heavy, intermediately deep soils with higher content structure.
31	Acid, unsaturated brown soils on gneiss and granite, different depth of profiles (shallow or intermediately deep) and differing content structure (slight to intermediate).
32	Mostly acid, brown soils on gneiss.
33	Deep brown soils in good climate and ground conditions.
34	Brown soils on gneiss of good properties.

TABLE I.13. RANGES OF pH VALUES FOR DIFFERENT SOIL TYPES*

Area	pH	Area	pH	Area	pH
1	6.6-7.2	12	5.6-7.2	23	4.6-5.5
2	6.6->7.2	13	4.6-6.5	24	5.6-7.2
3	6.6-7.2	14	5.6-6.5	25	6.6->7.2
4	6.6-7.2	15	5.6-6.5	26	5.6-6.5
5	4.6-6.5	16	5.6-6.5	27	5.6-7.2
6	6.6-7.2	17	4.6-5.5	28	5.6-6.5
7	6.6-7.2	18	4.6-6.5	29	4.6-5.5
8	<4.5-6.5	19	4.6-5.5	30	4.6-5.5
9	4.6-5.5	20	<4.5-5.5	31	4.6-6.5
10	6.6-7.2	21	<4.5	32	4.6-5.5
11	6.6-7.2	22	4.6-6.5	34	6.6-7.2

* Areas as shown in Figure I.4

TABLE I.14. SEEDING AREA IN REGION CB IN 1986 (hectare)

Product	Codes of individual subregions													
	AB	BN	BE	KL	KO	KH	ME	MB	NB	PH	PZ	PB	RA	Total
Wheat winter	2767	13707	7186	13408	16270	14761	10878	15797	16896	12597	8542	12812	11387	157008
Wheat spring	124	458	58	118	44	426	714	965	523	465	46	-	122	4063
Barley winter	842	5824	1431	1561	2044	4656	3179	4235	2718	2588	1661	4367	3022	38128
Barley spring	1085	12203	5126	7263	6266	4889	4266	5994	8435	2739	4018	7634	5708	75626
Rye	-	2467	-	-	210	391	853	1205	312	51	-	1184	409	7082
Oats	-	2225	231	110	154	746	290	387	128	230	189	1622	1595	7907
Pulses for grain	25	815	791	903	742	652	583	1197	1361	493	606	579	831	9578
Sugar beet	715	-	997	4925	6388	3834	4211	6590	7043	4094	3019	1	90	41907
Potatoes early	-	116	85	72	320	288	637	650	936	317	77	79	56	3633
Potatoes other	-	4707	121	457	426	1453	310	348	301	214	223	3307	700	12567
Fodder root crops	47	459	160	172	311	270	245	504	347	138	128	352	324	3457
Fodder arable 1y	2027	9663	4405	4905	6044	6894	4693	6722	6313	5014	5405	6726	7488	76299
Fodder arable xy	1436	14093	5286	8337	9481	9454	7150	10580	10514	6718	5800	10257	8490	107596
Fodder pasture	300	15349	5711	1129	2641	5376	1785	4984	2285	2254	2557	15127	3249	62747
Other tec.products	-	6103	1247	418	406	2708	384	1800	606	701	380	3223	1182	19158
Cabbage	7	14	9	10	108	154	35	32	36	62	69	11	6	553
Cauliflower	13	6	13	36	15	6	112	14	119	38	13	8	8	401

TABLE I.14 (cont.)

Product	Codes of individual subregions													
	AB	BN	BE	KL	KO	KH	ME	MB	NB	PH	PZ	PB	RA	Total
Kale	5	12	8	15	11	5	20	24	42	24	18	9	9	202
Kohlrabi	3	12	10	20	15	11	92	20	25	19	10	10	13	260
Celery	5	4	12	18	8	1	145	14	11	11	1	12	5	247
Carrots	0	21	22	24	55	151	281	110	34	44	68	28	18	856
Parsley	1	8	6	9	34	16	9	12	66	19	11	18	9	218
Gherkin	-	10	16	48	103	43	56	91	159	38	6	11	11	592
Cucumber	23	6	18	12	9	6	34	4	19	36	1	7	6	181
Green pepper	4	1	-	2	2	-	2	5	4	1	-	-	3	24
Onions	-	32	18	27	240	104	756	210	278	64	9	18	14	1770
Garlic	-	12	7	23	11	3	24	13	38	3	2	5	6	147
Lettuce	19	6	12	20	7	13	17	27	29	20	3	8	7	188
Spinach	-	2	3	-	4	-	-	-	4	149	21	-	-	183
Green beans	-	-	-	0	3	-	0	2	2	35	0	-	3	45
Green peas	-	4	2	207	2	1	1	4	82	135	2	-	2	442

Note: "0" means value lower than 0.5.

TABLE I.15. PLANT PRODUCTION IN REGION CB IN 1986 (tons)

Product	Codes of individual subregions												
	AB	BN	BE	KL	KO	KH	ME	MB	NB	PH	PZ	PB	RA	Total
Wheat winter	12844	52355	24321	57167	81592	67917	48039	78367	75540	62224	39486	48628	44933	693314
Wheat spring	589	1798	192	536	182	1899	3067	4273	2091	2316	198	-	411	17552
Barley winter	3834	25658	5077	6498	9654	22169	14700	20048	12758	13975	8833	18021	12800	174025
Barley spring	4637	51876	21199	31970	30828	21333	18733	28887	37592	13525	19874	30172	22625	333251
Rye	-	9320	-	-	738	1475	3010	4339	1132	145	-	4294	1357	25810
Oats	-	8181	879	369	535	3173	1112	1552	411	996	675	5920	5274	29077
Pulses for grain	75	1790	1284	2187	1439	1515	1075	2555	2371	1136	1269	1159	1349	19204
Sugar beet	30948	-	37036	171946	242690	147851	161081	276904	248899	177446	119893	33	4182	1618909
Potatoes early	-	980	775	649	4018	3651	6995	7636	9884	3501	770	1116	709	40684
Potatoes other	-	93846	985	7811	7835	27921	5839	6247	4433	4360	3962	52894	10250	226383
Fodder root crops	2854	14275	7597	6701	13990	9973	9498	21028	12178	6933	5201	8359	8740	127327
Fodder arable 1y	60228	377335	145978	172518	182317	227192	160504	226245	224349	175554	157460	249991	229816	2589487
Fodder arable xy	10963	119797	39948	61185	72690	79734	60467	89061	78266	52976	46968	82671	56308	851034
Fodder pasture	1255	53474	19598	2795	7088	18776	4529	14948	5768	5885	6455	62471	6454	209496
Other tec. products	-	14342	2633	553	301	8466	292	3509	451	1679	702	8583	2688	44199
Cabbage	216	182	139	238	4720	5198	1043	750	1039	2140	1690	515	137	18007
Cauliflower	197	30	143	541	382	106	3406	246	4166	339	110	131	87	9884

TABLE I.15 (cont.)

Product	Codes of individual subregions													
	AB	BN	BE	KL	KO	KH	ME	MB	NB	PH	PZ	PB	RA	Total
Kale	35	103	65	244	142	96	370	297	2042	459	283	254	33	4423
Kohlrabi	74	69	95	241	185	202	1190	268	913	302	74	143	675	4431
Celery	127	43	117	274	165	15	3947	264	246	254	12	114	43	5621
Carrots	1	189	398	674	2000	5059	11256	4219	3032	1382	390	332	251	29183
Parsley	9	40	77	160	458	163	129	223	810	240	16	314	56	2695
Gherkin	-	75	83	319	1326	329	497	677	1764	188	35	74	33	5400
Cucumber	2738	93	110	220	172	329	812	38	411	300	5	68	27	5323
Green pepper	97	1	-	11	50	1	33	30	40	10	-	-	7	280
Onions	-	475	209	248	2518	1114	13264	3437	3056	940	130	248	185	25824
Garlic	-	50	34	60	52	25	110	91	173	11	19	33	17	675
Lettuce	607	14	71	216	98	235	265	400	475	168	16	63	33	2661
Spinach	-	6	30	-	18	-	-	-	50	2711	139	-	-	2954
Green beans	-	-	-	0	15	-	0	14	5	5	1	-	12	52
Green peas	-	22	7	864	12	2	3	21	375	639	12	-	9	1966
Tomato	170	38	159	165	213	70	203	145	281	479	36	-	49	2008
Apples	14	7087	2089	2977	9752	12272	2334	1779	2112	3353	1466	2370	2936	50541
Pears	15	643	148	325	452	1162	204	777	532	710 1	197	345	322	5832

Note: - "0" means value lower than 0.5.

- Fodder arable 1y is given in fresh matter.
- Fodder arable xy and fodder pasture are given in dry matter (1kg of hay is produced from 4 kg of green grass).
- Very small harvest of vegetables in Prague - flood in the biggest farm.

TABLE I.16. INFORMATION ON ANIMAL PRODUCTION IN 1986
(A) YEARLY PRODUCTION

Product	Codes of individual subregions													
	AB	BN	BE	KL	KO	KH	ME	MB	NB	PH	PZ	PB	RA	Total
Number of farming animals at the end of 1986:														
dairy cow	3499	21027	9734	12294	16875	16858	11577	19654	17994	11922	11640	18409	11668	183151
beef cattle	5707	49124	19530	26091	31109	35170	23454	39372	31634	22421	19992	37318	25464	366386
pig	-	99089	32651	58852	76638	77468	42938	78136	74459	52105	29758	70992	49254	742340
hen	-	190568	121445	129953	65146	238721	54680	-	92677	63844	112090	108700	67672	1245496
sheep[a]	-	879	81	-	-	1121	-	1092	-	23	1081	335	439	5051
Production (flesh in tons of living weight, milk in thousands of litres, eggs in thousands of pieces):														
beef	1417	9438	4292	5857	7266	7893	5586	9229	8102	5206	4420	7534	5519	81759
pork	-	12434	5389	8484	10689	11091	5745	10038	10807	6710	3991	9923	7104	102405
poultry	-	2867	2623	398	1411	2398	92	2474	2007	1235	1983	2499	670	20657
milk	12794	78745	36452	46044	63199	63132	43354	73604	67389	44651	43592	68943	43696	685595
egg	-	42583	26541	59752	25536	48662	9630	98	38826	13481	29225	22710	29295	346339
Production of feed stuffs (tons):														
ensilage	44252	203166	67914	98899	144353	153099	203837	153796	175061	216938	142164	125944	104609	1834032
sugar beet[b]	19198	1791	14732	65703	140785	63708	6370	155799	159522	3742	1440	1100	4311	638201
sugar beet[c]	-	-	9478	-	15123	33391	-	87075	10323	10051	12100	227	-	177768
hay	3587	44523	12170	16871	24739	26383	19926	28621	38054	19736	11948	31960	20034	298552
ensilaged hay	2579	68741	5123	19910	23909	31000	20203	42381	45492	15695	27855	69325	32094	424307
green fodder	109848	453301	157882	196380	353930	338559	165172	258123	196912	196324	189486	317947	213393	3147257

TABLE I. 16 (cont.)
(B) DAILY PRODUCTION IN DAIRIES

Dairy	Code	Daily production (kL)		
		May 1986	Jun 1986	Dec 1986
Hostivice	D01	?	73.2	62.4
Kyje	D02	271.8	294	243.5
Radlice	D03	198.3	217	176.3
Troja	D04	185	122	98.5
Benesov	D05	235.6	195.3	218.7
Caslav	D06	111.4	101.5	95.7
Kacice	D08	?	86	63.5
Slany	D09	182	?	110
Kolin	D10	204.7	213.8[d] 38[e]	184.3
Velim[f]	D11			
Cejeticky	D12	97.7	103.2	82.7
Podebrady	D13	176.2	185	152.2
Pribram	D14	204	?	
Sedlcany	D15			108

[a] not for meat production
[b] mainly leaves
[c] mainly cuttings
[d] dried milk
[e] consumption milk
[f] milk farm in the gathering region of Kolin (D10) dairy. Cows were kept entirely on pasture in the first half of May 1986 and partly up to winter 1986

Note: - Mean gain (kg/d):

cattle	0.65 - 0.72
pig	0.53 - 0.58

- Mean consumption of cereals (kg/kg of gain or l of milk):

milk	0.20 - 0.23
cattle	1.87 - 2.36
pig	3.28 - 3.54
broiler	2.27 - 2.65

- Cattle is predominantly kept in stables.

TABLE I.17. SEEDING, SETTING AND HARVESTING TIMES IN CB

Product	Seeding or setting period	Harvesting period
Wheat winter	Sep 15 - Oct 31	Aug
Wheat spring	Mar 25 - Apr 10	Aug
Barley winter	Sep 10 - Sep 30	Jul
Barley spring	Mar 25 - Apr 10	Jul 20 - Aug 20
Rye	Sep 20 - Oct 10	Aug
Oats	Mar 25 - Apr 10	Aug
Pulses	Mar 25 - Apr 10	Aug - Sep
Sugar beet	Mar 31 - Apr 25	Oct
Potatoes early	Mar 25 - Apr 15	Jun 15 - Aug 31
Potatoes other	Apr 15 - Apr 30	Sep 10 - Oct 31
Fodder root crops	Apr 01 - Apr 20	Oct
Fodder arable 1a	Mar 25 - Apr 30	Aug - Sep
Fodder arable xa	see Table I.19	
Fodder pasture: 1st cut	Jun 01 - Jul 15	Jun 01 - Jul 15
Fodder pasture: 2nd cut	Aug 25 - Sep 15	Aug 25 - Sep 15
Vegetables:		
Cabbage	Apr - May	Jul - Oct
Cauliflower	Apr - Jun	Jul - Oct
Kale	Apr - Jun	Jul - Oct
Kohlrabi	Apr and Jun	Jun - Oct
Celery	May	October
Carrots	Apr and Jun	Jun - Oct
Parsley	Apr	Oct
Gherkin	May	Jul - Aug
Cucumber	May	Jul - Aug
Green pepper	May	Oct
Onions	May	Jun - Sep
Garlic	Oct	Jul
Lettuce	Apr	May - Jun
Spinach	Apr and Aug	May - Jun and Oct
Green beans	Apr	Jul
Green peas	Apr	Jul

TABLE I.18. LEAF AREA INDICES (LAI[a]) FOR WHEAT, BARLEY AND CLOVER[b]

Wheat			Barley		
Date	LAI		Date	LAI	
	mean	range		mean	range
3.5.	2.63	1.94-2.97	15.5.	1.60	1.23-1.90
26.5.	4.65	3.85-5.66	18.6.	5.29	4.83-6.17
17.6.	5.80	4.73-7.12	15.7.	4.05	3.16-4.84
2.7.	3.45	2.28-4.20	1.8.	1.13	0.96-1.40
28.7.	1.29	0.87-1.75			
Clover					
Period	LAI		Period	LAI	
	mean	range		mean	range
15.4.-30.4.	3.54	1.93-4.97	30.6.- 9.7.	2.68	1.62-3.61
1.5.- 9.5.	5.07	4.09-6.14	10.7.-20.7.	3.10	2.34-4.01
10.5.-19.5.	4.97	2.09-7.21	21.7.-29.7.	3.25	1.87-5.29
20.5.-31.5.	5.47	4.46-7.28	30.7.- 9.8.	3.76	2.34-5.43
1.6.- 9.6.	5.23	4.80-5.85			
10.6.-17.6.	5.17	4.85-5.40			

[a] Expressed as area of leaves per area of ground.

[b] Average values for the years 1980 to 1983.

TABLE I.19. VEGETATION PERIODS AND YIELD SHARES OF CLOVER AND ALFALFA

Cut	Clover		Alfalfa	
	Period (d)	Yield share (%)	Period (d)	Yield share (%)
1.	50-55	55	55-60	45
2.	35-40	45	40-45	20
3.			35-40	20
4.			45-50	15

TABLE I.20. FEEDING PRACTICES IN REGION CB
(A) AVERAGE FEED CONSUMPTION OF CATTLE*

Feed	Dairy cows		Beef cattle		Unit
	Summer	Winter	Summer	Winter	
Cereals	4	4.7	2.5	2.5	kg d^{-1}
Hay (1)	-	3.8	-	2	kg d^{-1}
Green fodder (2)	45	-	18	-	kg d^{-1}
Root crops	-	0.2	-	0.3	kg d^{-1}
Ensilaged crops (3)	5	25	7	15	kg d^{-1}
Silage (4)	2	8	2	3	kg d^{-1}
Straw (5)	3	3	2.5	2.5	kg d^{-1}
Water	about 60		about 50		L d^{-1}

* Weight at consumption

(B) AVERAGE FEED CONSUMPTION OF PIGS IN FATTENING

Feed	Months						Unit
	1	2	3	4	5	6	
Wheat	0.4	0.4	2.5	1.1	1.3	1.3	kg d^{-1}
Barley	0.3	0.3	0.75	0.8	1.3	1.3	kg d^{-1}
Dried milk	<0.1	<0.08	-	-	-	-	kg d^{-1}
Whey	2.5	2.5	2.5	2.5	2.5	2.5	L d^{-1}
About 10% of the diet comprises of different proteins and mineral vitamin concentrates.							
About 2.5 L d^{-1} of whey and/or other products after milk treatment. Consumption of water and/or other liquid: 7 - 8 L d^{-1} per kg of dry fodder matter.							

(C) AVERAGE FEED CONSUMPTION FOR HEN AND BROILER

- hen 120 g d^{-1} of feed mixture (70% cereals, 20% pollard and proteins and 10% mineral vitamin concentrates);
- broiler the same amount and composition of feed, except that mineral vitamin concentrates are by 5% less in favour of the protein component.

Remarks on feeding practices:

(1) hay or ensilaged hay is dried clover, alfalfa and pasture vegetation with a dry matter content of about 72%.
(2) green fodder is fresh a pasture vegetation and fresh clover and alfalfa.
(3) ensilaged crops is a mixture of maize and sugar beet leaves and tubers after processing in sugar-house.
(4) silage is a mixture of clover, alfalfa and pasture vegetation with a dry matter content of about 45%.
(5) consumed only partially.

TABLE I.21. INFORMATION ON AREA AND INHABITANTS OF CB REGION

Subregion	Area (km^2)	Inhabitants
AB - Prague	495	1 194 873
BN - Benesov	1444	89 730
BE - Beroun	662	78 307
KL - Kladno	692	153 390
KO - Kolin	819	95 190
KH - Kutna Hora	937	81 130
ME - Melnik	712	97 264
MB - Mlada Boleslav	1067	113 807
NB - Nymburk	881	92 492
PH - Prague-east	597	96 397
PZ - Prague-west	634	78 071
PB - Pribram	1628	108 757
RA - Rakovnik	930	56 448
Total	11498	2 335 856

TABLE I.22. AGE DISTRIBUTION OF CB'S POPULATION (%)

Age	Men	Women
< 1	0.58	0.55
1 - 4	2.39	2.27
5 - 9	3.36	3.21
10 - 14	4.26	4.07
15 - 19	3.46	3.31
20 - 29	6.00	5.96
30 - 39	7.61	7.71
40 - 49	7.28	7.73
50 - 59	5.02	5.59
60 - 69	4.80	6.23
70 - 79	2.25	3.91
>80	0.79	2.02

TABLE I.23. ANNUAL CONSUMPTION OF CHIEF KINDS OF FOOD PRODUCTS IN CB (kg or L a^{-1})

Food stuff	Age category (a)				
	adults	0-1	1-8	8-12	12-20
dairy products (1)	248	31.1	360.1	383.4	333.8
beef (2)	21.5	3.8	14.9	20.7	23.2
pork (2)	39.5	1.1	7.6	16.3	19.7
poultry	12.0	0.3	7.3	8.3	14.3
other meat (2,3)	3.7	-	2.4	3.3	3.4
cereals (4)	157	14.8	61.1	101.9	140.9
fruit	45	9.9	33.6	45.4	55.9
potatoes	80	4.4	36.6	50.7	77.1
vegetables (5)	75	23	44	55.4	69.4
eggs (6)	17.3	2.7	10.9	15.8	18.3
fats (7)	26	6.3	6.5	7.2	9.9
sugar (8)	37.5	9.6	25.4	27	29.6
mushrooms (9)	0.1				
fish (10)	2.3				
water/beverages (12, 13)	not available				
wine	16				
liquors	8.8				
beer (11)	131				

Milk consumption of adults can be divided into following products:

Product	L or kg a^{-1}	% of total raw milk
pasteurized milk	111.1	44.7
cream	4.5	1.8
curd	3.7	10.5
cheese	6.3	21.1
frozen products	2.8	0.6
milk powder	3.2	12.3
evaporated milk	1.7	1.8
other	7.2	7.2

TABLE I.23 (cont.)

Remarks on food consumption:

(1) Consumption of milk products is calculated into quantities of milk of which 99.44% is cow milk, 0.52% is ovine milk and 0.04% goat milk. The time between production and consumption of milk is about 4 d. For children up to one year of age, 22.2 kg of milk food a^{-1} must be added.

(2) Consumption values for meat are expressed in net weight including viscera. There are two types of information on production and consumption of meat:

- production of meat in living weight means weight before abattoir (see Table I.16).
- meat in net weight is used for information on human consumption. The time between production and consumption of meat is about 20 to 30 d.

(3) The annual consumption of mutton and of game is about 0.8% and 0.3% of total meat, respectively. These are included in the record 'other meat', which mostly means domestic rabbit. Canned meat is about 2.5% of total production.

(4) (Consumption of flour and flour products is expressed in the whole grain value. Its use normally starts in November but cannot be specified exactly. In general it is impossible to quantify times products are kept in storage. This concerns both the storage of raw and processed food products at producers and users.

(5) Vegetables comprise 24% leafy, 34% root and 42% other vegetables. 80% is consumed fresh, while 20% is used for conservation. Fruits are listed without citrus fruits. About 60% are consumed fresh, 40% are used for compotes, jams or cidres. About 40% of fruit consumed comprises apples and pears; data on other fruit are not vailable.

(6) The consumption of eggs is given in net weight (1 kg net weight equals 20 eggs without shells or 18 eggs with shell).

(7) Fats contain animal fat and vegetable oils.

(8) Sugar is produced from sugar beet, about 14-18% of sugar in tubers.

(9) The estimate of consumption of mushrooms of wild origin is not derived with the other values. That is why no splitting into age groups can be given.

(10) Consumption rates of fish include fish obtained from freshwater areas. However, they are not produced in CB. Activity concentrations found in freshwater fish (Bq kg^{-1} f.w.):

	Cs-137	Cs-134
1986	<5	<2
1987	<2	<1

(11) The production of 1 L of beer requires 0.15 kg barley malt.

(12) Some information on the contamination of drinking water is available. The water samples were taken from a reservoir with the following contamination levels in 1986 (Bq L^{-1}):

May 1 - 5	BDL*
May 6 - 10	0.3
May 11 - 15	BDL
May 15 - 20	0.08
May 21 - 31	0.2
June 1 - 10	0.1

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* BDL means below detection limit

These contamination levels are representative for the entire region. The main source area of drinking water for Prague is indicated in Figure I.2.

(13) Water contamination is so low that it does not significantly contribute to human contamination, as drinking water, or if used for agricultural purposes (animal drinking water or irrigation). Therefore, modelling of water contamination can be neglected.

TABLE I 24 TOTAL [WET AND DRY] DEPOSITION OF CS 137 [CB]

	$\bar{X}$ arithm	95% confidence interval bounds about x arithm [Bq/m²]		$\bar{X}$ geom	sigma about x geom	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/m²]		Number of samples		Number of degrees of freedom
	[Bq/m²]	lower	upper	[Bq/m²]	[1]	lower	upper	2 5%	97 5%	all	less than	
Total deposition in 1986	5530	4020	7610	2050	4 091	3 491	4 795	129 6	32447	152	1	151

TABLE I 25 CS-137 CONTENTS IN WHOLE BODY [CB]

W B C		$\bar{X}$ arithm	95% confidence interval bounds about x arithm [Bq]		$\bar{X}$ geom	sigma about x geom	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq]		Number of samples		Number of degrees of freedom
		[Bq]	lower	upper	[Bq]	[1]	lower	upper	2 5%	97 5%	all	less than	
monthly averages	May 1986	219	186	259	183	1 83	1 65	2 04	55 8	598	62	0	61
	Jun 1986	283	219	365	265	1 44	1 23	1 69	129	542	11	0	10
	Jul 1986	439	310	622	405	1 49	1 21	1 82	186	884	8	0	7
	Aug 1986	519	472	570	479	1 50	1 41	1 59	217	1050	79	0	78
	Sep 1986	584	525	649	539	1 49	1 39	1 60	246	1180	62	0	61
quarterly averages	IV 1986	753	693	818	676	1 59	1 51	1 68	272	1680	136	0	135
	I 1987	774	708	845	709	1 52	1 43	1 61	312	1610	94	0	93
	II 1987	827	780	876	761	1 50	1 45	1 56	342	1690	211	0	210
	III 1987	778	721	840	719	1 49	1 42	1 57	329	1570	117	0	116
	IV 1987	772	699	853	687	1 62	1 52	1 73	265	1780	105	0	104
	I 1988	524	478	575	438	1 82	1 71	1 93	136	1420	194	0	193
	II 1988	393	343	450	335	1 77	1 62	1 92	110	1020	81	0	80
	III 1988	334	285	392	256	2 07	1 87	2 29	61 6	1070	103	0	102
	IV 1988	325	278	379	257	1 98	1 80	2 18	67 1	983	97	0	96
	I 1989	255	217	300	200	2 00	1 81	2 22	51 4	781	90	0	89

TABLE I 26 CS-137 CONCENTRATIONS IN WHOLE BODY [CB]

W B C		$\bar{X}$ arithm	95% confidence interval bounds about x arithm [Bq/kg]		$\bar{X}$ geom	sigma about x geom	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		[Bq/kg]	lower	upper	[Bq/kg]	[1]	lower	upper	2 5%	97 5%	all	less than	
monthly averages	May 1986	3 21	2 73	3 77	2 70	1 80	1 62	2 00	0 859	8 51	62	0	61
	Jun 1986	3 99	3 35	4 74	3 86	1 29	1 16	1 44	2 34	6 35	11	0	10
	Jul 1986	6 39	4 89	8 35	6 09	1 36	1 16	1 60	3 31	11 2	8	0	7
	Aug 1986	7 27	6 64	7 96	6 73	1 48	1 39	1 57	3 13	14 5	79	0	78
	Sep 1986	8 11	7 34	8 96	7 55	1 46	1 36	1 56	3 60	15 8	62	0	61
quarterly averages	IV 1986	10 1	9 35	11 0	9 16	1 57	1 49	1 65	3 80	22 1	136	0	135
	I 1987	11 4	10 6	12 3	10 8	1 42	1 35	1 50	5 40	21 4	94	0	93
	II 1987	11 3	10 7	11 9	10 6	1 44	1 39	1 49	5 20	21 6	211	0	210
	III 1987	11 0	10 3	11 7	10 3	1 42	1 36	1 48	5 20	20 5	117	0	116
	IV 1987	10 7	9 856	11 6	9 85	1 49	1 41	1 58	4 49	21 6	105	0	104
	I 1988	6 96	6 43	7 53	6 07	1 69	1 60	1 78	2 17	16 9	194	0	193
	II 1988	5 27	4 72	5 88	4 72	1 60	1 49	1 72	1 87	11 9	81	0	80
	III 1988	4 37	3 80	5 01	3 55	1 90	1 74	2 08	1 01	12 5	103	0	102
	IV 1988	4 27	3 72	4 89	3 52	1 86	1 70	2 03	1 04	11 9	97	0	96
	I 1989	3 36	2 90	3 90	2 74	1 90	1 73	2 08	0 783	9 61	90	0	89

TABLE I 27 HUMAN CS-137 INTAKE [CB]

Intake	X̄ arithm	95% confidence interval bounds about x arithm [Bq/d]		X̄ geom	sigma about x geom	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/d]		Number of samples		Number of degrees of freedom
	[Bq/d]	lower	upper	[Bq/d]	[1]	lower	upper	2 5%	97 5%	all	less than	
7 6 -14 7 1987	5 73	3 32	9 88	3 93	2 38	1 75	3 24	0 717	21 5	16	1	15

TABLE I 28 CS-137 CONCENTRATIONS IN MILK [CB]

Milk		X̄ arithm	95% confidence interval bounds about x arithm [Bq/l]		X̄ geom	sigma about x geom	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/l]		Number of samples		Number of degrees of freedom
		[Bq/l]	lower	upper	[Bq/l]	[1]	lower	upper	2 5%	97 5%	all	less than	
monthly averages	May 1986	22 5	19 7	25 6	16 1	2 27	2 10	2 46	3 23	79 9	200	1	199
	Jun 1986	19 9	15 6	25 3	14 7	2 16	1 87	2 51	3 24	67 0	53	0	52
	Jul 1986	6 89	1 15	41 4	2 53	4 11	1 99	8 45	0 158	40 5	8	3	7
	Aug 1986	3 67	1 91	7 05	3 01	1 88	1 33	2 65	0 873	10 4	7	0	6
	Sep 1986	2 02	0 852	4 77	1 55	2 07	1 34	3 19	0 372	6 44	6	2	5
quarterly averages	IV 1986	3 94	2 63	5 90	2 62	2 47	1 96	3 11	0 446	15 4	30	4	29
	I 1987	6 01	3 84	9 41	4 41	2 20	1 69	2 85	0 944	20 6	18	2	17
	II 1987	4 33	3 12	6 02	3 40	2 01	1 64	2 45	0 867	13 3	24	1	23
	III 1987	0 890	0 669	1 18	0 724	1 90	1 59	2 26	0 206	2 55	26	1	25
	IV 1987	0 362	0 112	1 17	0 158	3 62	2 07	6 28	1 28E-2	1 97	12	5	10
	I 1988	0 511	0 256	1 02	0 365	2 27	1 56	3 29	7 31E-2	1 83	10	0	9
	II 1988	0 380	0 173	0 837	0 213	2 93	1 95	4 40	2 59E-2	1 76	14	2	13
	III 1988	0 104	3 29E-2	0 335	4 34E-2	3 77	2 12	6 67	3 22E-3	0 587	14	8	10
	IV 1988	0 190	4 29E-2	0 839	4 45E-2	5 49	2 72	11 0	1 13E-3	1 76	14	5	11
	I 1989	0 209	7 83E-2	0 557	8 25E-2	3 91	2 48	6 14	5 71E-3	1 19	18	4	17

TABLE I 29 CS-137 CONCENTRATIONS IN MILK [B]

MILK		X̄ arithm	95% confidence interval bounds about x arithm [Bq/l]		X̄ geom	sigma about x geom	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/l]		Number of samples		Number of degrees of freedom
		[Bq/l]	lower	upper	[Bq/l]	[1]	lower	upper	2 5%	97 5%	all	less than	
QUART AVER	III 1988	0 263	0 118	0 590	8 09E-2	4 65	3 13	6 88	3 98E-3	1 64	40	23	29
	IV 1988	0 571	0 219	1 49	0 102	6 39	4 28	9 53	2 69E 3	3 87	50	21	41
	I 1989	0 378	0 189	0 754	0 116	4 65	3 39	6 38	5 68E-3	2 36	49	14	45

TABLE I 30 CS-137 CONCENTRATIONS IN MILK [OTH]

MILK		X̄ arithm	95% confidence interval bounds about x arithm [Bq/l]		X̄ geom	sigma about x geom	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/l]		Number of samples		Number of degrees of freedom
		[Bq/l]	lower	upper	[Bq/l]	[1]	lower	upper	2 5%	97 5%	all	less than	
QUART AVER	III 1988	0 326	0 160	0 664	0 150	3 47	2 34	5 13	1 31E-2	1 72	26	15	19
	IV 1988	0 684	0 251	1 86	0 158	5 54	3 57	8 58	5 50E-3	4 52	36	16	29
	I 1989	0 490	0 196	1 23	0 144	4 79	3 18	7 19	6 69E 3	3 09	31	10	28

TABLE I 31 CS-137 CONCENTRATIONS IN BEEF [CB]

Beef		X̄ arithm	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom	sigma about x geom	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		[Bq/kg]	lower	upper	[Bq/kg]	[1]	lower	upper	2 5%	97 5%	all	less than	
monthly averages	May 1986	72 9	N/A	N/A	49 9	N/A	N/A	N/A	N/A	N/A	2*)	0	
	Jun 1986	95 7	14 4	635	51 6	3 04	1 45	6 33	5 84	456	5	0	4
	Jul 1986	35 9	11 9	108	22 9	2 58	1 53	4 35	3 55	147	7	0	6
	Aug 1986	10 0	5 47	18 3	9 03	1 58	1 16	2 13	3 70	22 0	5	0	4
	Sep 1986	7 34	3 89	13 9	6 83	1 46	1 10	1 94	3 25	14 4	4	0	3
quarterly averages	IV 1986	13 0	5 74	29 2	7 04	3 02	1 98	4 58	0 809	61 3	14	1	13
	I 1987	14 3	4 47	45 8	8 10	2 91	1 68	5 00	1 00	65 6	8	0	7
	II 1987	20 8	11 8	36 8	11 8	2 90	2 13	3 93	1 47	95 2	24	0	23
	III 1987	16 3	6 71	39 5	7 97	3 31	2 13	5 11	0 765	83 0	15	0	14
	IV 1987	3 29	1 21	8 99	1 15	4 26	2 69	6 72	6 73E-2	19 7	21	7	19
	I 1988	1 78	0 389	8 13	0 419	5 48	2 93	10 2	1 50E-2	11 7	18	9	14
	II 1988	2 60	0 867	7 80	0 869	4 40	2 68	7 19	4 77E-2	15 8	19	5	17
	III 1988	4 36	2 95E-2	645	7 28E-2	17 5	5 36	56 4	2 67E-4	19 8	16	10	11
	IV 1988	5 22	6 98E-2	391	7 37E-2	18 5	6 57	51 9	2 41E-4	22 5	21	13	15
	I 1989	861	0 159	4 66	0 153	6 43	3 39	12 1	3 98E-3	5 85	20	10	16

*) Since only two values are available no other estimates were done

TABLE I 32 CS-137 CONCENTRATIONS IN BEEF [B]

BEEF		X̄ arithm	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom	sigma about x geom	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		[Bq/kg]	lower	upper	[Bq/kg]	[1]	lower	upper	2 5%	97 5%	all	less than	
QUARTERLY AVERAGES	IV 1987	3 28	2 11	5 11	1 63	3 27	2 58	4 14	0 159	16 6	52	14	48
	I 1988	1 65	0 827	3 27	0 562	4 33	3 10	6 04	3 18E-2	9 94	45	21	37
	II 1988	2 34	1 54	3 57	1 05	3 56	2 87	4 42	8 68E 2	12 6	70	16	66
	III 1988	1 79	0 679	4 73	0 347	6 13	4 16	9 01	9 92E-3	12 1	48	20	42
	IV 1988	1 53	0 424	5 53	0 130	9 21	5 94	14 3	1 67E 3	10 1	63	35	49
	I 1989	1 07	0 359	3 18	0 181	6 59	4 29	10 1	4 48E 3	7 28	45	22	37

TABLE I 33 CS-137 CONCENTRATIONS IN BEEF [OTH]

BEEF		X̄ arithm	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom	sigma about x geom	95% confidence interval bounds of sigma geom [1]		quantils of log normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		[Bq/kg]	lower	upper	[Bq/kg]	[1]	lower	upper	2 5%	97 5%	all	less than	
QUARTERLY AVERAGES	IV 1987	3 26	2 10	5 07	2 02	2 66	2 07	3 41	0 298	13 8	31	7	29
	I 1988	1 59	0 755	3 33	0 679	3 68	2 51	5 38	5 29E-2	8 72	27	12	22
	II 1988	2 26	1 45	3 54	1 12	3 28	2 59	4 15	0 109	11 5	51	11	48
	III 1988	1 44	0 698	2 96	0 570	3 90	2 75	5 52	3 96E-2	8 19	32	10	29
	IV 1988	0 987	0 307	3 18	0 161	6 72	4 25	10 6	3 84E 3	6 73	42	22	33
	I 1989	1 23	0 278	5 44	0 209	6 57	3 68	11 7	5 23E 3	8 37	25	12	20

TABLE I 34 CS-137 CONCENTRATIONS IN PORK [CB]

PORK		X̄ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
			lower	upper			lower	upper	2 5%	97 5%	all	less than	
monthly averages	May 1986										0		
	Jun 1986	14 8	6 93	31 7	12 1	1 90	1 29	2 78	3 43	42 5	6	0	5
	Jul 1986	9 20	2 30	36 8	5 49	2 76	1 50	5 07	0 750	40 2	6	0	5
	Aug 1986	12 8	8 13	20 0	12 3	1 32	1 10	1 62	7 16	21 1	4	0	3
	Sep 1986	13 0	3 56	47 3	11 6	1 61	1 10	2 45	4 58	29 4	3	0	2
quarterly averages	IV 1986	18 1	12 6	26 0	16 4	1 56	1 26	1 93	6 84	39 3	9	0	8
	I 1987	18 7	12 9	27 0	17 1	1 52	1 23	1 89	7 49	39 0	8	0	7
	II 1987	22 1	16 5	29 6	18 4	1 83	1 53	2 20	5 61	60 3	22	0	21
	III 1987	14 5	11 0	19 1	12 6	1 69	1 42	2 01	4 52	35 1	18	0	17
	IV 1987	3 88	2 40	6 27	2 91	2 14	1 62	2 82	0 657	12 9	15	1	14
	I 1988	0 991	0 643	1 53	0 821	1 85	1 42	2 41	0 246	2 74	12	4	10
	II 1988	2 62	0 263	26 2	0 499	6 19	2 70	14 1	1 40E-2	17 7	11	5	9
	III 1988	1 77	0 439	7 11	0 682	3 97	2 12	7 41	4 56E-2	10 2	11	4	9
	IV 1988	0 661	8 66E-2	5 05	0 187	4 91	2 17	11 0	8 26E-3	4 22	10	6	7
	I 1989	0 905	0 271	3 02	0 428	3 40	1 95	5 91	3 89E-2	4 71	10	3	9

TABLE I 35 CS-137 CONCENTRATIONS IN PORK [B]

PORK		X̄ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
			lower	upper			lower	upper	2 5%	97 5%	all	less than	
QUART AVER	III 1988	1 33	0 696	2 54	0 623	3 43	2 46	4 78	5 56E-2	6 97	29	9	26
	IV 1988	0 674	0 322	1 41	0 250	4 09	2 83	5 90	1 58E-2	3 96	35	17	28
	I 1989	0 704	0 439	1 13	0 383	3 01	2 32	3 91	4 41E-2	3 33	38	12	34

TABLE I 36 CS-137 CONCENTRATIONS IN PORK [OTH]

PORK		X̄ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
			lower	upper			lower	upper	2 5%	97 5%	all	less than	
QUART AVER	III 1988	1 18	0 531	2 35	0 589	3 10	2 10	4 57	6 40E-2	5 42	18	5	16
	IV 1988	0 688	0 299	1 58	0 272	3 91	2 59	5 88	1 88E-2	3 93	25	11	21
	I 1989	0 642	0 381	1 08	0 369	2 86	2 14	3 82	4 70E-2	2 90	28	9	25

TABLE I 37 CS-137 CONCENTRATION IN CEREALS - WINTER WHEAT [CB]

Winter Wheat	X̄ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		lower	upper			lower	upper	2 5%	97 5%	all	less than	
harvest 1986	13 2	10 4	16 8	9 33	2 31	2 00	2 68	1 82	48 0	65	7	63
harvest 1987	0 127	5 47E-2	0 295	7 96E-2	2 63	1 60	4 30	1 20E-2	0 530	16	13	7
harvest 1988	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8 *)	7	

*) Since only one significant value is available the software used for data processing does not provide any results

TABLE I 38 CS-137 CONCENTRATION IN CEREALS WINTER WHEAT [B]

Winter Wheat	X̄ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		lower	upper			lower	upper	2 5%	97 5%	all	less than	
harvest 1986	13 2	10 4	16 8	9 33	2 31	1 99	2 67	1 81	48 0	65	7	63
harvest 1987	436	4 17E-2	4 55	1 92E-2	12 2	5 52	26 7	1 44E 4	2 57	50	44	19
harvest 1988	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	28	26	

*) Since only two values are available the obtained wide estimates of confidence intervals as well as other parameters are not realistic and are not presented therefore

TABLE I 39 CS-137 CONCENTRATION IN CEREALS - WINTER WHEAT [OTH]

Winter Wheat	X̄ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		lower	upper			lower	upper	2 5%	97 5%	all	less than	
harvest 1986										0		
harvest 1987	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	34 *)	31	
harvest 1988	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	20 *)	19	

*) Since only three significant values are available the obtained wide estimates of confidence intervals as well as other parameters are not realistic and are not presented therefore

**) Since only one value higher than the minimum significant value is available the software used for data processing does not provide any results

TABLE I 40 CS-137 CONCENTRATION IN ANIMAL FEED - STORED FEED-STUFFS [CB]

Stored feed-stuffs	X̄ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		lower	upper			lower	upper	2 5%	97 5%	all	less than	
harvest 1986	47.6	9 30	243	0 648	18 7	12 2	28 7	2 07E-3	203	115	62	90
harvest 1987	6 85	0 220	214	0 148	16 0	6 50	39 0	6 47E-4	33 7	27	18	18
harvest 1988										0		

These results present the sum of ensilaged crops and ensilaged hay

TABLE I 41 CS-137 CONCENTRATION IN ANIMAL FEED - STORED FEED-STUFFS [B]

Stored feed-stuffs	X̄ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		lower	upper			lower	upper	2 5%	97 5%	all	less than	
harvest 1986	1 10E+4	1 63E+3	7 44E+4	2 36	61 0	42 7	87 0	7 50E-4	7450	299	134	256
harvest 1987	2 08	0 753	5 72	0 444	5 79	3 75	8 94	1 42E-2	13 9	39	19	31
harvest 1988										0		

These results present the sum of ensilaged crops and ensilaged hay

TABLE I 42 CS-137 CONCENTRATION IN ANIMAL FEED - STORED FEED-STUFFS [OTH]

Stored feed-stuffs	X̄ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		lower	upper			lower	upper	2 5%	97 5%	all	less than	
harvest 1986	2 70E+4	2 68E+3	2 72E+5	7 24	57 7	37 2	89 5	2 56E-3	2 05E+4	184	72	164
harvest 1987	1 05	0 665	1 66	0 849	1 92	1 47	2 51	0 236	3 06	12	1	11
harvest 1988										0		

These results present the sum of ensilaged crops and ensilaged hay

TABLE I 43 CS-137 CONCENTRATION IN ANIMAL FEED - ENSILAGED HAY [CB]

Ensilaged Hay	X̄ arithm	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom	sigma about x geom	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
	[Bq/kg]	lower	upper	[Bq/kg]	[1]	lower	upper	2 5%	97 5%	all	less than	
harvest 1986	506	23 5	1 09E+4	5 45	20 3	8 98	45 7	1 49E 2	1990	29	8	26
harvest 1987	22 8	0 411	1 27E+3	1 38	10 7	3 41	33 1	1 33E 2	143	9	3	8
harvest 1988										0		

TABLE I 44 CS-137 CONCENTRATION IN ANIMAL FEED - ENSILAGED HAY [B]

Ensilaged Hay	X̄ arithm	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom	sigma about x geom	95% confidence interval bounds of sigma geom [1]		quantils of log normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
	[Bq/kg]	lower	upper	[Bq/kg]	[1]	lower	upper	2 5%	97 5%	all	less than	
harvest 1986	1220	500	3000	47 1	12 8	9 62	17 1	0 316	7010	154	22	150
harvest 1987	11 7	0 905	152	1 52	7 54	3 15	17 9	2 91E-2	79 9	11	3	10
harvest 1988										0		

TABLE I 45 CS-137 CONCENTRATION IN ANIMAL FEED - ENSILAGED HAY [OTH]

Ensilaged Hay	X̄ arithm	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom	sigma about x geom	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
	[Bq/kg]	lower	upper	[Bq/kg]	[1]	lower	upper	2 5%	97 5%	all	less than	
harvest 1986	877	410	1870	76 6	9 10	6 90	12 0	1 01	5800	125	14	123
harvest 1987	1 65	N/A	N/A	1 52	N/A	N/A	N/A	N/A	N/A	2 *)	0	
harvest 1988										0		

*) Since only two significant values are available no other estimates were done

TABLE I 46 CS-137 CONCENTRATION IN ANIMAL FEED - ENSILAGED CROPS [CB]

Ensilaged Crops	X̄ arithm	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom	sigma about x geom	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
	[Bq/kg]	lower	upper	[Bq/kg]	[1]	lower	upper	2 5%	97 5%	all	less than	
harvest 1986	3 98	1 50	10 6	0 475	7 86	5 47	11 3	8 36E-3	27 0	86	54	62
harvest 1987	0 322	118	880	147	3 51	1 92	6 38	1 25E-2	1 71	18	15	8
harvest 1988										0		

TABLE I 47 CS-137 CONCENTRATION IN ANIMAL FEED - ENSILAGED CROPS [B]

Ensilaged Crops	X̄ arithm	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom	sigma about x geom	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
	[Bq/kg]	lower	upper	[Bq/kg]	[1]	lower	upper	2 5%	97 5%	all	less than	
harvest 1986	2 72	0 903	8 21	0 163	10 7	7 48	15 4	1 55E-3	17 1	145	112	83
harvest 1987	0 598	0 389	0 919	0 398	2 46	1 88	3 22	6 82E-2	2 33	28	16	21
harvest 1988										0		

TABLE I 48 CS-137 CONCENTRATION IN ANIMAL FEED - ENSILAGED CROPS [OTH]

Ensilaged Crops	$\bar{X}$ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		$\bar{X}$ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		lower	upper			lower	upper	2 5%	97 5%	all	less than	
harvest 1986	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	59 *)	58	
harvest 1987	0 922	0 562	1 51	0 756	1 88	1 41	2 50	0 220	2 60	10	1	9
harvest 1988										0		

*) Since only one value higher than the minimum significant value is available the software used for data processing does not provide any results

TABLE I 49 CS-137 CONCENTRATION IN ANIMAL FEED - SPRING BARLEY [CB]

Spring Barley	$\bar{X}$ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		$\bar{X}$ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		lower	upper			lower	upper	2 5%	97 5%	all	less than	
harvest 1986	18 1	6 11	53 4	1 94	8 27	5 61	12 2	3 08E-2	122	74	42	57
harvest 1987	216	0 163	0 285	0 195	1 56	1 31	1 86	8 18E-2	0 467	20	13	12
harvest 1988	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8*)	6	

*) Since only two values are available the obtained wide estimates of confidence intervals as well as other parameters are not realistic and are not presented therefore

TABLE I 50 CS-137 CONCENTRATION IN ANIMAL FEED - SPRING BARLEY [B]

Spring Barley	$\bar{X}$ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		$\bar{X}$ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		lower	upper			lower	upper	2 5%	97 5%	all	less than	
harvest 1986	18 1	6 11	53 4	1 94	8 27	5 61	12 2	3 08E-2	122	74	42	57
harvest 1987	228	0 171	0 304	0 180	1 99	1 65	2 41	4 67E-2	0 694	61	49	25
harvest 1988	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9*)	7	

*) Since only two values are available the obtained wide estimates of confidence intervals as well as other parameters are not realistic and are not presented therefore

TABLE I 51 CS-137 CONCENTRATION IN ANIMAL FEED - SPRING BARLEY [OTH]

Spring Barley	$\bar{X}$ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		$\bar{X}$ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		lower	upper			lower	upper	2 5%	97 5%	all	less than	
harvest 1986										0		
harvest 1987	0 235	0 138	0 399	0 163	2 34	1 69	3 23	3 08E 2	0 866	41	36	13
harvest 1988	< 0 4*)	N/A	N/A	< 0 4*)	N/A	N/A	N/A	N/A	N/A	1	1	

*) The minimum significant value (censoring limit) is given instead of x arithm as well as x geom

TABLE I 52 CS-137 CONCENTRATION IN ANIMAL FEED - PASTURE VEGETATION [CB]

Pasture Vegetation	$\bar{X}$ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		$\bar{X}$ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		lower	upper			lower	upper	2 5%	97 5%	all	less than	
May 1986	685	538	872	608	1 63	1 39	1 90	235	1580	20	0	19
June 1986	291	197	431	244	1 81	1 43	2 28	76 4	781	13	0	12
May *) 1986	431	183	1020	358	1 85	1 23	2 76	108	1190	5	0	4
June *) 1986	231	133	401	169	2 20	1 61	3 00	36 1	792	13	0	12

*) Grass mowed on Apr 30

TABLE I 53. CS-137 CONCENTRATION IN ANIMAL FEED - PASTURE VEGETATION [B]

Pasture Vegetation	X̄ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		lower	upper			lower	upper	2.5%	97.5%	all	less than	
May 1986	1600.	1240.	2060.	667.	3.75	3.29	4 27	50.0	8900	197	0	196
June 1986	165.	122.	225	110.	2.46	2.06	2 95	18.8	645.	49	2	48

TABLE I.54. CONCENTRATION IN ANIMAL FEED - PASTURE VEGETATION [OTH]

Pasture Vegetation	X̄ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		lower	upper			lower	upper	2 5%	97.5%	all	less than	
May 1986	1760.	1320.	2350.	674.	4.00	3.46	4 62	44.6	1.02E+4	177	0	176
June 1986	116.	84.0	160	82.8	2.27	1.88	2 75	16.5	414.	36	2	35

TABLE I.55. CS-137 CONCENTRATION IN FRUIT - APPLES/PEARS [CB]

Apples / Pears	X̄ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		lower	upper			lower	upper	2 5%	97.5%	all	less than	
harvest 1986	26.2	20.3	33.7	23.6	1 57	1 34	1 84	9.75	57.2	16	0	15
harvest 1987	N/A	N/A	N/A	N/A	10.1	N/A	N/A	N/A	N/A	3	2	
harvest 1988	1.66	0.335	8.21	0.683	3.79	1.91	7 47	5 01E-2	9.30	8	2	7

*) Since only one value is available the obtained wide estimates of confidence intervals as well as other parameters are not realistic and are not presented therefore.

TABLE I.56. CS-137 CONCENTRATION IN FRUIT - APPLES/PEARS [B]

Apples / Pears	X̄ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		lower	upper			lower	upper	2.5%	97.5%	all	less than	
harvest 1986	24.7	19.3	31.8	16.1	2.53	2 18	2 92	2 62	99.1	79	7	78
harvest 1987	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	17 *)	15	
harvest 1988	1.64	0.740	3.62	0.670	3.81	2.59	5.58	4 88E-2	9 19	25	6	23

*) Since only two values are available the obtained wide estimates of confidence intervals as well as other parameters are not realistic and are not presented therefore.

TABLE I.57. CS-137 CONCENTRATION IN FRUIT - APPLES/PEARS [OTH]

Apples / Pears	X̄ arithm [Bq/kg]	95% confidence interval bounds about x arithm [Bq/kg]		X̄ geom [Bq/kg]	sigma about x geom [1]	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
		lower	upper			lower	upper	2 5%	97.5%	all	less than	
harvest 1986	24.1	17 6	33 1	14.5	2 74	2.30	3 27	2 01	105	63	7	62
harvest 1987	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	14 *)	13	
harvest 1988	1.62	0 606	4.36	0 664	3 81	2 41	6 02	4 82E-2	9 14	17	4	16

*) Since only one value is available the obtained wide estimates of confidence intervals as well as other parameters are not realistic and are not presented therefore

TABLE I 58 CS-137 CONCENTRATION IN LEAFY VEGETABLES [CB]

Leafy Vegetables	$\bar{X}$ arithm	95% confidence interval bounds about x arithm [Bq/kg]		$\bar{X}$ geom	sigma about x geom	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
	[Bq/kg]	lower	upper	[Bq/kg]	[1]	lower	upper	2 5%	97 5%	all	less than	
harvest 1986	220	52 5	925	16 5	9 75	6 00	15 8	0 190	1430	46	13	42
harvest 1987	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	12	11	
harvest 1988	< 2**)	N/A	N/A	< 2**)	N/A	N/A	N/A	N/A	N/A	5	5	

*) Since only one value is available the obtained wide estimates of confidence intervals as well as other parameters are not realistic and are not presented therefore

**) The highest of the minimum significant values (censoring limits) are given instead of x arithm as well as x geom

TABLE I 59 CS-137 CONCENTRATION IN LEAFY VEGETABLES [B]

Leafy Vegetables	$\bar{X}$ arithm	95% confidence interval bounds about x arithm [Bq/kg]		$\bar{X}$ geom	sigma about x geom	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
	[Bq/kg]	lower	upper	[Bq/kg]	[1]	lower	upper	2 5%	97 5%	all	less than	
harvest 1986	154	46 4	512	6 42	12 4	8 61	18 0	4 58E-2	899	108	50	90
harvest 1987	0 463	0 102	2 11	0 133	4 85	2 27	10 3	6 03E-3	2 94	17	14	8
harvest 1988	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	20 *)	19	

*) Since only one value is available the obtained wide estimates of confidence intervals as well as other parameters are not realistic and are not presented therefore

TABLE I 60 CS-137 CONCENTRATION IN LEAFY VEGETABLES [OTH]

Leafy Vegetables	$\bar{X}$ arithm	95% confidence interval bounds about x arithm [Bq/kg]		$\bar{X}$ geom	sigma about x geom	95% confidence interval bounds of sigma geom [1]		quantils of log-normal distribution [Bq/kg]		Number of samples		Number of degrees of freedom
	[Bq/kg]	lower	upper	[Bq/kg]	[1]	lower	upper	2 5%	97 5%	all	less than	
harvest 1986	69 0	29 0	165	22 0	4 53	3 03	6 76	1 14	426	30	8	27
harvest 1987	0 600	0 114	3 14	0 391	2 52	1 25	5 05	6 38E-2	2 40	5	3	3
harvest 1988	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	15 *)	14	

*) Since only one significant value is available the obtained wide estimates of confidence intervals as well as other parameters are not realistic and are not presented therefore

TABLE I 61 ESTIMATED GEOMETRIC (g) AND ARITHMETIC (a) MEAN [Bq/kg] WITH ENFORCED VALUE OF GSD

Region	C B				OTH				B			
Enforced GSD	4		2		4		2		4		2	
Mean	g	a	g	a	g	a	g	a	g	a	g	a
Wheat 87	0 07	0 18	0 1	0 13	0 5	1 3	1 2	1 5	0 1	0 26	0 2	0 25
Wheat 88	0 09	0 24	0 25	0 32	0 03	0 08	0 08	0 1	0 03	0 08	0 15	0 19
Ensil hay 87	1 3	3 4	-	-	1 0	2 6	-	-	1 4	3 8	-	-
Ens crops 87	0 1	0 26	0 4	0 5	-	-	-	-	-	-	-	-
Barley 88	0 15	0 4	0 35	0 45	-	-	-	-	0 15	0 4	0 4	0 5
Apple/Pear 87	2 0	5 0	4 0	5 0	0 5	1 3	1 5	1 9	0 7	2 8	2 0	2 5
Leafy Veg 87	0 5	1 3	1 0	1 3	0 25	0 65	0 5	0 65	0 2	0 5	0 45	0 55
Leafy Veg 88	-	-	-	-	0 025	0 07	0 1	0 13	0 02	0 05	0 07	0 09
Beef III/88	0 4	1 0	-	-	-	-	-		-	-	-	
Beef IV/88	0 25	0 65	-	-	-	-	-	-	-	-	-	-

TABLE I.62. VARIABILITY OF ^{137}CS DEPOSITION IN CB REGION

Region	Geometric mean	Arithmetic mean	GSD
	(kBq.m^{-2})	(kBq.m^{-2})	
CB region	1.98	5.05	3.93
Subregions:			
AB	4.31	5.82	2.17
BN	12.06	22.05	3.0
BE	1.21	1.73	2.33
KL	0.17	0.23	2.19
KO	1.25	2.11	2.78
KH	6.55	9.82	2.46
ME	1.9	2.54	2.14
MB	2.89	3.12	1.48
NB	3.16	4.34	2.22
PH	6.07	7.1	1.75
PZ	1.99	2.74	2.22
PB	0.75	0.9	1.84
RA	1.3	1.6	2.1
Squares:			
BN large	11.7	15.41	2.1
BN small	9.39	10.11	1.47
ME large	1.53	2.74	2.94
ME small	2.8	3.49	1.94

TABLE I.63. DEPOSITION MEASURED IN LARGE AND SMALL SQUARES IN BN SUBREGION IN THE VICINITY OF SAMPLING SITE S019 (SAMPLING ON 26-SEP-1986) (SEE FIG.I.3)

Sample	^{137}Cs	^{134}Cs
	(kBq.m^{-2})	(kBq.m^{-2})
1. Large square		
1	10.08	5.37
2	9.56	4.44
3	6.48	3.1
4	8.43	3.89
5	22.8	10.05
6	3.09	3.09
7	36.6	16.15
8	20.4	8.72
9	14.7	6.26
2. Small square		
10	6.97	3.19
11	5.09	2.38
12	9.01	3.9
13	15.6	7.2
14	12.4	5.43
15	11.7	5.4
16	10.08	5.08
17	13.3	6.15
18	5.28	2.25
19	10.5	4.81

TABLE I.64. DEPOSITION MEASURED IN LARGE AND SMALL SQUARES IN ME SUBREGION IN THE VICINITY OF SAMPLING SITES ME S075 AND ME S076 (SAMPLING *ON 30-SEP-86) (SEE FIG I.3)*

Sample	^{137}Cs	^{134}Cs
	(kBq.m^{-2})	(kBq.m^{-2})
1. large square		
1(N)	5.22	2.12
2	3.6	1.3
3(E)	0.66	<MDA
4	missing	
5	1.93	0.64
6(S)	0.53	<MDA
7	0.39	<MDA
8(W)	6.23	2.49
9	0.99	0.39
2. small square		
I	1.12	0.31
II	1.53	0.55
III	6.85	2.41
IV	missing	
V	4.15	1.59
VI	missing	
VII	2.96	1.17
VIII	missing	
IX	3.37	1.53

TABLE I. 65. RESULTS OF IN-SITU GAMMA SPECTROMETRY

Date	Sampling site*	^{137}Cs (kBq.m^{-2})
26-Aug-88	aerosol sampling station AB	3.89
15-Nov-90	aerosol sampling station AB	3.62
23-Aug-91	aerosol sampling station AB	3.84
29-Aug-91	BN S013 (arable)	36.2 (Bq kg^{-1})
29-Aug-91	BN S013 (meadow)	13.71
30-Aug-91	KL S038	1.89
30-Aug-91	RA S148	1.44
05-Sep-91	AB	2.95
05-Nov-91	ME small square	4.8
05-Nov-91	ME large square 6 (S)	12.4 (Bq kg^{-1})
05-Nov-91	ME large square 8 (W)	2.7
01-Jun-93	N on the line connecting sampling sites S013 and S021 4 km from site S013	31
01-Jun-93	BN on the line connecting sampling sites S013 and S021 3.5 km from site S013	26.5
01-Jun-93	BN on the line connecting sampling sites S013 and S021 3 km from site S013	1.9
01-Jun-93	BN on the line connecting sampling sites S013 and S021 1 km from site S013	15.8

* approximate

TABLE I.66. MEASURED DEPTH-DISTRIBUTION OF ^{137}Cs AND ^{134}Cs IN THE SOIL

(A) SAMPLING SITE S019 (THE SAME PLACE AS SAMPLE 7 IN TABLE I.63), SAMPLING ON 6-JUL-87

Soil layer (cm)	^{137}Cs (Bq.kg^{-1})	^{134}Cs (Bq.kg^{-1})
0-1	161.6	54.6
1-5	51.5	16.2
5-10	6.1	0.3
10-20	4.8	<MDA
20-35	4.3	<MDA

Note: Measured values correspond to exponential depth distribution with relaxation depth of about 2 cm.

(B) SAMPLING SITE AB (SAME AS THE ONE FOR IN SITU MEASUREMENT ON 05-SEP-91, SAMPLING ON 17 NOV-87)

Soil layer (cm)	^{137}Cs (Bq.kg^{-1})	^{134}Cs (Bq.kg^{-1})
0-3	42.7	15.5
3-7	24	6.8
7-12	10.7	2.4
12-15	8.6	1.7
15-20	6.4	1.3
20-25	3.8	<MDA

Note: Measured values correspond to exponential depth distribution with relaxation depth of about 5 cm.

TABLE I.67. BODY CONTENT OF ^{137}CS IN PEOPLE FROM CB REGION

Time period	Body content as measured by WBC $\bar{x}_{arithm}$ * (Bq)	95% confidence bounds (Bq)	No. of people	Time period	Body content as calculated from urine measurements		95% confidence bounds about $\bar{x}_{arithm}$	geometric standard deviation (GSD)	No. of samples
					$\bar{x}_{arithm}$ (Bq)	$\bar{x}_{geom}$ (Bq)			
1987 III. Q	778	722-893	116	1987 Oct	734	648	597-887	1.65	25
1987 IV. Q	772	700-852	104						
1988 II. Q	393	344-449	80	1988 Mar	290	266	242-347	1.54	28
1988 III. Q	334	285-391	102						
1989 I. Q	255	217-299	89	1989 May	218	166	161-290	2.09	29

* Geometric means and GSD are given in Table I.25.

TABLE I.68. CALCULATED INGESTION INTAKES OF ^{137}CS FROM WHOLE BODY COUNTING

Time period	Apparent single intake (Bq)	Daily intake (Bq)
May 86	74*	2.4
Jun 86	126	4.2
Jul 86	252	8.1
Aug 86	195	6.3
Sep 86	191	6.4
IV.Q 86	636	6.9
I.Q 87	512	5.8
II.Q 87	582	6.4
III.Q 87	474	5.1
IV.Q 87	508	5.5
I.Q 88	136	1.5
II.Q 88	154	1.7
III.Q 88	185	2.0
IV.Q 88	217	2.4
I.Q 89	114	1.3
Total	4356	

* Equivalent of the inhalation intake was already subtracted.

Appendix II

DESCRIPTION OF MODELS USED IN SCENARIO CB

D. Galeriu, B. Kanyar, V. Kliment, T. Hinton, S.R. Peterson

II.1. INTRODUCTION

Within the working group for the CB Scenario, comparison of predictions with observations revealed which models had the most accurate predictions. Subsequently, explanations for success or failure were obtained through comparison of model structure, assumptions, and parameter values. This document provides the descriptions for all participating models of the assumptions, equations, and parameter values used to calculate the initial predictions which were "frozen" for model intercomparison. It will help the reader understand the different model predictions and to intercompare the results meaningfully. As much as possible, the same outline is maintained for each model description to make the comparison easier. Answers to a questionnaire were combined with information from supplementary discussions to produce this document.

Two constraints exist and need to be stressed. First, as mentioned, the model descriptions are restricted to codes used for the first set of predictions only. Even before the end of the exercise, and certainly afterwards, some aspects of most models were changed. Also, we can only offer a condensed version of the model descriptions. If the reader intends to reconstruct the models or to try to use parts of them, he should contact the developer for necessary details.

Generally the conceptual form of all models is represented by networks of compartments and subcompartments (shown in figures in the document) with special constraints existing among variables and parameters of the transport processes (discussed in the text). When possible, tables of comparative parameter values have been prepared. Most of the models participating in the CB Scenario also participated in BIOMOVS Scenario A4 (air-forage-milk) [II.1]. Many of these models have grown along with the demands placed on them by participation in these model testing exercises; time dependency and uncertainty analysis are two example of additions made to simpler codes. Because of the evolution of most models, a description can be based on no single classification. Rather, mixed models have been used.

In most of the cases the mathematical form of the compartmental system can be given by the following linear differential equation:

$$\frac{dq_x}{dt} = \sum_{x \neq y} k_{yx} \cdot q_y - q_x \cdot \left[\sum_{x \neq y} k_{xy} + k_x + \lambda_r \right] + I_x$$

where q_x is the radioactivity in the compartment x, k_{yx} is the transfer coefficient from compartment y to x, k_x is the outflow coefficient from x, λ_r is the radioactive decay constant, and I_x is the intake rate into compartment x. To solve the set of differential equations, initial values of q_x are introduced. By use of some limitations on the parameters k_{xy}, k_x, and I_x, the solutions like q_x can be expressed in explicit algebraic forms (mainly sums of exponentials) with time-dependency, as is done in most of the models. Other models use numerical methods to solve the differential equations, and in this case it may be easier to consider the time-dependency of the transfer coefficients and the nonlinear terms of the models. Most of the models used for the CB Scenario were developed or revised based on experiences from the Chernobyl accident.

The reader should consult the symbol list, prior to any attemp to utilize the model descriptions.

II.2. MODELS AND USERS

CLRP	Pietrzak-Flis, Z., Krajewski, P., Central Laboratory for Radiological Protection, Dept.of Radiation Hygiene, Warsaw, Poland.
DOSDIM	Sohier, A., Zeevaert, T., SCK/CEN Radiation Protection Dept., Mol, Belgium.
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GENII, HEDR	Napier, B., Battelle Pacific Northwest Laboratory Richland, Washington, USA.
ENCONAN	Kliment, V., Prouza, Z., National Institute of Public Health, Prague, Czech Republic.
CHERPAC	Barry, P., Peterson, S.R., Chalk River Laboratories, Canada.
ECOSYS	Müller, H., Pröhl, G, GSF Institut für Strahlenschutz, Neuherberg, Germany.
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II.3. LIST OF SYMBOLS

A_x	radionuclide whole body content for humans (x=HB) or animals (x=a) (Bq)
a_j	parameter in milk dynamic model in DOSDIM model
AB	as index means the subregion AB in CB region
B_{vx}	concentration factor for uptake of Cs from the soil to plant tissues at equilibrium for the x-th kind of plant and soil respectively (Bq kg^{-1} dry weight of forage or fresh weight of other plants per Bq kg^{-1} dry soil)
b	parameter in beef dynamic model (e.g. DOSDIM model)
C_a	radionuclide concentration in air at ground level (Bq m^{-3})
C_{ai}	time integrated radionuclide concentration in air (Bq d m^{-3})
C_x	radionuclide concentration in the x-th compartment (for subscript above), (Bq kg^{-1}, Bq L^{-1})
C_{xd}	radionuclide concentration in the x-th kind of plant in dry weight (Bq kg^{-1})
C_{xf}	radionuclide concentration in the x-th kind of plant in fresh weight (Bq kg^{-1})
C_s	radionuclide concentration in soil (Bq kg^{-1})
D	total deposition (Bq m^{-2})
$D(\Delta t)$	mean deposition for the time interval Δt
D_d	dry deposition (Bq m^{-2})
Dcf_x	dose conversion factor by pathway x; inhalation (c) (Sv Bq^{-1}), ingestion (i) (Sv Bq^{-1}), external from cloud (m) (Sv $m^3(Bq\ s)^{-1}$) or ground deposition (g) (Sv $m^2(Bq\ s)^{-1}$)
D_L	total deposition in location (Bq m^{-2})
D_w	wet deposition (Bq m^{-2})
F	body burden conversion parameter (Sv d^{-1} Bq^{-1})
F_x	the fraction of the animal's daily intake of the radionuclide that appears in each unit amount of animal product (d L^{-1}, d kg^{-1})
F_i	distribution fraction in ENCONAN model (-)
f_1	fraction of material reaching the transfer compartment (body fluids) through the walls of the gastrointestinal tract
f_L	fractional area of subregion L (model DOSDIM)
f_u	fraction of the deposit that remains fixed on urban surfaces
g_x	fraction of population in x-th occupational group
H_i	committed dose effective equivalent by pathway i (mSv)
I_j	daily precipitation in day j (mm)
I_s	average daily precipitation (mm d^{-1})

K_r	resuspension coefficient (m^2/m^3)
K_d	distribution coefficient in soil solution (L/kg)
LAI	leaf area index (m^2 plant leaves per m^2 soil)
L_m	mixing height (m)
L_s	soil layer depth
M	human body mass (kg)
O_i	occupancy factor (fraction of time spent on activity i)
P	effective "surface density" for the effective root zone in soil (kg dry weight m^{-2})
p_j	parameters of time course of plant weight
$Q_{x,a}$	animal's radionuclide daily intake of for x-th kind of feed (Bq d^{-1})
$Q_{x,HB}$	human radionuclide daily intake from food kind x (Bq d^{-1})
R	interception factor (-)
RA_{HB}	human body retention function
R_s	transfer factor for soil adhesion (-)
$R_{w,x}$	interception factor for wet deposition [for surface type x] (-)
SF_x	shielding factor for pathway x (-)
T	time dependent translocation factor defined as concentration in edible portion of plant per concentration initially retained (-)
t	time period (d)
t_i	time period -- day i after beginning of fallout
t_{fe}	time of end of fallout (d in calendar year)
t_{fs}	time of beginning of fallout (d in calendar year)
t_h	time of harvest or cutting (d in calendar year)
t_o	time of beginning of vegetation period (d in calendar year)
U_c	breathing rate (m^3 d^{-1})
$U_{x,a}$	daily animal intake of x-th feed stuff (kg d^{-1})
$U_{x,HB}$	daily human intake of x-th food stuff (kg d^{-1})
v_i	deposition velocity of airborne particles -- i=d dry deposition; i=w wet deposition (m s^{-1})
$v_{d,x}$	dry deposition velocity on surface type x (m s^{-1})
$v_{d,max,x}$	maximum dry deposition velocity on surface x (m s^{-1})
$\dot{x}$	time derivative dx(t)/dt
Y_{xd}	yield of the x-th kind of plant in dry weight (kg m^{-2})
$Y_{xd}(t_o)$	yield of the x-th kind of plant remaining: after harvest or cutting during a winter period; after(n-1)- th cutting at the time of beginning of n-th vegetation period (d)
$Y_{x,f}$	yield of the x-th kind of plant in fresh weight (kg m^{-2})
W	animal mass (kg)

w	washout constant (Bq m^{-3} rain per Bq m^{-3} air)
α_b	parameter of whole body retention function i (-)
α_g	weathering parameter of external irradiation (-)
α_j	parameter in milk dynamic model in DOSDIM model
β_j	parameter in beef dynamic model in DOSDIM model
γ_j	transfer parameter in animal model
ε	soil porosity
Λ	washout coefficient (s^{-1})
λ_{bi}	rate constant of whole body retention function i (d^{-1})
$\lambda_{E(a,z)}$	effective rate constant for processes of "a" and "z" (e.g. $\lambda_{E(w,r)} = \lambda_w + \lambda_r$) (d^{-1}). Processes included are: r-radioactive decay; w-weathering; tr-translocation; m-migration in deep layers; f-fixation in soil
λ_f	fixation rate in soil (d^{-1})
λ_{gi}	weathering rate constant i of external irradiation
λ_i	rate constant for transport of material from body organs and tissues (d^{-1})
λ_m	rate constant for radionuclide migration into the soil layer below root zone (d^{-1})
λ_p	rate constant for the reduction of radionuclide concentration in animal due to physiological processes (d^{-1})
λ_r	radioactive decay constant of nuclide (d^{-1})
λ_{tr}	rate constant for translocation of cesium in plant in DOSDIM model (d^{-1})
λ_u	rate constant of uptake by root (d^{-1})
λ_w	rate constant for reduction of the concentration of material deposited on the surface of vegetation due to processes other than radioactive decay (d^{-1})
μ	Chamberlain's parameter of aerosol deposition on vegetation (m^2 kg^{-1})
τ	time delay (d)
Δt	time interval (d)

Unification of subscripts

Materials

a	air
p	pasture
pg	pasture grass
pc	clover, alfalfa
s	soil
g	grain

gw	wheat grain
gb	barley grain
gm	maize
w	water
wd	drinking water
m	milk
mc	dairy cow milk
mg	sheep, goat milk
f	meat
fb	beef
fp	pork
fm	mutton
fp	poultry
v	vegetables
vl	leafy v.
vr	root v.
vf	fruit v.
e	egg
eh	ensilaged hay
h	hay
l	silage
lm	specific type of silage, e.g. maize (m)
u	mushroom

Animals

p	pig
c	cattle, bull
d	dairy cow
l	lamb,sheep
g	goat
fs	fish
ffs	fresh-water fish
mfs	marine fish
k	chicken
h	hen
r	roe-deer

Pathways

c	inhalation
g	ground deposition, external irradiation
m	cloud irradiation
i	ingestion
r	inhalation from resuspended material
s	swimming
b	staying on beach
f	fishing or boating

II.4. MODEL DESCRIPTIONS

II.4.1. CLRP

The model was created as a part of the cooperative research project "Long-lived Post-Chernobyl Radioactivity and Radiation Protection Criteria for Risk Reduction" with the U.S. Environmental Protection Agency. The aim of the project was to examine the fate of long-lived radionuclides in the terrestrial ecosystem. The transfer of radiocesium through the soil column and its transfer from soil to grass have been studied particularly. Also the influence of resuspension of cesium from the ground on concentrations in plants has also been investigated. A simplified flow chart is given in Figure II.1.

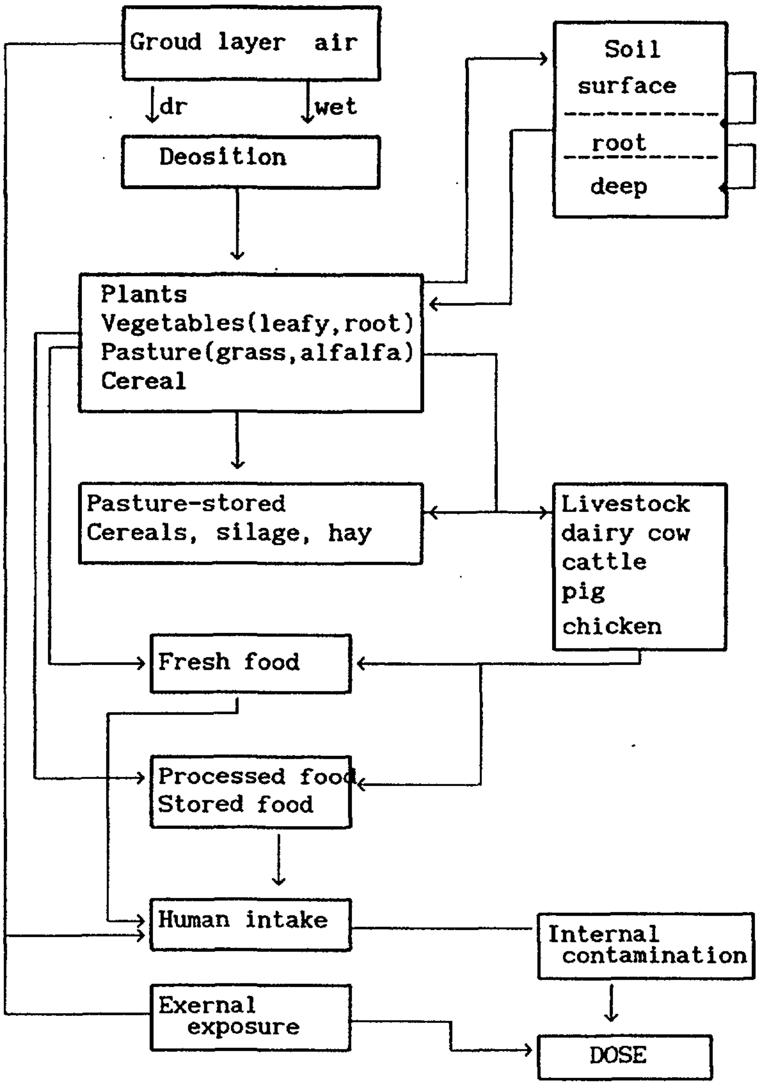


FIG. II.1. Flow chart of CRLP.

II.4.1.1. Atmospheric deposition, contamination of soil and vegetation

The dry deposition for n sampling periods is given by:

$$D_d(t) = v_d \sum_{=1}^{n} C_a^i \Delta t_i \qquad \text{(II.1)}$$

The wet deposition for m days with rain is:

$$D_w(t) = L_m \sum_{j=1}^{m} C_a^{j}(t) \{1 - \exp[-\Lambda \, (I_j/I_s)]\} \tag{II.2}$$

Total deposition (sum of dry and wet deposition) and the following quantities were determined for each of 13 subregions, and the arithmetic mean and 95% confidence interval assuming normal distribution were computed for the CB region.

The radionuclide concentration in plants due to n days of airborne particle deposition on plants is expressed as:

$$C_{xf}(t) = \sum_{i=1}^{n} D(t_i) \; R(t_i) \; T \; \exp[-\lambda_{E(w,r)}(t - t_i)]/Y_{xf}(t) \tag{II.3}$$

with

$$R(t) = 1 - \exp\{-\mu[Y_{xd}(t_o) + (Y_{xd}(t) - Y_{xd}(t_o))\cdot(t - t_o)/(t_h - t_o)]\} \tag{II.4}$$

The radionuclide concentration in plants due to root uptake is given by:

$$C_{xf}(t) = \sum_{i=1}^{n} D(t_i) \; B_{vx} \; \exp\{-\lambda_{E(m,u,r)}(t - t_i)\}/P_s \tag{II.5}$$

II.4.1.2. Contamination of feed stuffs and animal products

An equation similar to (II.3) is used for forage (dry weight). The total radionuclide concentration of each plant was calculated and then the monthly average was obtained as a sum of concentrations due to deposition and root uptake.

The radionuclide concentration in milk and/or animal products at time t_j with n kinds of feed used for fattening at time t_i is:

$$C_x(t_j) = \sum_{i=0}^{j} F_x \; \exp[-\lambda_p(t - t_i)] \sum_{k=1}^{n} Q_{x_k,a}(t_i) \tag{II.6}$$

II.4.1.3. Human body content and dose assessments

The radionuclide whole body concentration at time t with n categories of food consumed at time $t_i$is expressed as:

$$A_{HB}(t) = [\alpha_b \; \exp(-\lambda_{b1}(t-t_i) + (1-\alpha_b) \; \exp(-\lambda_{b2}(t-t_i)\cdot\sum_{k=1}^{n} Q_{x_k,HB}(t_i) \tag{II.7}$$

The committed effective dose equivalent by ingestion is given by:

$$H_i(t) = Dcf_i \int_{t_{fs}}^{t} A_{HB}(t) \; dt \tag{II.8}$$

and by inhalation of cloud for n aerosol sampling periods:

$$H_c(t) = Dcf_c\ U_c \int_{t_i}^{t_n} C_a(t)dt \qquad (II.9)$$

The mean external dose equivalent from ground deposition only is:

$$H_g(t) = Dcf_g \int_{t_{fs}}^{t} D(t)[\alpha_g \exp(-\lambda_{g1}t) + (1-\alpha_g)\exp(-\lambda_{g2}t)]dt \qquad (II.10)$$

The model parameters used for CB scenario are given in Section II.5.

II.4.2. DOSDIM

The outline of the model has already been described in the BIOMOVS A4 document [II.1]. All the dose assessment calculations start with the measured airborne concentrations. The measured air concentration was assumed to be the same for the whole CB region, while the deposition was different for each subregion, depending on the precipitation. For a simplified flow chart see Figure II.2.

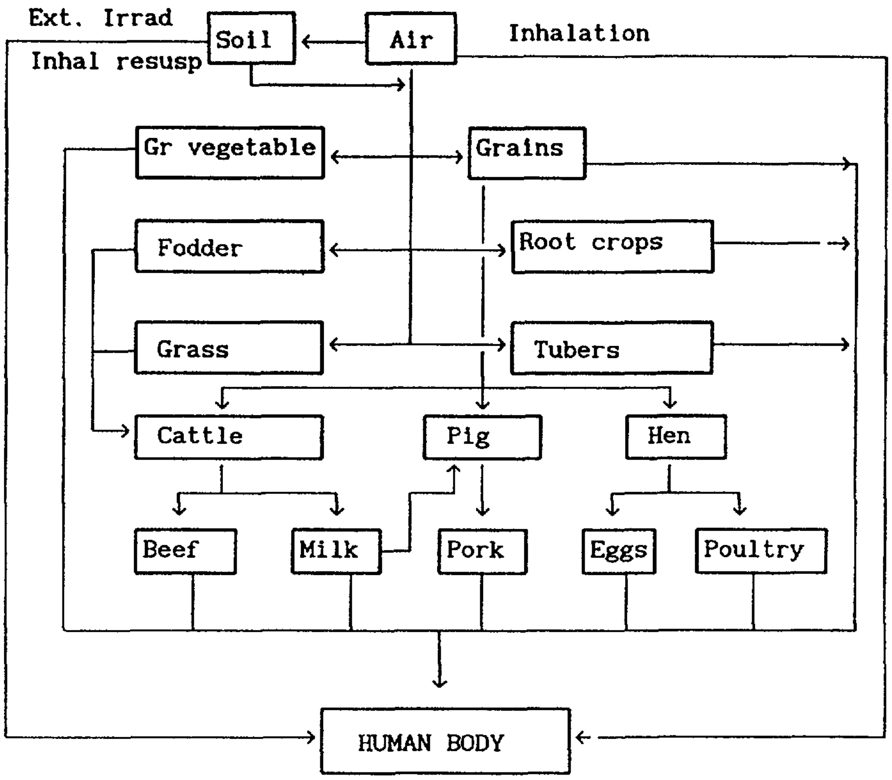


FIG. II.2. Flow chart of DOSDIM.

II.4.2.1. Atmospheric deposition, contamination of soil and vegetation

The assessment of dry deposition is based on average values of ground level air concentration in AB; the assessment of wet deposition is based on site-specific precipitation measurements:

$$D(t) = \int_{t_{fs}}^{t_{fe}} C_a(t)[v_d \cdot 86400 + I_j\ \Lambda\ L_m/1.5]dt \tag{II.11}$$

where the time unit is day (note that we have 86400 s/d).

The equation for contamination of vegetation due to direct deposition is given by the following expression:

$$C_{xf}(t) = D(t)[R/Y_{xf}]\ \exp[-\lambda_{E(w,r)}(t_h - t_{fs})] \tag{II.12}$$

and that due to direct deposition with a translocation to the edible part of plant:

$$C_{xf}(t) = D(t)[R/Y_{xf}] \cdot [\lambda_{tr}/\lambda_{E(tr,w)}][1 - \exp\{-\lambda_{E(tr,w)}(t_h - t_{fs})] \cdot \exp\{-\lambda_r(t_h - t_{fs})\} \tag{II.13}$$

The radionuclide concentration in plants due to root uptake is:

$$C_{xf}(t) = D(t)\ B_{Vx}\ \exp[-\lambda_{E(m,r)}(t_h - t_o)] \tag{II.14}$$

II.4.2.2. Contamination of animal products

The dynamic model for assessment of radionuclide concentration in milk and in beef uses:

$$C_m(t) = \sum_{j=1}^{3} a_j\ \exp(-\alpha_j t)\ \exp(-\lambda_r t) \tag{II.15}$$

$$C_f(t) = b[\exp(-\beta_1 t) - \exp(-\beta_2 t)]\exp(-\lambda_r t) \tag{II.16}$$

for unit intake at t=0.

The equation for radionuclide concentration in other animal products at time t with n kinds of feed used for fattening at time t_j is:

$$C_x(t) = F_x \sum_{i=1}^{n} Q_x^i(t_j) \tag{II.17}$$

II.4.2.3. Human body content and dose assessment

The committed effective dose equivalent by ingestion due to consumption of x kinds of food stuffs is:

$$H_i(t) = Dcf_i \sum_x [\ U_{x,HB} \int_{t_{fs}}^{t} C_{x,AB}\ (t)] \sum_L [f_L D_L(t)/D_{AB}(t)] \tag{II.18}$$

where the average concentration for each food item x is computed by scaling the value for AB region with the mean deposition. The mean deposition is computed using the subarea deposition D_L and the fractional area contribution f_L for the subarea.

The estimate of cesium retention in man is based on the ICRP 56 model. It assumes complete resorption through the walls of the gastrointestinal tract into body fluids and uniform distribution in body organs and tissues.

The committed effective dose equivalent by inhalation of the cloud is expressed as:

$$H_c(t) = Dcf_c\, U_c \int_{t_{fs}}^{t_{fe}} C_a(t)dt \qquad (II.19)$$

and by inhalation of resuspended material:

$$H_r(t) = Dcf_c\, U_c \int_{t_{fe}}^{t} C_a(t)\, dt \sum_L f_L D_L(t)/D_{AB}(t) \qquad (II.20)$$

The equation for the mean external dose for adults due to direct irradiation from cloud for x occupational groups is:

$$H_m(t) = Dcf_m \sum_x [g_x(SF_x O_i + 1 - O_i)] \int_{t_{fs}}^{t_{fe}} C_a(t)dt \qquad (II.21)$$

and from ground deposition:

$$H_g(t) = Dcf_g\, SF_g \sum_L f_L \int_{t_{fs}}^{t} D_L(t)[\alpha_g \exp(-\lambda_{g1}t) + (1 - \alpha_g)\exp(-\lambda_{g2}t)]dt \qquad (II.22)$$

Model parameters are given in Section II.5.

II.4.3. HUMOD

A simplified flow chart of HUMOD is given in Figure II.3.

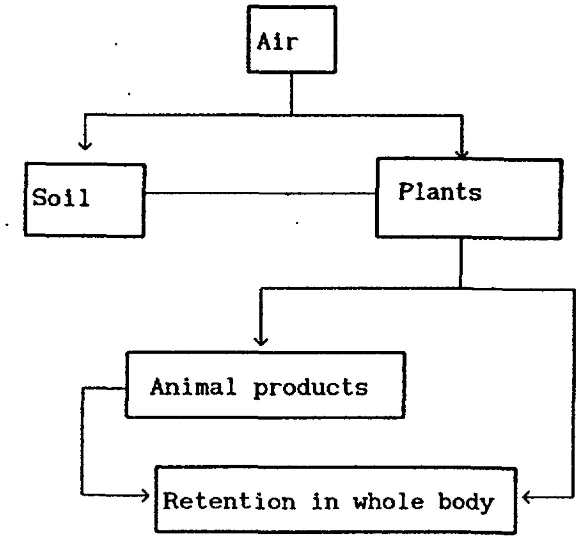


FIG. II.3. Flow chart of HUMOD.

II.4.3.1. Atmospheric deposition, concentration in soil and vegetation

The dry and wet deposition for the n-th time interval is:

$$D(t_n) = D(t_{n-1}) \exp(-\lambda_{E(m,r)}\Delta t_n) + (v_d + I_s w)\, C_a(t_n) \cdot \\ (1 - \exp(-\lambda_{E(m,r)}\Delta t_n))/\lambda_{E(m,r)} \qquad \text{(II.23)}$$

The equation for the concentration of Cs in vegetation, wheat and other plants in the n-th time interval is:

$$C_x(t_n) = C_x(t_{n-1}) \exp\{-\lambda_{E(w,r)}\Delta t_n\} + D(t_n)\, B_{Vx} / P_s + (v_d + I_s \Lambda) \cdot \\ C_a(t_n)\, R\, T\, LAI\, \{1 - \exp(-\lambda_{E(w,r)}\Delta t_n\} / [Y_{x,f}(t_n) \lambda_{E(w,r)}] \qquad \text{(II.24)}$$

II.4.3.2. Contamination of feed stuffs and animal products

The silage is composed of "fodder arable 1a" (24%), "fodder arable xa" (72%), root crops (3.5%) and some technical products (1.2%).

The radionuclide concentration in milk and/or animal products at time t with n kinds of feed used for fattening at time t_i is:

$$C_x(t) = F_x \sum_{k=1}^{n} Q_{x_k,a}(t_i) \qquad \text{(II.25)}$$

II.4.3.3. Human Body content and dose assessment

The committed effective dose equivalent by ingestion due to consumption of x kinds of food stuffs is:

$$H_i(t) = Dcf_i \sum_x U_x \int_{t_{fs}}^{t} C_x(t)\, dt \qquad \text{(II.26)}$$

The committed effective dose equivalent by inhalation of the cloud is:

$$H_c(t) = Dcf_c\, U_c \int_{t_{fs}}^{t_{fe}} C_a(t)\, dt \qquad \text{(II.27)}$$

and that by inhalation of resuspended radionuclide:

$$H_r(t) = Dcf_c\, U_c\, K\, D\, (\Delta t) \qquad \text{(II.28)}$$

with K the resuspension factor (Bq/m^3 air per Bq/m^2).

The equation for external dose due to direct irradiation from the cloud is:

$$H_m(t) = Dcf_m\, SF_m \int_{t_{fs}}^{t_{fe}} C_a(t)\, dt \qquad \text{(II.29)}$$

and that from ground deposition:

$$H_g(t) = Dcf_g\, SF_g\, D\, (\Delta t) \qquad \text{(II.30)}$$

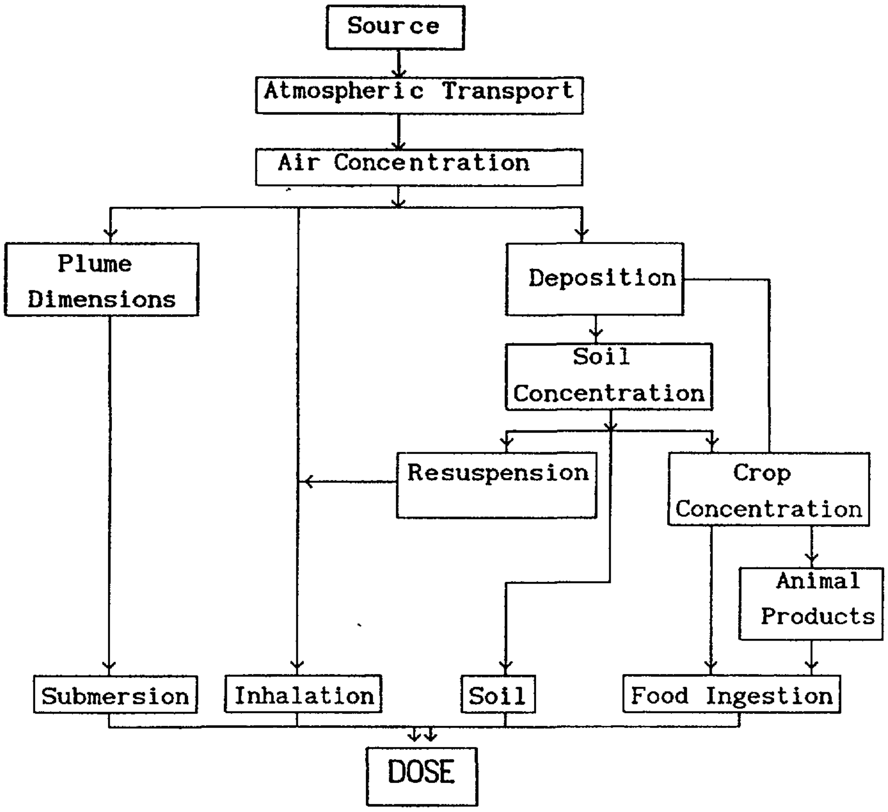


FIG. II.4. Flow chart of GENII.

II.4.4. GENII

The model is the second generation of environmental pathways analysis models used at Hanford and can be used for chronic or acute releases from atmospheric or aquatic source terms. A simplified flow chart is given in Figure II.4.

More details of GENII are provided in [II.2].

II.4.4.1. Deposition and resuspension

Soil data were processed as described for the HEDR model (see Section II.4.8). The median value from the HEDR analysis was used as a known "derived concentration" for the GENII input. The time-integrated air concentration was back-calculated from the soil data using a nominal deposition velocity of 1 cm/s. The initiating parameter in all of the following equations is the initial deposition on the ground and plant surfaces. This may be defined from the integrated air concentration as:

$$D = (v_d + v_w)\cdot\int_{t_{fs}}^{t_{fe}} C_a(t)\,dt \qquad \text{(II.31)}$$

Resuspension calculations are based on the assumption that the particulate matter in the air has the same activity as the soil at the location; the mass loading approach is used.

II.4.4.2. Radionuclide concentrations in vegetation

The initial plant concentration due to the initial deposition decreases over time by means of radiological decay and weathering. These processes are assumed to occur continuously from deposition to harvest during the period of t_h. Therefore the plant concentration at harvest is:

$$C_x(t_h) = D\ R\ T/Y_{x,f}\ \exp(-\lambda_{E(r,w)}\ t_h) \tag{II.32}$$

For subsequent years, the model reverts to a simple equilibrium model with soil uptake and some resuspension. The basic model is similar for all vegetation. From direct deposition onto leaves, the integral of the radionuclide concentration in the plant at the time of consumption is calculated as follows:

$$C_x = D\ R\ T[1 - \exp(-\lambda_{E(r,w)}(t_h - t_{fs}))]/(\lambda_{E(r,w)}\ Y_{xf})\ \exp[-\lambda_r(t_h - t_{fe})] \tag{II.33}$$

From the root uptake pathway, the integral of radionuclide concentration in the plant is calculated as follows for air deposition pathways:

$$C_x = [C_{sd}\delta_d + (C_{ss}/P_s + C_{ss-})\delta_s]\ B_{v_x}\ \exp[-\lambda_r(t_h - t_{fe})] \tag{II.34}$$

where δ_s and δ_d are root penetration factors for deep and surface soil; C_{ss} and C_{sd} are concentrations in surface and deep soil; C_{ss-} is the residual concentration in the upper soil layer from the previous years' deposition. The total plant concentration at the time of consumption is then calculated as the sum of the contributions from direct deposition and soil uptake.

II.4.4.3. Intake of animals

The basic formulation for animal as well as human intake of contaminated crops is dependent on the times of deposition, harvest, and consumption.

The concentration in an animal product (like milk) resulting from animal ingestion of contaminated feed is calculated as follows:

$$C_m(t) = C_p(t)\ F_m\ U_{p,a}\ \exp[-\lambda_r(t - t_h)] \tag{II.35}$$

This animal product concentration is not strictly appropriate, because the equilibrium constant (for milk, F_m) does not directly apply to the transient case; but the integral of the concentration is appropriate. The GENII model reports only "meat", using beef-based transfer factors. Pork was not reported.

Food storage times are implicit in the integral formulation of the equations presented in the former paragraphs. Essentially, following harvest, foods are assumed to be consumed at a constant rate until the following harvest.

No food preparation losses are accounted for in GENII.

II.4.4.4. Whole body content and dose assessment

The GENII code uses precalculated radiation dose factors for determining doses from ingestion. Those used are essentially equivalent to the ICRP Publication 30 values for adults. Given this structure, body-burdens were not reported.

The GENII model uses external dose rate factors for an infinite slab source of contaminated soil 15 cm thick. No other shielding is considered - the person is assumed to spend the entire period exposed out-of-doors. This is considered to give an overestimate of the expected dose.

Inhalation exposure may result from inhalation of the passing plume or from inhalation of resuspended activity. The dose to an individual from inhalation of contaminated air is calculated from the individual breathing rate and the air concentration .No shielding factors are used.

II.4.5. ENCONAN

The model was especially created for evaluation of contamination after the Chernobyl accident. The method of concentration factors is used with the exception of pork contamination (method of system analysis). Model calculations are based on knowledge of the average surface activity of the CB region measured in June 1986. See Figure II.5 for a flow chart.

All quantities of environmental contamination are computed as regional means.

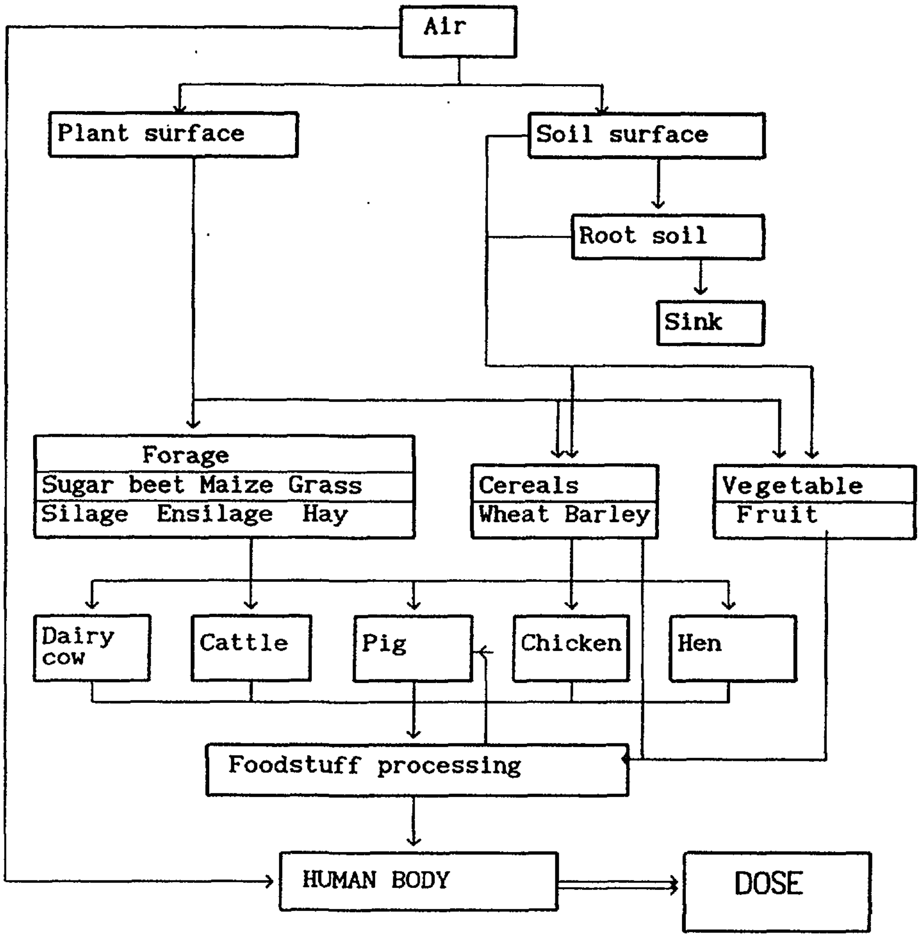


FIG. II.5. Flow chart of ENCONAN.

II.4.5.1. Contamination of vegetation and feed stuffs

The radionuclide concentration in leafy vegetables, pasture and forage (alfalfa and clover) due to airborne particle deposition is:

$$C_{xf}(t) = D(t_{fe})\ R(t_{fe})\ \exp[-\lambda_{E(w,r)}(t - t_{fe})]/Y_{xf}(t) \qquad (II.36)$$

with

$$R(t) = 1 - \exp[-\mu\ Y_{xd}(t_{fe})] \qquad (II.37)$$

For leafy vegetables and pasture the yield is described as:

$$Y_{xf}(t) = Y_{xf}(t_h)[(t_{fe} - t_o)/(t_h - t_o)] \qquad (II.38)$$

and for wheat and forage the yield is:

$$Y_{xf}(t) = p_1/\{1 + \exp[(p_2 - (t - t_o))/p_3]\} \qquad (II.39)$$

with p_i (i=1,3) as model parameters.

The radionuclide concentration in barley due to foliar deposition is described by the model of Aarkrog:

$$C_{xf}(t) = D(t_{fe})\ 0.098\ \exp\{-0.0013[(t_h - t_{fe}) - 34]^2\} \qquad (II.40)$$

The radionuclide concentration in plants due to root uptake is:

$$C_{xf}(t) = D(t_{fe})\ B_{V_x}\ \exp[-\lambda_{E(m,r)}(t - t_{fe})]/P_s \qquad (II.41)$$

A similar equation is used for forage (dry weight). The radionuclide concentration of each plant was calculated as the sum of the concentrations due to deposition and root uptake, and then a monthly average was taken.

II.4.5.2. Contamination of animal products

The radionuclide concentration in milk and/or animal products (with the exception of pork) at time t with n kinds of feed used for fattening at time t_i is given by the equation:

$$C_x(t_i) = F_x \sum_{k=1}^{n} Q_{x_{k,a}}(t_i) \qquad (II.42)$$

The dynamic model of pork contamination is described by a set of linear first-order differential equations (see the flow chart for PORK, Figure II.6).

II.4.5.3. Human body content and dose assessment

The radionuclide whole body concentration at time t following the food consumption in the CB scenario is described by a set of linear first-order differential equations following Publication ICRP 30.

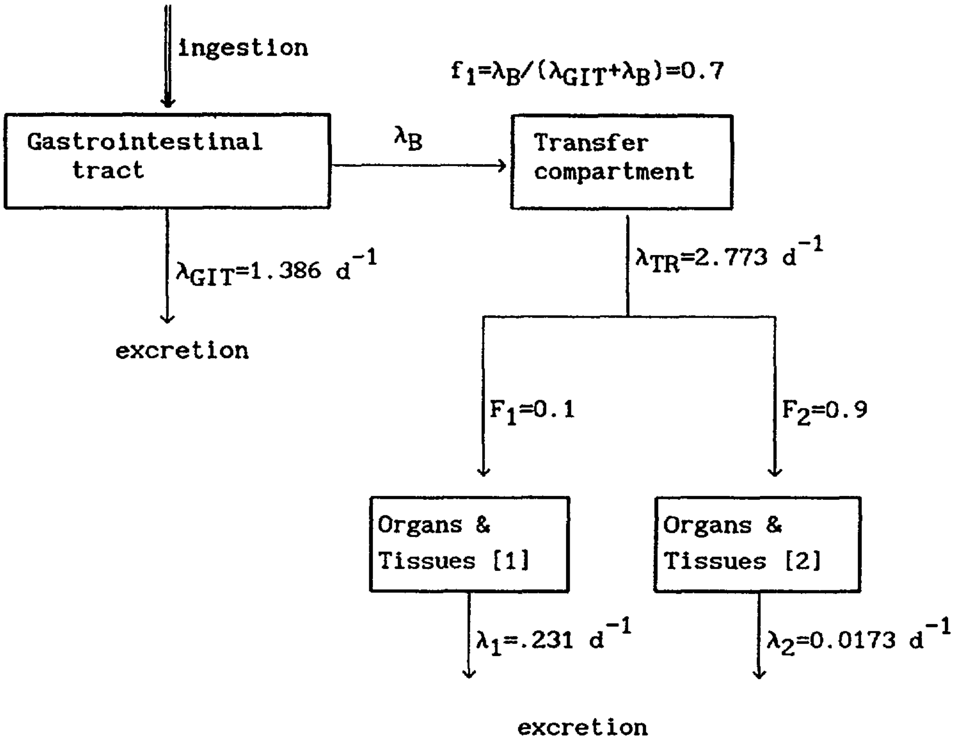


FIG. II.6. Flow chart of ENCONAN PORK model.

The assessment of committed effective dose equivalent by ingestion due to consumption of x kinds of food stuffs is given by:

$$H_i(t) = Dcf_i \int_{t_{fs}}^{t} \sum_x U_{x,HB}\, C_x(t)\, dt \tag{II.43}$$

and that by inhalation from the cloud for n aerosol sampling periods:

$$H_c(t) = Dcf_c\, U_c \int_{t_{fs}}^{t_{fe}} C_a(t)\, dt \tag{II.44}$$

The mean external dose equivalent of adults due to direct irradiation from the cloud is:

$$H_m = Dcf_m(1 - O_i + O_i SF_m)\int_{t_{fs}}^{t_{fe}} C_a(t)dt \tag{II.45}$$

and for the ground deposition:

$$H_g = Dcf_g\, D(t_{fe})(1 - O_i + SF_g O_i)(1 - g_x + f_u g_x) \tag{II.46}$$

Model parameters are given in Section II.5.

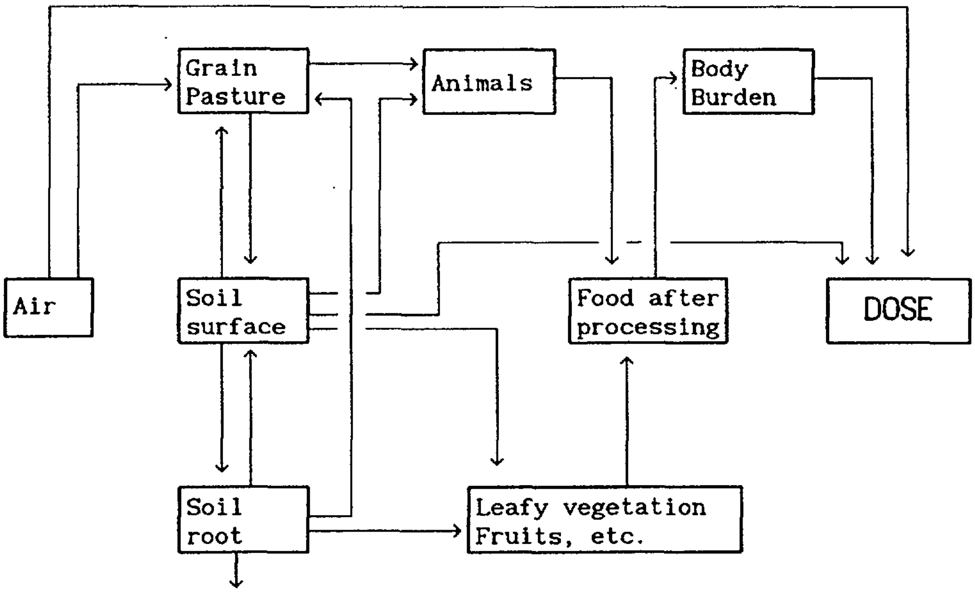


FIG. II.7. Flow chart of CHERPAC.

II.4.6. CHERPAC

The deterministic model CHERPAC was developed as part of a general assessment capability which includes atmospheric transport and urban contamination. For the CB scenario, the model was changed to a stochastic version. A simplified flow chart with main compartments is given in Figure II.7. The prediction model applies transfer ratios and differential equations.

II.4.6.1. Atmospheric deposition, contamination of vegetation and soil

The equation for rate of total deposition from air to vegetated soil is given by the following expression:

$$\dot{D} = C_a \cdot (v_d + w \cdot I_j) = \dot{D}_d + \dot{D}_w \qquad \text{(II.47)}$$

Pasture contamination is calculated with a differential equation for atmospheric contamination (giving a concentration C_{va}) to which the contribution from root uptake (transfer factor approach) is added:

$$C_v = C_{va}/Y_{v,f} + (B_{vp} \cdot C_s) \qquad \text{(II.48)}$$

$$\dot{C}_{va} = (\dot{D}_d + R_w \cdot \dot{D}_w) - \lambda_{E(w,r)} \cdot C_{va} \qquad \text{(II.49)}$$

The grain concentration at harvest is calculated daily and summed as follows:

$$C_g = \sum\{\dot{D}_v(t_i)\ 9.8E{-2}\ \exp[-0.0013(t_i - 34)^2]\} + C_s B_{vg} \qquad \text{(II.50)}$$

where $D_v = D_d + R_w \cdot D_w$, and time (t) is counted from time of deposition to harvest day.

The equation for predicting the concentration in leafy vegetables includes uptake from soil and soil adhesion:

$$C_{vl} = C_s \cdot (Bv_{vl} + R_s) \tag{II.51}$$

where R_s is the transfer factor from adhering soil.

Concentration in fruit is calculated using generic root uptake without any other processes.

The soil concentration is given by:

$$C_s = D/P_s \tag{II.52}$$

II.4.6.2. Concentration in feed and animal products

Daily feed intake for cows is calculated as:

$$Q_a = U_{g,a} \cdot C_g + U_{p,a} \cdot C_p + U_{l,a} \cdot C_l + U_{inh,a} C_a \tag{II.53}$$

where the daily amount of hay and grain is seasonally varied. The feeding diet ignores silage and alfalfa.

Milk and meat concentrations are calculated assuming a direct dependence on the body burden of the cow, as in the following equations:

$$C_x = (F_x \cdot \lambda_p / f_1) \cdot A_{a,x} \tag{II.54}$$

$$dA_{a,x}/dt = f_1 \cdot Q_a - \lambda_p \cdot A_{a,x} \tag{II.55}$$

The equations are applied separately for milk or meat. Pigs are modelled similarly to human beings.

II.4.6.3. Human body content and dose assessments

Losses due to storage are not considered, but processing losses are included. The daily diet was obtained from the input information. The body burden includes the contribution from inhalation and is given by solving the following differential equation:

$$dA_{HB}/dt = (Q_{HB} + U_c \cdot C_a)/M - \lambda_b \cdot A_b \tag{II.56}$$

where M is the mass of the standard man.

The dose due to ingestion and inhalation is calculated by integrating the body burden (whole body) and multiplying with a dose conversion factor.

The dose from the immersion in the cloud is given by Eq. (II.56) and the external dose due to contaminated soil:

$$H_g = Dcf_g\, D \cdot FR \cdot [1 - O_i + O_i\, SF_g] \tag{II.57}$$

where FR is a reduction factor due to initial penetration of fallout into the soil.

Model parameters are given in Section II.5.

II.4.7. ECOSYS

ECOSYS started in 1980 as an assessment model for radiation exposure after accidental releases of radionuclides. The first version was developed as a system of differential equations with capabilities for probabilistic assessment and uncertainty analysis. The present version, ECOSYS-87, used for VAMP, was developed after Chernobyl as a deterministic model with specific characteristics. Time-dependent processes are modelled with tabulated functions or simple mathematical fits of experimental data, and the majority of parameters are experimentally determined.

The ECOSYS model is used also in Switzerland. A separate description is not necessary. The differences in model assumptions and parameters are explained at the end of the original ECOSYS description. A simple flow chart is given in Figure II.8.

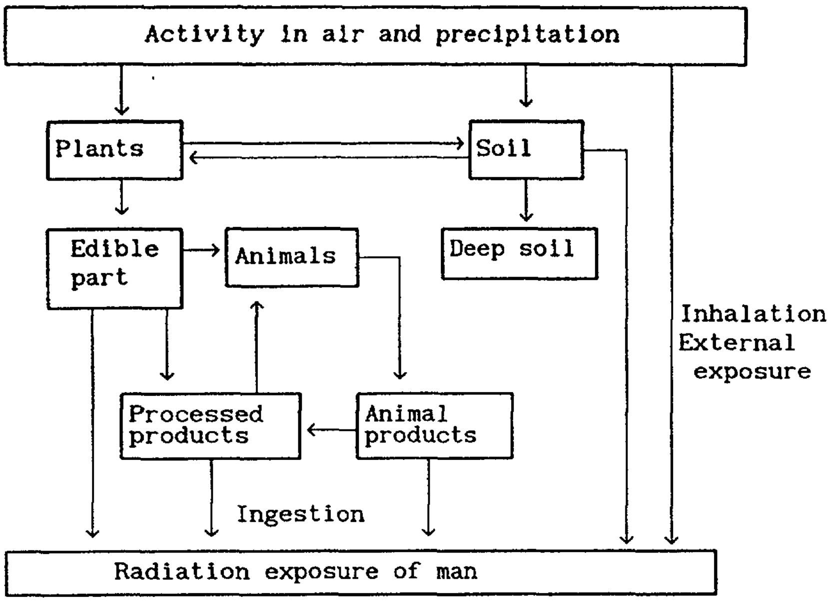


FIG. II.8. Flow chart of ECOSYS.

II.4.7.1. Atmospheric deposition, soil and vegetation contamination

The time integrated total deposition to bare soil, D_{soil}, is assessed from the input data (surface soil contamination in CB).

The time-integrated wet deposition D_W (the same for soil and plants) is obtained by subtracting dry soil deposition $D_{d,s}$ from the total:

$$D_w = D - D_{d,s} \tag{II.58}$$

The time-integrated dry deposition onto soil surface (bare soil) is given by:

$$D_{d,s} = C_{ai} \cdot v_{d,s} \tag{II.59}$$

where the time integrated air concentration C_{ai} and dry deposition velocity to soil $v_{d,s}$ are used.

The dry deposition to plant species x is given by the equation:

$$D_{d,x} = C_{ai} \cdot v_{d,x} \tag{II.60}$$

where the dry deposition velocity of airborne radioactivity onto plant species *x* is time- and plant characteristic-dependent. For pasture the dry deposition velocity is calculated:

$$v_{d,p} = v_{dmax,p} \{1 - \exp[-k_g\ Y_p(t)]\} \tag{II.61}$$

where the plant biomass $Y_p(t)$ is given by linear interpolation between a minimum mass in early spring and a maximum mass at grass maturity and k_g is a model parameter.

For leafy vegetables, cereals, and fruits the dry deposition velocity depends on leaf area index at the time of deposition:

$$v_{d,x} = v_{d,max,x} \cdot LAI\ (t)/LAI_{max} \tag{II.62}$$

with the LAI given by simple interpolation between experimental data. The wet interception factor for plants is calculated using the amount of precipitation I_j, the stage of plant development (related to leaf area index) and the properties of the particular radionuclide:

$$R_{w,x} = \min\{1.; [k_{1,x}\ LAI(t)(1. - \exp(-\ln 2\ I_j/k_{2,x}))/I_j]\} \tag{II.63}$$

where $k_{i,x}$ are parameters depending on vegetation type. The LAI for pasture is deduced from the yield and the maximum LAI as:

$$LAI = LAI_{max,p}[1 - \exp(-k_g\ Y_p(t))] \tag{II.64}$$

The initial activity on plants covering 1 m^2 of soil is given by:

$$D_x = D_{d,x} + R_{w,x} \cdot D_w \tag{II.65}$$

The radionuclide concentration in leafy vegetables at harvest (t days after deposition) is given by the equation:

$$C_{vl} = \{D_{vl} \exp(-\lambda_w t)/Y_{vl,f} + D \cdot (B_{vvl} + R_s)\exp(-\lambda_{E(f,m)} t)/P_s\}\exp(-\lambda_r t) \tag{II.66}$$

The equation for radionuclide concentration in pasture at harvest is:

$$C_p = (D_p\cdot((1 - a)\cdot\exp(-(\lambda_w + \lambda_{gd})\cdot t) + a\cdot\exp(-\lambda_t\cdot t))/Y_{p,f} + D\cdot(B_{vp} + R_s)\cdot\exp(-\lambda_{E(f,m)}\cdot t)/P_s)\cdot\exp(-\lambda_r\cdot t) \qquad (II.67)$$

where λ_t is the rate for the translocation to and from the root zone and "a" is the fraction translocated. The growth dilution rate λ_{gd} is assumed to be dependent on the month.

The concentration in grain and fruit at harvest is given by:

$$C_x = \{D_x\cdot T_x(t)/Y_{x,f} + D\cdot(B_{vx} + R_s)\exp(-\lambda_{E(f,m)}t)/P_s\}\cdot\exp(-\lambda_r t) \qquad (II.68)$$

where $T_x(t)$ is the translocation factor (Bq/m^2 in grain or fruit per Bq/m^2 deposited on leaves) which depends on time t between deposition and harvest and is given by interpolation between experimental data points.

II.4.7.2. Concentration in animal products

The transfer of activity from feed to animal products is modelled with the following convolution integral:

$$C_x(t) = F_x\int_0^t Q_{x,i}(\tau)\{a_1\lambda_{x1}\exp[-\lambda_{x1}(t - \tau)+a_2\lambda_{x2}\exp[-\lambda_{x2}(t - \tau)\} \cdot\exp(-\lambda_r(t - \tau)\, d\tau \qquad (II.69)$$

The equation applies to milk, beef, pork, lamb, and poultry meat. $\lambda_{x_1}, \lambda_{x_2}$ are rate constants for the reduction of activity by physiological processes (with fractional contribution a_1 and a_2).

The daily intake of activity, Q_i, is calculated from the scenario's feeding regime and the daily concentration in various feed items.

II.4.7.3. Human body content and dose assessment

For the daily intake of activity, the raw data on human diet in the input scenario were multiplied by correction factors of 0.75-0.9 to include losses due to non-human usage of products, food processing losses, and culinary preparation. The model also includes losses due to storage time, but this is of little concern for the CB scenario.

The calculation of the whole-body concentration is given by the following equation:

$$A_{HB}(t) = \int_0^t Q_{HB}(\tau)/M\cdot RA_{HB}(t - \tau)\cdot d\tau \qquad (II.70)$$

with the retention function given by:

$$RA_{HB} = f_1\cdot[\alpha_b\exp(-\lambda_{b1}\cdot t) + (1 - \alpha_b)\exp(-\lambda_{b2}\cdot t)] \qquad (II.71)$$

The ingestion dose is calculated from the time integrated intake of activity and the dose conversion factor from the input scenario.

The mean external dose due to cloud is calculated from:

$$H_m = Dcf_m \cdot C_a \sum_i (O_i \cdot SF_{i,m}) \tag{II.72}$$

The mean external dose due to ground exposure is obtained from the equation:

$$H_g(t) = D \int_0^t y(t) \cdot \exp(-\lambda_r \cdot t) \cdot dt \cdot Dcf_g \cdot \sum_i (O_i \cdot SF_{i,g}) \tag{II.73}$$

where the correction function for leaching of the radionuclide in soil is given by:

$$y(t) = \alpha_g \cdot \exp(-\lambda_{g1} \cdot t) + (1 - \alpha_g) \cdot \exp(-\lambda_{g2} \cdot t) \tag{II.74}$$

with a fast (λ_{g1}) and a slow (λ_{g2}) leaching rate.

Model parameters for ECOSYS are given in Section II.5.

II.4.7.4. Details on ECOSYS version in Switzerland

(a) Dry deposition velocity to grass is modelled as for leafy vegetables. The maximum leaf area index is LAI_{max} = 5.9, as compared with 7.0 in the German version.

(b) The growing period was assumed to occur earlier than specified by default values in the original model. For pasture a 30-day difference from the default value is assumed, and the deduced LAI is 5.9 as compared to 4.2 in the German version. For cereals and vegetables a 15-day difference was implemented. All LAIs are greater and as a consequence all deposition velocities and initial activities are greater than for the German approach.

(c) Wet deposition was assessed with a washout factor:

$$D_w = I \cdot w \cdot C_a \tag{II.75}$$

where w is 5.5 E 2 Bq/mm rain per Bq/m^3 air, I is the daily rain (mm/d), and C_a is expressed in Bq d/m^3.

(d) Parameter values for alfalfa includes a yield of 2.6 kg/m^2, a B_v of 0.02, and four harvests (15 June 45%, 1 Aug. 20%, 1 Sept. 20%, and 15 Oct. 15 %). Planting occurs on 14 April, and the maximum LAI is 6.5.

(e) Silage contamination was obtained from a "silage plant" model with planting date 15 March, harvest 1 Sept., yield 2.5 kg/m^2, maximum LAI = 6.4.

(f) Human intake rates were based on OECD dietary data for Yugoslavia and on the VAMP scenario with no reduction due to industrial usage. Intake rate was modelled with an analytical function fitted to calculated results. A single compartment retention function was used with a half time of 110 days. The body concentration was calculated from the differential equation:

$$dA_{HB}/dt = Q_{HB}(t)/M - \lambda_b \cdot A_{HB} \qquad (II.76)$$

II.4.8. HEDR

The HEDR (Hanford Environmental Dose Reconstruction project) model contains stochastic procedures designed to approximate time-dependent solutions using transfer parameters and quasi-steady-state algorithms. It operates on a time step of one month over a non-uniform spatial area consisting of up to 99 locations. Extensive input data are necessary to fully describe food production and distribution within the study area. Most input values are provided as ranges with arbitrary distributions.

The documentation consists of a design report and a series of unpublished user's manuals. The design report contains all code logic and equations [II.3].

The HEDR code is written in a modular format. A simplified conceptual logic diagram for calculating doses from atmospheric releases is shown in Figure II.9.

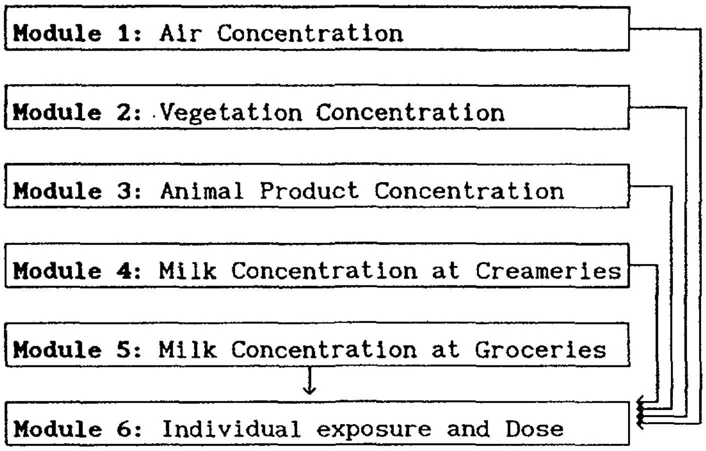


FIG. II.9. Flow chart of HEDR.

II.4.8.1. Air and soil monitoring data

To model the air concentrations and surface deposition over both time and space, the air concentration and rate of deposition in each region were assumed to be proportionally related to each other. Thus the monitored air concentration data given for Region AB was extrapolated spatially, based on the relative average soil concentrations in each region as observed June 16-18, 1986. The soil concentration data for each region was then extrapolated temporally by solving a simple linear differential equation that assumes the rate of change of soil concentration is equal to the deposition rate (assumed to be directly proportional to air concentration for that region). The air pathway code then took random samples from an empirical piecewise-linear cumulative distribution function formed from the monitored (June 1986) data points for each region and multiplied these sampled values by the surface concentration ratio from that region's "source term" file for the appropriate month. For each Monte Carlo simulation run, one random sample from a region's empirical distribution of soil data values was selected and used (multiplied by the monthly ratio) for all months for that region.

II.4.8.2. Contamination of the vegetation

The logic of Module 2 is shown in Figure II.9. The purpose of this module is to calculate or input concentrations of radionuclides on vegetation. Input to this module may be either the histograms of deposition rate and total deposition from Module 1 or measured values of air concentration from the monitoring database. Vegetation types considered are leafy vegetables, other vegetables, fruits, and grains for human consumption, and grains, pasture grass, silage, and alfalfa hay for animal consumption.

The equations to be used for Module 2 and the concentration for vegetables, etc., are the following:

$$C_{v1} = D\ T\ R[1 - \exp(-\lambda_{E(w,r)}t)]/[Y_{v,f}\ \lambda_{e(w,r)}] + C_{-1}\ \exp(-\lambda_{E(w,r)}t)Y_{-1}/Y_{v,f} \qquad \text{(II.77)}$$

$$Cv2 = D\ B_v/P_s \qquad \text{(II.78)}$$

$$R = 1 - \exp(-\mu\ Y) \qquad \text{(II.79)}$$

where C_{v1} and C_{v2} are the concentrations due to direct deposition and the root uptake; subsequently:

C_{-1} = sum of the two concentrations in the previous month
Y_{-1} = biomass in the previous month (kg/m^2)
μ = function of plant type
t = number of days in current month

Note: if plant cut or harvested in the previous month (-1), then $C_{-1}/(Y/Y_{-1})$ term should go to zero.

Important parameters include time-dependent biomass, rates of washoff and weathering, and soil-to-plant concentration ratios. Provision was made to incorporate periodic harvesting of certain types of vegetation.

II.4.8.3. Contamination of animal products

The purpose of Module 3 is to calculate concentrations of radionuclides in meat, milk, and eggs produced in each census tract for each monthly increment. Input to this module for VAMP was calculated vegetation concentrations from Module 2.

Additional input is information on the diets of farm animals as a function of location and time, provided from the main database.

The concentration of animal products x was calculated as:

$$C_x = \sum_{mlj} U\ C_{lmj}\ F_{lmj}\ \exp(-\lambda_r t) \qquad \text{(II.80)}$$

where the summation is over the feed type m, harvest in month j, and location l.

Calculations could be made of concentrations in meat, poultry, eggs and milk. Milk is assumed to be produced by cows or goats. Cows are allowed to eat several types of diets. Each diet is defined as a sum of fractional feed type intakes. Currently, four feeding regimes are supported by the code.

For milk concentrations Eq. (II.80) is used for three different types of cow-milk (backyard cow, specific creamery and grocery milk) with different holdup delays. For the human consumption, a weighted sum of them was calculated. This may be used directly in Module 6, if the milk source is known by name, or as input to Module 5.

Pork is not a meat product handled by the HEDR code.

II.4.8.4. Contamination of human body and dose assessments

Foods are assumed to be eaten fresh during the months in which they are harvested. Following harvest, foods are assumed to be contaminated with the level of radionuclides present at harvest, as decayed to that point in time. This continues until the next harvesting period begins. No food preparation losses are considered in this version of the HEDR model.

Air submersion doses were specified by:

$$H_m = Dcf_m C_a (t_{fe} - t_{fs}) \tag{II.81}$$

The groundshine doses are:

$$H_g = D\ Dcf_g\ t \tag{II.82}$$

Inhalation doses are given by:

$$H_c = Ca\ U_c\ Dcf_c\ t \tag{II.83}$$

where t means the duration of exposure.

II.4.9. PRYMA

The basic model was developed for BIOMOVS and considers the air-feed-animal product pathway. It includes the animal model from NRPB. For VAMP-MP the "PORKY" model based on ENCONAN-Cs was added, and new submodels for vegetables and cereals were developed. In the time of VAMP CRP, the model was continuously improved and the following description is appropriate only for the initial prediction for CB scenario.

The model uses differential equations, but root uptake is simply modelled by a transfer factor. The compartments are defined for a surface area of 1 m^2, and the final concentration in each compartment is obtained by dividing of the compartment mass.

II.4.9.1. Atmospheric deposition, contamination of vegetation and soil

The usual expression for deposition rate is:

$$\dot{D} = \dot{D}_d + \dot{D}_w = C_a \cdot (v_d + w \cdot I_j) \tag{II.84}$$

with the washout constant defined for an atmospheric mixing height of 1000 m, and the daily precipitation rate, I_j, obtained from data on station 518 (scenario input).

The soil is divided into an upper soil layer of 1 cm depth, a root layer (1-20 cm depth) and a deep layer. For pasture, the root zone is subdivided into two layers (1-5 and 5-10 cm depth) and the total root zone extends up 10 cm depth.

Two compartments are considered for vegetation (pasture, leafy vegetables, and alfalfa): external C_{ve} and the internal parts C_{vi}. The internal vegetation compartment is not modelled by a differential equation; only the root uptake is considered and the transfer factor approach is chosen.

The general expression for vegetation concentration is given by:

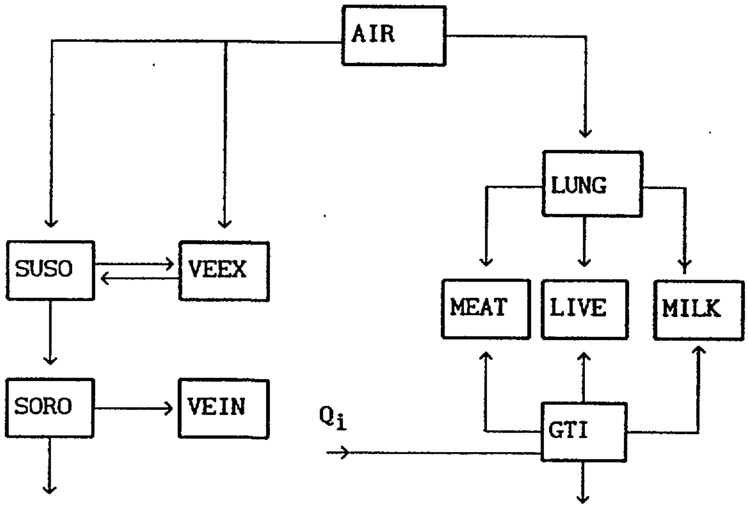
$$C_v = C_{ve} + C_{vi} \qquad (II.85)$$

where the internal concentration is:

$$C_{vi} = B_{vx} \cdot (C_{SOSU} + C_{SORO}) \qquad (II.86)$$

with the concentrations for surface and root layers of soils (C_{SOSU}, C_{SORO}) or the sum of roots layers for pasture added in parentheses.

The concentration in external vegetation C_{ve} and in various soil layers is obtained by solving the system of differential equations based on transfer processes as shown in the Figure II.10.



SUSO surficial soil layer; SORO root soil layer

VEEX external compartment plant; VEIN internal compartment plant

FIG. II.10. Flow chart of PRYMA.

The transfer rate between soil layers $\lambda_{\text{layer1,layer2}}$ is deduced from the water percolation rate , the retardation factor and the soil layer depth with the following general expression:

$$\lambda_{\text{layer1,layer2}} = \frac{I_j/\varepsilon}{L_s(1+K_d\delta(1-\varepsilon)/\varepsilon)} \qquad \text{(II.87)}$$

where the soil porosity ε, the layer depth L_s, the soil bulk density δ and the distribution coefficient K_d are introduced.

The inflow rates to the surface soil and external vegetation surface are given by:

$$I_{\text{SUSO}} = \dot{D}\cdot(1 - R); \; I_{\text{VEEX}} = \dot{D}\cdot R \qquad \text{(II.88)}$$

where the interception factor R has constant values for pasture, leafy vegetables and grain.

The resuspension rate $K_{\text{SUSO,VEEX}}$ is proportional to the cube of the friction velocity v_*, which is calculated for a neutral atmospheric stability.

Weathering and field loss processes include the explicit effect of wind and rain. The wind contribution is considered as an average, but the rain effect depends on the daily rain as in the input scenario:

$$K_{\text{VEEX,SUSO}} = 3.02\text{E-}2 + K_w\cdot I_j \qquad \text{(II.89)}$$

with the rain proportionality factor K_W. For pasture the field loss is increased due to grazing by animals.

II.4.9.2. Concentration in the feed and animal products

The daily intake for cows is given in summer time by:

$$Q_a = U_a[C_p(f_p - f_s) + C_{s1}f_s + C_gf_g + C_hf_h + C_{eh}f_{eh} + C_lf_l)] \qquad \text{(II.90)}$$

where we introduce f_x, the fraction of various feeds and the concentration in first soil layer C_{s1}. In winter time no soil ingestion is allowed, and the diet also include root crops (rc).

Milk and meat concentrations are computed by solving the differential equations based on the flow chart (see Figure II.10) and then by division of the compartment activity with the corresponding mass (daily milk production or cow soft tissues mass).

The concentration for pork is computed following the model based on ENCONAN, PORKY. The concentrations for poultry and eggs are calculated with a concentration factor method.

II.4.9.3. Human body content and dose assessment

Daily intake for man is calculated with no food processing losses using the diet as given in the input scenario.

The whole body concentration is calculated starting with daily intake and using the retention function:

$$RA_{HB}(t) = \alpha_b \cdot \exp(-\lambda_{b1} \cdot t) + (1 - \alpha_b) \cdot \exp(-\lambda_{b2} \cdot t) \qquad (II.91)$$

The equation for whole body concentration is:

$$A_{HB}(t_n) = \sum_{i=1}^{n} Q_{HB}(t_i)\, R_{HB}(t_n - t_i)/M \qquad (II.92)$$

The external dose H_e includes the cloud and soil contribution from:

$$\begin{aligned} H_e &= H_m + H_g \\ H_m &= C_a \cdot t_c \cdot Dcf_c \\ H_g &= C_{SUSO} \cdot \delta \cdot h \cdot t_e \cdot Dcf_g \end{aligned} \qquad (II.93)$$

with t_c the time spent under the cloud (1 day), t_e the time spent outdoors, h the surface layer (SUSO) depth, and δ the soil density.

The inhalation dose is calculated starting with the daily mean air concentration given in the input scenario and using the mean adult respiratory rate (8400 m^3/y). Dose conversion factors as given in the input scenario were used all the time.

II.4.9.4. Model parameters

Parameters which have no equivalent in other models are given below and other parameters are included in Section II.5.

Atmospheric deposition and soil:

water rate = 1000 $L/(m^2y)$ for vegetables and grain (it includes irrigation = 500 $L/(m^2y)$ for pasture);
$\varepsilon = 0.5$ (porosity);
$\delta = 1.5$ E3 kg/m^3 (density);
$K_d = 0.3\ m^3/kg$;
soil depth: 0.01 m SUSO; 0.19 m SORO; 0.04 m SOR1; 0.05 m SOR2 pasture

Resuspension rate

$K_{SUSO,VEEX} = 1.76$ E-12 s^{-1} (for a wind speed of 3 m/s)

Weathering rate rain factor K_w (mm^{-1})
1.97 E-2 leafy vegetables; 3.4 E-2 pasture
weathering rate for alfalfa 1.05 E-1 d^{-1}
$K_{VEEX} = 3.0$ E-2 d^{-1} loss rate due to grazing (pasture)

Animal products
fractional digestibility in feed
pasture 0.07; grain 0.60; hay 0.20; silage 0.46
fraction of soil consumption $f_s = 0.04$

inhalation rate Q_{inh} (m^3/d)
cow: 150; beef: 150

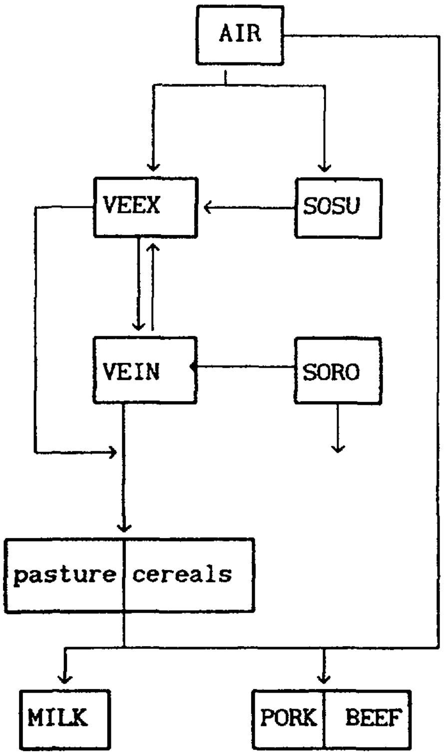


FIG. II.11. Flow chart of SCHRAADLO-T.

II.4.10. SCHRAADLO-T

The model was developed to assess the environmental impact of nuclear facilities and a former version was used in the validation study of BIOMOVS Scenario A4 [II.1]. Now mainly the parameter values of the model have been modified based on Chernobyl experiences. It uses a combination of kinetic rate constants and equilibrium concentration factors to describe the transfer of radionuclides. The structure of the compartmental model can be seen in Figure II.11.

II.4.10.1. Atmospheric deposition

The total deposition rate is derived by the sum of dry and wet ones according to:

$$\dot{D} = C_a \; [v_d + w \sqrt{E \; I_s}] \qquad \text{(II.94)}$$

where E is an empirical constant and E = 1.5 mm/d.

II.4.10.2. Contamination of soil and vegetation

The contamination of the different parts of soil and vegetation (external, internal, pasture root zone, etc.) is calculated by numeric solution of the linear differential equations. The variables of the equations are the radioactive concentrations in the compartments instead of the radioactivity. The concentrations of the external and internal parts of the vegetation are defined in the following forms:

$$\dot{C}_{VEEX} = (D + v_d \cdot K_r\ C_s)R/Y_{v,f} - (\lambda_w + \lambda_r)C_{VEEX} \tag{II.95}$$

$$\dot{C}_{VEIN} = k_{VEEX,VEIN}\ C_{VEEX} + k_{SORO,}k_{VEIN}\ C_{SORO} - (k_{VEIN} + \lambda_r)C_{VEIN} \tag{II.96}$$

The contamination of pasture, hay, ensilage, and other kinds of feeding are derived from the external (surface) and internal parts of the vegetation. The concentration after harvesting should result from the initial values of the contamination at harvest time and the radioactive decay. The concentrations in soil compartments are influenced by the parameter values for diffusion in soil ($k_{SORO,SOSO}$ and $k_{SOSU,SORO}$), for resuspension ($k_{SOSU,VEEX}$), and for root uptake ($k_{SORO,VEIN}$). The concentration in surface soil is defined by:

$$\dot{C}_{SOSU} = D/P_s + k_{SORO,SOSU}\ C_{SORO} - (k_{SOSU} + \lambda_r)C_{SOSU} \tag{II.97}$$

A similar equation can be used for the root soil compartment.

II.4.10.3. Contamination of the food stuffs

The contamination in milk and meat are given by concentration factors:

$$\begin{aligned} C_m(t) = {} & \{[U_{p,a}\ C_p(t_h) + U_{l,a}\ C_l(t_h)]f + U_sC_s\}F_m \\ & + [U_{p,a}\ C_p(t_{h-1}) + U_{l,a}\ C_l(t_{h-1})](1 - f)F_m \end{aligned} \tag{II.98}$$

where $C_p(t_h)$ is the radionuclide concentration in pasture vegetation at the time of harvesting, $C_p(t_{h-1})$ the concentration of pasture harvested in the previous year, and f the fraction of the animal feed harvested at t_h. The contamination in beef (C_{fb}) and pork (C_{fp}) are calculated by similar forms as for milk, but instead of F_m the appropriate transfer factors for beef (F_{fb}) and pork (F_{fp}) and feeding habits are to be used.

II.4.10.4. Contamination of the human body and dose assessments

The time dependent content of the human body (A_{HB}) is defined by the differential equation:

$$\dot{A}_{HB} = f_1\sum U_{x,HB}\ C_x - (\lambda_b + \lambda_r)A_{HB} \tag{II.99}$$

The doses due to inhalation (H_c), to ground deposition (H_g), and to ingestion (H_i) are assessed in a similar manner as with ENCONAN.

II.4.10.5. Model parameters

For vegetation:

$K_r = 2.4 \cdot 10^{-7}$ kg/m; $\lambda_d = 0.016\ d^{-1}$

$k_{VEEX,VEIN} = 0.016\ d^{-1}$; $k_{SOSU,SORO} = 0.0003\ d^{-1}$

$k_{SORO,VEIN} = 3.2 \cdot 10^{-4}\ d^{-1}$; $k_{SORO,SOSU} = 2.4 \cdot 10^{-3}\ d^{-1}$

$k_{SORO} = 1.1 \cdot 10^{-4}\ d^{-1}$

For milk, beef and pork:

	milk	beef	pork	
$U_{p,a}$	55	35	5	kg/d
$Q_{s,a}$	0.5	0.5	0.5	kg/d
F_m, F_{tb}, F_{tp}	0.004	0.008	0.04	d/kg
k_c		0.02	0.02	d^{-1}
f	0.8	0.8	0.5	(in summer, 1986)
P_3	24 kg/m^2			

II.4.11. SPADE2

The structure of the model and transfer rates or coefficients between the compartments are mainly defined directly by the user. The flow chart of the model version that was used is given in Figures II.12 and II.13. The radiocaesium transport among the different compartments is described by linear differential equations.

II.4.11.1. Atmospheric deposition and contamination of vegetation

The model introduced a generic deposition rate by the equation:

$$\dot{D} = C_a \cdot v, \tag{II.100}$$

where two different values were used for deposition velocity v_g depending on whether it was raining or not. After taking a surface of 1 m^2 the transfer from air to the soil was taken into consideration by the atmospheric deposition:

$$I_{SOSO} = \dot{D} \cdot f_{SOL}, \tag{II.101}$$

where f_{SOL} is the soluble fraction in the air. By the same way the deposition of the inorganic and organic forms of the radionuclides can be defined. The deposition onto the vegetation is calculated from the deposition rate:

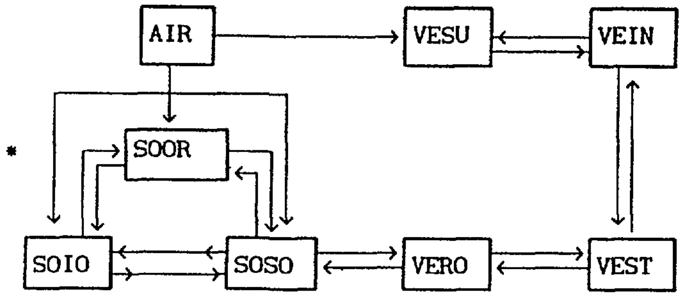
$$I_{VEEX} = \dot{D} \cdot R, \tag{II.102}$$

where the interception factor was defined by Chamberlain's expression:

$$R = 1 - \exp(-\mu \cdot Y_{xd}). \tag{II.103}$$

II.4.11.2. Transfer in soil, vegetation, and animals

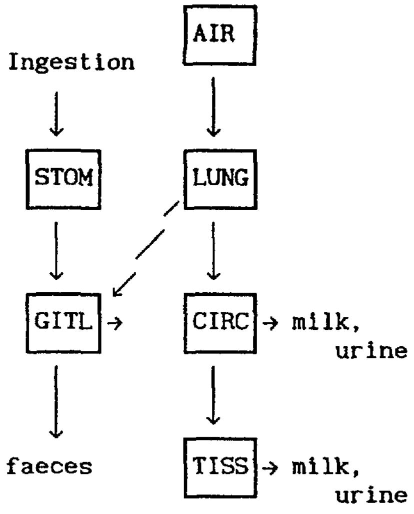
The transfer processes between the different parts of the vegetation, soil, and animal tissues are defined by differential equations and transfer coefficients. The transport in soil was described by assumption of 10 layers and compartments separately for soluble, organic and inorganic forms of the radiocaesium. Conversions among the three different chemical forms can be performed in every layer. In addition to the differential equations, the model defines the concentration in animal milk by the loss parameters from animal tissues and systematic circulation in the following form:



* 10 identical soil
layer compartments

SOOR: soil organic, SOIO: soil inorganic, SOSO: soil soluble form,
VESU: surface of vegetation, VEIN: internal part of vegetation,
VERO: root part of vegetation, VEST: stem of vegetation.

FIG. II.12. Flow chart of SPADE2 soil and vegetation model.



STOM: stomach, GITL: g.i.t. lower, CIRC: systematic circulation,
TISS: accumulation tissue.

FIG. II.13. Flow chart of SPADE2 animal model.

$$\dot{C}_m = F_{1m} \cdot k_{CIRC} \cdot C_{CIRC} + F_{2m} \cdot k_{TISS} \cdot C_{TISS}, \qquad \text{(II.104)}$$

The concentration in animal muscle is:

$$C_f = 0.7 \cdot (A_{CIRC} + A_{TISS})/W \qquad \text{(II.105)}$$

where W is the muscle mass; for the cattle W = 200 kg. In Equations II.104 and II.105, the total activity A and concentration C in compartments TISS and CIRC are obtained from solving the system of differential equations describing the flow chart II.13.

II.4.11.3. Model Parameters

The parameters used for the ^{137}Cs-transfer in soil are the following:

$k_{SOSO,SOOR} = 8.64\cdot10^{-3}\ d^{-1}$; $k_{SOOR,SOSO} = 8.64\cdot10^{-3}\ d^{-1}$
$k_{SOSO,SOIO} = 1.21\cdot10^{-2}\ d^{-1}$; $k_{SOIO,SOSO} = 1.21\cdot10^{-6}\ d^{-1}$
$k_{SOSO} = 4.32\cdot10^{-3}\ d^{-1}$;
$k_{SOOR} = 4.32\cdot10^{-6}\ d^{-1}$ (pasture) and $2.16\cdot10^{-6}\ d^{-1}$ (cereals)
$k_{SOIO} = 4.32\cdot10^{-6}\ d^{-1}$ (pasture) and $2.16\cdot10^{-6}\ d^{-1}$ (cereals)

The k_{SOSO}, k_{SOOR} and k_{SOIO} mean the transfer from the root soil layer to the deeper one.

The parameter values (d^{-1}) related to the vegetation are:

	Pasture	Cereals		Pasture	Cereals
$k_{SOSO,VERO} =$	$4.9\cdot10^{-2}$	$5.8\cdot10^{-6}$;	$k_{VERO,VEST} =$	$2.6\cdot10^{-2}$	$4.3\cdot10^{-3}$
$k_{VEST,VERO} =$	$2.6\cdot10^{-2}$	$1.6\cdot10^{-2}$;	$k_{VEST,VEIN} =$	$7.8\cdot10^{-3}$	$7.8\cdot10^{-3}$
$k_{VEIN,VEST} =$	$2.6\cdot10^{-2}$	$2.6\cdot10^{-2}$;	$k_{VESU,VEIN} =$	0.17	0.17
$k_{VEIN,VESU} =$	$6.0\cdot10^{-4}$	$6.0\cdot10^{-4}$;	$k_{VEIN,GRAI} =$	$3.5\cdot10^{-3}$	$3.6\cdot10^{-3}$
$k_{VEST,GRAI} =$	$3.5\cdot10^{-3}$	$3.0\cdot10^{-4}$			

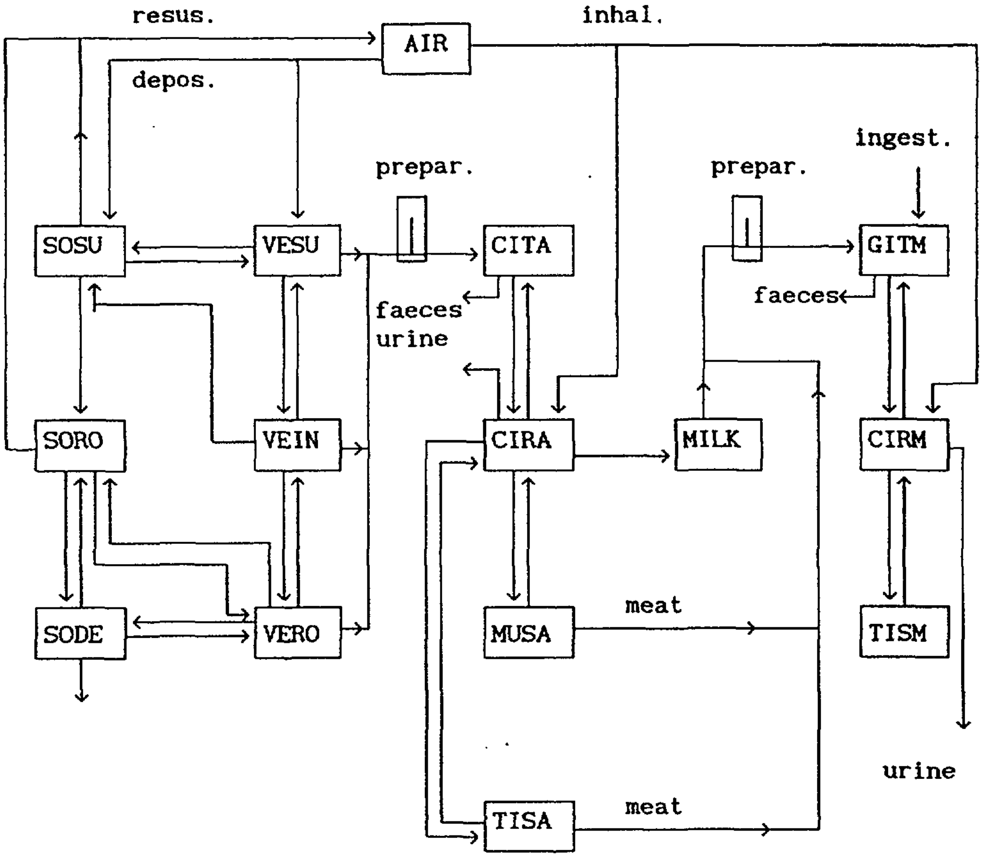
The transport coefficients of the radiocaesium in cattle:

$k_{STOM,GITL} = 1.0\ d^{-1}$ $k_{GITL} = 3.0\ d^{-1}$

	Dairy cattle	Beef cattle	
$k_{CIRC,TISS} =$	0.058	0.64	d^{-1}
$k_{CIRC} =$	0.64	0.057	d^{-1}
$k_{TISS} =$	0.02	0.02	d^{-1}

II.4.12. TERNIRBU

The compartmental model given in Figure II.14 was developed after the Chernobyl accident to assess the radionuclide concentrations in the terrestrial environment. The compartments are normalized to a ground surface of 1 m^2. The mathematical description of the model contains non-linear terms, so numerical methods are used to solve the differential equations. The flow chart contains two sections called preparation. They indicate that the feed and food can be stored, mixed, cooked, etc. The different types of preparation are taken into consideration by factors used to multiply the former concentrations or by time delays.



SOSU: soil surface, SORO: soil root, SODE: soil deep root,
VESU: surface of vegetation, VEIN: internal part of vegetation,
GITA: g.i.t.of animal, CIRA: systemic circulation of animal,
MUSA: muscle of animal, TISA: accumulation tissue of animal,
GITM: g.i.t.of man, CIRM: systemic circulation of man,
TISM: accumulation tissue of man.

FIG. II.14. Flow chart of TERNIRBU.

The model can be divided into four main subsystems, the compartments of soil, vegetation, animals and man. The different types of vegetation (pasture, cereals, fruit, vegetables, etc.), soils (sandy, loam, etc.), animals (cow, pig, etc.) and man (children, adults, etc.) are modelled using appropriate parameter values, such as transfer coefficients, interception factors, yields, etc.

To simulate the seasonal variation of growth of vegetation and feeding regimes a periodic function S(t) has been introduced (see Figure II.15). The time-dependent S(t) is defined by functions of arctan, and the values of it are proportional to the air temperature. By modifying the parameter values of the function S(t), the curve can be moved and smoothed. The period-time of S(t) is 1 year, the maximum value being in the growing season and the minimum in winter.

II.4.12.1. Atmospheric deposition, contamination of vegetation and soil

The rate of total deposition from the air is calculated by:

$$\dot{D} = C_a \cdot (v_d + w \cdot I_s). \qquad (II.106)$$

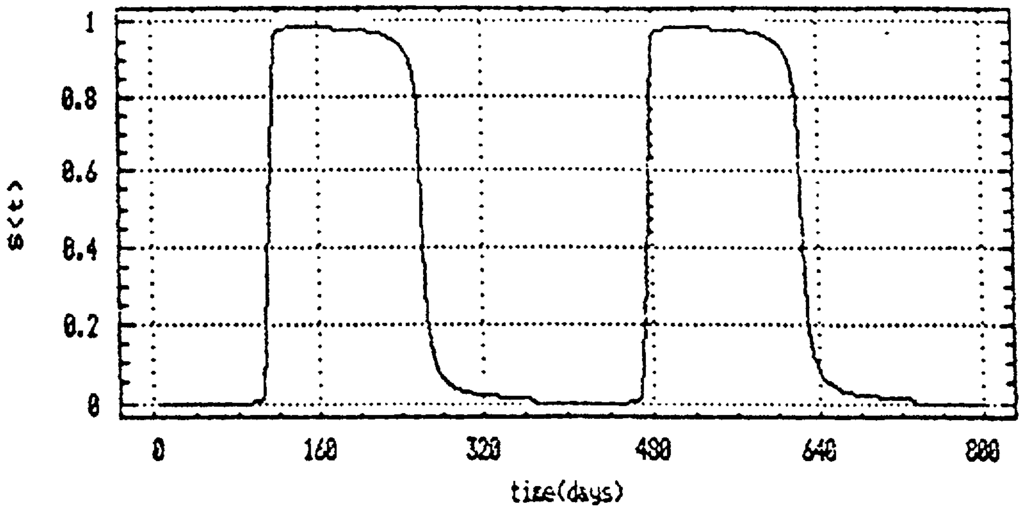


FIG. II.15. The seasonality function S(t) with time period of 1 year (t_b: beginning; t_e: end of growing).

The contamination from air of the upper soil layer and the external part of the vegetation is calculated with inflow rate given by:

$$I_{SOSU(fromair)} = \dot{D}\cdot(1 - R\cdot S(t)), \tag{II.107}$$

where S(t) is the seasonality function. The resuspensions from the soil surface (SOSU) and the soil root (SORO) layers are modelled using the transfer coefficients of:

$$k_{SOSU,AIR} = 0.5\cdot[1 + S(t)]\cdot RF_1 \tag{II.108}$$

$$k_{SORO,AIR} = 0.5\cdot[1 + S(t)]\cdot RF_2 \tag{II.109}$$

with RF_1, RF_2 the resuspension factors for the upper 2 soil layers.

The radionuclide concentration in the vegetation is used as the ratio of the radioactivity and mass. Therefore the mass of vegetation M_p is defined from a differential equation as follows:

$$\dot{M}_p = \alpha\cdot S(t) - \beta\cdot M_p \tag{II.110}$$

where α means the maximal growing rate and β the coefficient of reduction of the mass. The maximum value of M_p is less than the yield, so $\alpha<\beta\cdot Y$. It is assumed that the changes of the edible vegetation are proportional to the total mass M_p. The values of the transport coefficients for vegetation are influenced by the seasonality function, S(t). In case of grains (wheat) the inner part of the vegetation was modelled, and the transfer coefficients were chosen to produce the same results that would have been achieved using a translocation factor.

II.4.12.2. Concentration in the feed and radionuclide intake of animals

Concentrations in the fresh feed are calculated by the ratio of radioactivity and the mass of the edible (external, internal or root) part of the pasture or other vegetation. The edible part of the plant is derived as a weighted sum of the three compartments of VESU, VEIN and VERO. The stored feed is a weighted sum of the earlier harvested fresh feed, taking into account the radioactivity decay.

The rates of the animal intake of radioactivity Q_{fr} (fresh) and Q_{st} (stored) are the following:

$$Q_{fr}(t) = U_{fr,a}\cdot f_{fr}\cdot S(t)\cdot C_{fr}(t) + U_s\cdot C_{SOSU}(t) \qquad (II.111)$$

$$Q_{st}(t) = U_{st,a}\cdot[1 - f_{fr}\cdot S(t)]\cdot\sum[\eta_i\cdot C_{fr}(t_i)\cdot E(t_i) \qquad (II.112)$$

where f_{fr} is the fraction the fresh feed, $U_{fr,a}$ and $U_{st,a}$ are the daily intake , $C_{fr}(t)$ is the radionuclide concentration in the fresh feed at time t, $C_{fr}(t_i)$ the concentration at harvesting time t_i, η_i is the fraction of used stored feed harvested at t_i $[\sum \eta_i=1]$, and E is the loss coefficient due to the radioactive decay. The Q_{fr} and Q_{st} refer to concentration in animal feed and not to areal concentration. In addition to intake from contaminated vegetation there may be additional ingestion to transfer to compartment GITA (gastrointestinal tract, animal). The rate of that additional transfer is a parameter value controlled by the input data.

The rate of excretion to the milk is determined by the radioactivity in compartment CIRA and the value of $k_{CIRA,MILK}$. The radioactivity in compartments MUSA and TISA (special tissues of animal) give the different types of meat contamination. The section for preparation, in Figure II.14, means time delays in the use of milk and meat as well as other loss factors.

II.4.12.3. Radioactivity in man and dose assessments

There are two ingestion paths to the compartment GITM, one from processed milk and meat and one from direct intake. In general, the intake of the activity from vegetables, bread and other foods is modelled by the direct way. The transport processes in man are described by three compartments, the GITM, CIRM and TISM (for caesium in the muscle). Dose assessment is calculated using simple dose factors from the CB scenario description.

II.4.12.4. Model parameters

(In parentheses the minimal and maximal values for uncertainty analysis provided by triangular distributions of the parameters)

Deposition, resuspension:

v_g = 180 (100-250) m/d; $RF_1 = 1(0.3\text{-}2.0)\cdot 10^{-4}\ d^{-1}$

$w = 2.5\ (1.5\text{-}3.5)\cdot 10^5$; $RF_2 = 1(0.3\text{-}2.0)\cdot 10^{-6}\ d^{-1}$

Soil:
Thickness of layers (not varied)
$d_{SOSU} = 0.001$ m; $d_{SORO} = 0.099$ m; $d_{SODE} = 0.20$ m

Transfer coefficients (1/d)

$k_{SOSU,SORO} = 3\ (1\text{-}10)\cdot 10^{-3}$; $k_{SORO,SODE} = 1\ (0.4\text{-}3)\cdot 10^{-4}$

$k_{SODE,SORO} = 3\ (1\text{-}10)\cdot 10^{-5}$; $k_{SODE} = 4\ (2\text{-}10)\cdot 10^{-5}$

Vegetation:

	pasture	winter wheat	spring barley (alfalfa, grass)
$k_{VEEX,SOSU}$ =	0.06	0.08	
	(0.03-0.15)	(0.03-0.2)	
$k_{SOSU,VESU}$ =	$4\cdot10^{-4}$	$1\cdot10^{-4}$	
	$(2-10)\cdot10^{-4}$	$(0.3-5)\cdot10^{-4}$	same
$k_{VEIN,SOSU}$ =	0.02	0.003	
	(0.01-0.05)	(0.001-0.01)	as
$k_{SORO,VERO}$ =	$5\cdot10^{-6}$	$5\cdot10^{-6}$	
	$(2-15)\cdot10^{-6}$	$(1.5-15)\cdot10^{-6}$	winter
$k_{VERO,SORO}$ =	0.01	0.01	
	(0.004-0.03)	(0.002-0.05)	wheat
$k_{SODE,VERO}$ =	$3\cdot10^{-7}$	$3\cdot10^{-7}$	
	$(1.5-8)\cdot10^{-7}$	$(1-10)\cdot10^{-7}$	
$k_{VERO,SODE}$ =	0.002	0.002	
	(0.001-0.005)	(0.0005-0.007)	
$k_{VESU,VEIN}$ =	0.1	0.007	0.01
	(0.05-0.3)	(0.004-0.02)	(0.004-0.03)
$k_{VEIN,VESU}$ =	0.05	0.08	
	(0.05-0.15)	(0.03-0.15)	
$k_{VEIN,VERO}$ =	0.002	0.002	
	(0.001-0.005)	(0.0005-0.01)	same
$k_{VERO,VEIN}$ =	0.02	0.02	
	(0.01-0.05)	(0.005-0.1)	as
α =	0.1	0.015	
	(0.05-0.2)	(0.005-0.3)	winter
β =	0.04	0.02	
	(0.01-0.1)	(0.005-0.05)	wheat
Preparation losses =	0	0.5	(0.2-0.8)
time-lag =	20	90	
	(15-30)	(30-100)	
t_b =	1 May	20 April	20 May
	(20 Apr-10 May)	(10 Apr-1 May)	(10 May-30 May)
t_e =	1 Sept	1 Aug	10 Aug
	(15 Aug-15 Sept)	(15 July-15 Aug)	(20 July-20 Aug)

All the transfer coefficients k - in relation to the vegetation - are modified by the seasonality function S(t). Therefore the effective values of the transport coefficients between the compartments related to the vegetation are less than the given ones. Almost all of the values of the transfer coefficients for spring barley are the same as for winter wheat, the main difference being only the seasonality function S(t), with a delay of 30 days and smaller yield. A delay of 45 days is used for silage but the parameters are similar to those of pasture.

The contamination of leafy vegetables and fruits is calculated by the model SIRATEC (see [II.1]). The yield of leafy vegetables was 2 kg/m^2 (fresh) and the weathering half-life time 10 days. The uptake from soil was modelled by a concentration factor.

Animal:

		cow	pig
$U_{x,a}$(kg/d)	=	13 (9-18)	4 (2-6)
$U_{s,a}$(kg/d)	=	0.5 (0.1-2)	0.2 (0.05-0.3)
$U_{c,a}$(m^3/d, inhal.)	=	130 (90-170)	25 (15-35)
M (1/d)	=	10 (6-14)	0.03 (0.01-0.1)
W_{CIRA} (kg)	=	50 (30-70)	10 (7-20)
W_{MUSA} (kg)	=	250 (180-350)	60 (30-90)
W_{TISA} (kg, liver)	=	6 (4-8)	3 (2-7)
$k_{GITA,CIRA}$	=	0.3 (0.1-0.6)	0.3 (0.1-0.5)
k_{GITA} (to faeces)	=	0.6	0.3 (0.1-0.5)
$k_{CIRA,GITA}$	=	0.02 (0.005-0.05)	0.02 (0.007-0.07)
k_{CIRA} (to milk)	=	0.07 (0.03-0.2)	0.01 (0.005-0.015)
k_{CIRA} (to urine)	=	0.08 (0.04-0.3)	0.02 (0.01-0.1)
$k_{CIRA,MUSA}$	=	0.8 (0.4-1.2)	0.8 (0.4-1.5)
$k_{MUSA,CIRA}$	=	0.05 (0.02-0.1)	0.03 (0.003-0.1)
$k_{CIRA,TISA}$	=	0.03 (0.01-0.08)	0.03 (0.005-0.1)
$k_{TISA,CIRA}$	=	0.05 (0.02-0.15)	0.05 (0.02-0.2)
k_{TISA} (to bile)	=	0.07 (0.03-0.2)	0.07

Man:

W_{HB} (kg) = 70 (45-110)

$U_{c,HB}$ (m^3/d, inhal.) = 22 (10-40)

k_{GITM} (to faeces) = 0.2 (0.1-0.4)

$k_{GITM,CIRM}$ = 0.8 (0.4-1.5)

$k_{CIRM,GITM}$ = 0.03 (0.01-0.1)

k_{CIRM} (to urine) = 0.2 (0.1-0.5)

$k_{CIRM,TISM}$ = 0.7 (0.3-2)

$k_{TISM,CIRM}$ = 0.05 (0.02-0.1)

where M = daily amount of milk and W_x = mass of compartment x.

To calculate the external dose from the soil surface, the dose conversion factor was modified by factors of 1 for compartment SOSU, 0.5 for SORO and 0.2 for SODE. Because the radioactivity in the compartment of SODE is small, the dose contribution of it was negligible.

Using the computer code TAMDYN [II.4], all the parameter values for the differential equations can be modified by the user. Similarly, countermeasures and other irregular changes can be modelled. Therefore the predicted results are strongly dependent upon the user. For uncertainty analysis the code of TAMDYN was used.

II.4.13. LINDOZ

The model is developed to describe the radionuclide transport processes in the food chain and to assess the dose contributions from the different pathways. The whole model can be described in terms of the following subsystems, submodels:

- soil and vegetation (Figure II.16)
- transport in animal (Figure II.17)
- dose assessment

The model includes sensitivity and uncertainty analysis for human whole body only. Numerical methods used to solve the differential equations.

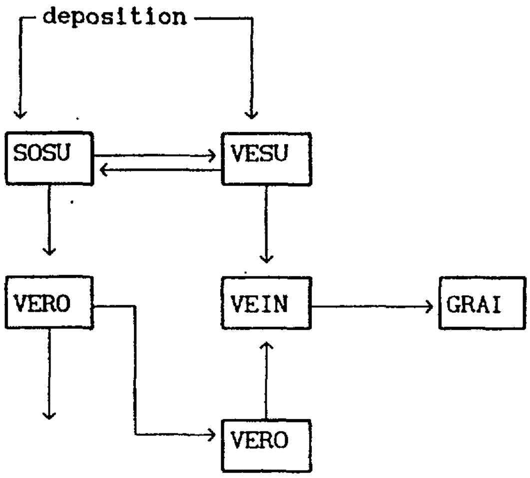


FIG. II.16. Flow chart of LINDOZ soil and vegetation model.

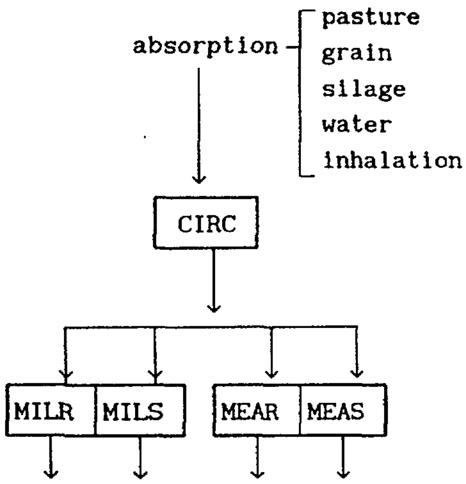


FIG. II.17. Flow chart of LINDOZ animals model.

II.4.13.1. Submodel for vegetables and cereals

According to Figure II.16, there are two soil compartments (SOSU = soil surface, SORO = soil root zone), three compartments for vegetation (external, internal and root) and one for the grain or fruit. The concentrations used in the model refer to a unit of area and not to the mass. The source term used for the scenario CB is the deposition rate in units of $Bq/m^2/d$.

In case of leafy vegetables the compartment of GRAI (grain) is ignored. The deposition to the leafy vegetables is influenced by the interception factor and for dry deposition R is a linear function during the growing period up to a value of 0.8. For wet deposition on pasture:

$$R = 1. - \exp\{-Y_{xd}[0.35 + 2.0 \exp(-0.48\ I_s)]\} \tag{II.113}$$

For cereals, the wet retention was modelled as in ECOSYS. The transfer coefficient of $k_{SOSU,VESU}$ is used for the resuspension, the $k_{VESU,VEIN}$ for foliar absorption, and the $k_{VESU,SOSU}$ for the weathering effect. The root uptake is taken into consideration by the $k_{SORO,VERO}$.

For contamination of cereals the translocation from the internal part of vegetation (VEIN) to grain interior (GRAI) is described as follows:

$$\dot{C}_{GRAI} = k_{VEIN,GRAI} \cdot C_{VEIN} - \lambda_r \cdot C_{GRAI}. \tag{II.114}$$

The straw concentration was obtained from the VEIN compartment for cereals (wheat, barley). The differences between winter wheat and spring barley were only parameter values related to the growing period.

For pasture the submodel in Figure II.16 was modified a little by adding more soil compartments, by eliminating the compartments of root vegetation and grain, and by taking into consideration the loss from the external vegetation by grazing. The same modifications were used for alfalfa, but instead of continuous grazing, cuttings at 5-cm height were introduced. The supplementary compartments take into account soluble and insoluble forms of fallout for surface soil and plant surface. The foliar absorption rate acts only for soluble cesium, while field loss rate affect both compartments for plant surfaces. In surface soil, the fixation rate transfers the pollutant from the soluble form compartment to the insoluble one.

In the case of silage (mainly green maize), direct deposition was neglected during the accident because of the later growing season. In the following years the contamination was calculated by a simple concentration factor (B_v).

II.4.13.2. Submodel for animals

According to Figure II.17, the animal is divided into compartments of gastrointestinal tract (GIT), milk, and meat (with rapid and slow rates). The daily rate of radioactivity intake is a sum of all the pathways:

$$\begin{aligned} Q_{GIT} = {} & f_{inh} \cdot U_{c,a} \cdot C_a + U_w \cdot C_w + U_s \cdot C_{SOSU} + \\ & U_f(f_p \cdot C_p + f_g \cdot C_g + f_l \cdot C_l) \end{aligned} \tag{II.115}$$

where f_{inh} is the absorbed fraction from inhalation on the circulation fluids with respect to the ingestion.

The milk concentration is derived from the equations:

$$\begin{aligned} C_m &= C_{m,1} + C_{m,2} \\ C_{m,i} &= \gamma_{M,i}\ I_{CIRC} - (k_{MILK,I} + \lambda_r) C_{m,i} \end{aligned} \tag{II.116}$$

where γ_M is the fraction of daily intake transferred to the litre of milk and k_{MILK} the transfer coefficient out from the milk. A similar description is used for the concentration in meat (both for beef and pork). This approach is equivalent to the convolution integral for a two-terms retention function.

II.4.13.3. Transport in man and dose assessment

The caesium retention in the human body was considered by a sum of two exponentials with half-lives of 1.7 and 91.2 days, as follows:

$$RA_{HB} = 0.145 \cdot \exp(-0.4 \cdot t) + 0.855 \cdot \exp(-0.0076 \cdot t) \qquad (II.117)$$

The radioactivity intake was considered in the same form as for animals; the input is defined by ingestion rate. The dose contributions from the pathways of external radiation, inhalation and ingestion were calculated for different population groups k.

The average individual external dose due to the ground deposition is given by:

$$H_g = \sum_{i,k} g_{i,k} \cdot O_{i,k} \cdot SFg_{ik} \cdot Dcf_g \cdot D \qquad (II.118)$$

where k means the population group (indoor workers, farmers, children, etc.), i the occupational term (activity category like time spent outdoors) and g_k the population fraction in the group.

The inhalation dose (individual committed effective dose equivalent) is calculated by:

$$H_c = \sum G_{ik} \cdot O_{ik} \cdot SF_{cik} \cdot Dcf_c \cdot U_c \cdot C_a \qquad (II.119)$$

In similar way he ingestion dose is estimated with modified parameter values; instead of the production of $U_{inh} \cdot C_a$, the rate of activity intake (Q_{HB}) is used.

II.4.13.4. Model parameters (not included in Section II.5)

Atmospheric deposition and contamination of vegetation:

	L.Veget.	Pasture	W.Wheat	Sp.Barley	Fruit	
Y	2.0	1.8	0.9	0.9	na	kg/m^2
k_W	0.05	0.05	0.04	0.04	na	d^{-1}
$k_{SOSU,VESU}$	0.003	0.0003	0.0003	0.0003	na	d^{-1}
$k_{VESU,VEIN}$	0.01	0.005	0.005	0.005	na	d^{-1}

Transport in animals:

	cow	pig	
U_{inh}	150	30	m^3/d
U_a	60	7	L/d

	milk	meat		
$\gamma_{i,r}$	0.003	$2.5\ 10^{-4}$	0.007	
$\gamma_{i,s}$	$8\cdot10^{-5}$	$2.8\ 10^{-4}$		
$k_{i,r}$	0.6	0.152	0.023	d^{-1}
$k_{i,s}$	0.04	0.019		d^{-1}

Parameters for external dose:

categ.	urban work		transport		indoor		outdoor	
	O	SF	O	SF	O	SF	O	SF
ind. work	1/3	0.15	1/24	0.5	0.5	0.1	3/24	1.
constr.	1/3	0.3	1/24	0.5	0.5	0.1	3/24	1.
office	1/3	0.1	1/24	0.5	0.5	0.1	3/24	1.
farmer	0.		0.		1/3	0.2	2/3	1.

II.5. MODEL PARAMETERS

This section describes the model parameters used in individual models which are not included in the main text of model description. When possible, parameter values are collected in tables, to facilitate a model intercomparison. For models using differential equations, the transfer rates are given in the main text. Model parameters not included in general tables or in the main text are given below before the general tables (Tables II.1 to II.7).

CLRP

External dose

- α_g=0.63; λ_{g1}=1,13 y^{-1}; λ_{g2}=0.075 y^{-1}; (only open field)

DOSDIM

External dose

- Same parameter as CLRP but SF_g=0.2

ENCONAN

Vegetation characteristics (following Equation (II.38))

	P_1	P_2	P_3
wheat w.	1.16	41.3	12.5
alfalfa	5.25	12.7	19.0

CHERPAC

Deposition, soil

- P_s= 240 kg/m^2 with 15 cm depth

(but 16 kg/m^2 for the first year unplowed soil)

Vegetation

- Wet interception factor R_w=0.1
- Soil adhesion transfer factor R_s =1.62 E-4

Animal

- Fraction absorbed by the gut F=0.3
- The grain portion of the diet for cow consists of 30% spring grain and 70% winter grain. The cow receives 50% contaminated feed between 2 and 16 May. After 16 May all feed is contaminated.

Man

- External dose was calculated considering an average worker spending 2 hours outdoors during the week and 5 hours outdoors on the weekend. The shielding factor is 0.5 for cloud and 0.23 for terrain. The dose reduction factor FR = 0.7, due to nonuniformity of surface.

ECOSYS

Dry deposition on soil and plants

- Maximum deposition velocity (m/s): soil 0.0005; leafy vegetables 0.002; pasture 0.0015; cereals 0.002; fruit tree 0.005

Plant characteristics

pasture yield:	minimum value on Mar 25	0.05	kg f.w./m^2
	maximum value on May 25	1.5	

normalization factor $k_g = 1\ m^2/kg$

Leaf area index

leafy vegetables:	linear increase from 0 to 5 by day 50 of growing time
winter wheat:	linear increase from 1 (20 Apr) to 7 (10 June); decrease to 1 on 5 Aug
spring barley:	increase from 0 (15 Apr) to 5 (15 June); decrease to 1 at harvest on 5 Aug
fruit tree:	from 0 (15 Apr) to 5 (1 Jul)

Wet interception factor

$k_{1,x}$= 0.3 mm $k_{2,x}$= 0.9 mm leafy vegetables and fruit

$k_{1,x}$= 0.2 mm $k_{2,x}$= 0.6 mm pasture and cereals

Translocation

(time before harvest (d), translocation factor)

winter wheat	(0,0.075)	(30,0.1)	(55,0.1)	(95,0.005)	(150,0)
spring barley	(0,0.075)	(25,0.1)	(50,0.1)	(75,0.01)	(110,0.)
fruit	(0,0.02)	(14,0.1)	(106,0.1)	(183,0.)	

Soil adhesion R_s = 0.001 Bq/kg f.w. per Bq/kg d.w.soil

Miscellaneous transfer rate (d^{-1})

λ_w = 2.77 E-2; λ_f = 2.24 E-4; λ_m = 3.1 E-6; λ_{gd} = 3.9 E-2;

λ_t = 1.16 E-2 (a=0.05)

Man and dose assessment

fraction of time spent indoor or outdoor, and shielding factors

	O_i	$SF_{i,m}$	$SF_{i,g}$
outdoors rural	0.1	1	1.
urban	0.1	0.6	0.3
indoors single family houses	0.5	0.3	0.1
large buildings	0.3	0.05	0.01

PRYMA

Vegetation Interception factor R

pasture, alfalfa, silage	0.25
leafy vegetables	0.3
grains	0.012

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[II.2] NAPIER, B.A., PELOQUIN, R.A., STRENGE, D.L., RAMSDELL, J.V., GENII - The Hanford Environmental Radiation Dosimetry Software System, PNL-6584, Vol. 1-3, Pacific Northwest Laboratory, Richland, Washington (1988).

[II.3] NAPIER, B.A., Computational Model Design Specification for Phase I of the Hanford Environmental Dose Reconstruction Project, PNL-7274 HEDR, Pacific Northwest Laboratory, Richland, Washington (1991).

[II.4] KANYAR, B., NIELSEN, S.V., User's Guide for the Program TAMDYN, BIOMOVS Technical Report No. 4, National Institute of Radiation Protection, Stockholm (1989)

TABLE II.1. SOIL-PLANT TRANSFER PARAMETERS - LEAFY AND ROOT VEGETABLES, POTATO AND FRUITS, TRANSLOCATION FACTOR

Model	B_{vl}	B_{vr}	B_{vp}	B_{vf}	T
CRLP	0.05	0.005	0.01	0.014	0.1-0.5
DOSDIM	0.02	0.0085	0.012	NA	0.1-0.5
HUMOD	0.03	0.03	0.03	0.03	1.(vl) 0.1
GENII	0.02	0.02	0.02	0.02	1.(vl) 0.1
ENCONAN	0.1	0.07	0.024	0.4	NA
CHERPAC	0.027	0.0086	0.027	0.102	NA
HEDR	0.01-0.04	0.01-0.04	0.01-0.04	0.01-0.04	0.01-0.1
ECOSYS	0.02	0.01	0.01	0.02	*
PRYMA	0.017	0.062	0.062	0.026	NA

* ECOSYS uses a time-dependent translocation factor; see above for ECOSYS parameters.

TABLE II.2. A COMPARISON OF THE DEPOSITION AND INTERCEPTION PROCESSES CONSIDERED BY MODELS

	CL(1)	DO	HU	GE	HE	EN	CH	EC	SC	PR	SP	TE	LI
Account for both dry and wet depos	X	X	X				X	X	X	X	X	X	X
AMAD dependence	X												X
Depos dependent on veg. type				X	X			X					
Wet depos--washout ratio(2)			0.3				0.58	0.5	0.53	0.59(5)		0.25	0.6
Wet depos--washout rate(3)	3	10								0			
Dry interception--Chamberlain	X			X	X	X							X
Dry interception LAI								X					X
Dry interception fixed		X	X				X		X	X			
Specification dry/wet interception								X					X
Dry deposition values mm/s	0.5	1.0	3.5	1.0	1.0		1.2	(4)	1	2	1.5	2	1.1

(1) Code for model names: CL=CLRP, DO=DOSDIM, HU=HUMOD, GE=GENII, HE=HEDR, EN=ENCONAN, CH=CHERPAC, EC=ECOSYS, SC=SCHRAADLO-T, PR=PRYMA, SP=SPADE2, TE=TERNIBU, LI=LINDOS.

(2) 10^6 * Bq m^{-3} rain * (Bq m^{-3} air)$^{-1}$.

(3) 10^{-5} s^{-1}.

(4) Dry deposition velocity dependent on plant species and stage of development.

(5) mm^{-1}.

TABLE II.3. A COMPARISON OF THE PROCESSES AND MECHANISMS CONSIDERED BY MODELS IN THE VAMP CB EXERCISE FOR THE CONTAMINATION OF PLANTS (AN "X" INDICATES A POSITIVE RESPONSE OR THAT THE PROCESS WAS INCLUDED FOR THE CB EXERCISE.)

	CL(1)	DO	HU	GE	HE	EN	CH	EC	SC	PR	SP	TE	LI
Foliar interception	(2)	x	x	x	x	x	(2)	x	x	x	x	x	x
Weathering	x	x	x	x	x	x	x	x	x	x	x	x	x
Growth dilution	x				x	x		x	x		?(3)	x	x
Root uptake	x	x	x	x	x	x	x	x	x	x	x	x	x
Resuspension onto plants	?			(4)				x	x	x		x	x
Rainsplash onto plants	?						x						x
Translocation to edible plant parts	x	(5)	x	x	x			x	x	(6)	x	x	x
Leaching from root zone	x	x	x	x			x	x	x	x	x	x	x
Plowing effects	x				x	x	x				?	x	x
Storage and/or processing	s/p	s(7)		s/p	s	s/p	p	s/p	p	s/p	?	s/p	s/p
Plant partitioning	x		x					x	x	x	x	x	x
Loss from harvest/grazing	x					x				x	?	x	x
Grain types specified	x					x		x			?	x	x
Soil types considered											x		
Counter-measures considered(8)	x	x			x	x	x	x	x	x		x	x

(1) Code for model names: CL = CLRP, DO = DOSDIM, HU = HUMOD, GE = GENII, HE = HEDR, EN = ENCONAN, CH = CHERPAC, EC = ECOSYS, SC = SCHRAADLO-T, PR = PRYMA, SP = SPADE2, TE = TERNIRBU, LI = LINDOZ

(2) for pasture and grains only

(3) data not provided by modeler, information unknown

(4) considered after the first year

(5) for root crops and tubers only

(6) for cereals only

(7) processing was only taken into account for vegetables

(8) i.e. restricted grazing on contaminated pastures during May 1986

TABLE II.4. A COMPARISON OF PASTURE AND GRAIN PARAMETERS USED BY MODELS IN THE VAMP CB EXERCISE

Model	LAI(a)	RY^{-1}	Resusp.	Ps	λw	λg	λm	λtr	Bv (Fr.Wt.)	Harvest Date	Yield @ Harvest
DOSDIM											
Pasture		0.23	nc(c)	195	0.05	nc	1.8E-6	nc	0.022	no cut	nc
Grain(b)		0.0(d)	nc	390	0.00	nc	8.8E-7	nc	0.014	01/08	0.2
ECOSYS-G											
Pasture	4.2(e)		0.001(f)	140	0.027	0.039(g)	7.8E-6	nc	0.05	01/05	1.5
Grain											
- winter wheat	2.2		0.001	350	nc	nc	3.1E-6	0.005(h)	0.02	05/08	0.5
- spring barley	1.2		0.001	350	nc	nc	3.1E-6	0.004	0.02	05/08	0.4
ECOSYS-CH											
Pasture	4.8(e)		0.001(f)	140	0.027	0.039(g)	7.8E-6	nc	0.05	01/05	1.9
Grain											
- winter wheat	3.3		0.001	350	nc	nc	3.1E-6	0.005(h)	0.02	05/08	0.5
- spring barley	2.0		0.001	350	nc	nc	3.1E-6	0.004	0.02	05/08	0.4
HUMOD											
Pasture	1.0		nc	240	0.047	nc	2.7E-5	1.0	0.03	30/05	1.8
Grain(b)	3.6		nc	240	0.047	nc	2.7E-5	0.1	0.03	30/07	0.4

(a) Code for headings: LAI = leaf area index; Resusp. = resuspension of contaminated soil; Ps = soil density ($kg\ m^{-2}$); λw = radionuclide weathering rate from plants (d^{-1}); λg = reduction in radionuclide concentration due to growth of plant (d^{-1}); λm = radionuclide leaching rate into deep soil layer (d^{-1}); λtr = translocation rate to edible plant parts (d^{-1}); Bv = soil to plant concentration ratio ($Bq\ kg^{-1}$ fresh plant/$Bq\ kg^{-1}$ dry soil).

(b) Types of grain not distinguished.

(c) Not considered

(d) Assumed grain had not emerged.

(e) At time of deposition.

(f) $Bq\ kg^{-1}$ fresh weight plant / $Bq\ kg^{-1}$ dry soil.

(g) Time dependent, value given is for May 1986.

(h) In ECOSYS translocation is not modeled as a rate but by a factor representing the fraction of activity translocated.

TABLE II.4 (cont.)

Model	LAI	RY^{-1}	Resusp.	Ps	λw	λg	λm	λtr	Bv (Fr.Wt.)	Harvest Date	Yield @ Harvest
PRYMA											
Pasture			8.4E-7(i)	1500(ii)	0.049	nc	1.2E-4	nc	.02	Jul	0.9
Grain(b)			5.4E-5	1500	0.049	nc	1.9E-5	.064	nc	Aug	0.44
ENCONAN											
Pasture			nc	195	0.046	yes	4%/a	nc	0.10(dw)	10/06	4.75
Grain											
- winter wheat			nc	325	0.046	yes	4%/a	nc	0.014(fw)	01/08	0.44
- spring barley			nc	325	0.046	yes	4%/a	nc	0.15(fw)	01/08	0.45
CLRP											
Pasture			nc	400	0.49	?	1.1E-4	1.0	1.0	01/06	1.8
Grain											
- winter wheat			nc	400	0.49	?	1.1E-4	1.0	1.0	15/08	0.4
- spring barley			nc	400	0.49	?	1.1E-4	1.0	1.0	15/08	0.4
SCHRAADLO-T											
Pasture		0.25	2.4E-7(j)	240	0.05	0.016	1.1E-4	0.016	0.02	Jun	nc
Grain(b)		0.25	2.4E-7	240	0.05	0.016	1.1E-4	0.016	0.02	Aug	nc
CHERPAC											
Pasture			nc	240	0.495	nc	1.8E-4	nc	0.02	15/08	0.54
Grain			nc	240	nc	nc	1.9E-5	nc	0.03	winter: 15/07 spring: 15/08	
GENII											
Pasture			k	224	0.049	nc	3.0E-6	1.0	0.02	contin.	1.5
Grain(b)			k	224	0.049	nc	3.0E-6	0.1	0.01	Jul	0.8

(i) PRYMA uses wind velocity dependent resuspension rate (d^{-1}).

(ii) Ps in kg m^{-3}.

(j) kg m^{-3} air mass loading.

(k) uses a resuspension factor (m^{-1}).

TABLE II.4 (cont.)

Model	LAI	RY^{-1}	Resusp.	Ps	λw	λg	λm	λtr	Bv (Fr.Wt.)	Harvest Date	Yield @ Harvest
HEDR											
Pasture			nc	240	0.035- 0.087	nc	nc	1.0	0.02	01/07	1.5
Grain(b)			nc	240	0.035- 0.087	nc	nc	0.01- 0.1	0.01	05/08	.8
SPADE2											
Pasture			nc	?	4.6E-6	?	4.3E-6(l)	3.5E-3(m)	?	?	?
Grain(b)			nc	?	4.6E-6	?	2.2E-6	3.6E-3	?	?	?
TERNIRBU											
Pasture			10^{-4}(n)	1700(ii)	0.06	Yes	4E-5(l)	0.1(o)	?	01/09	2.0
Grain(b)			10^{-6}	1700	0.08	Yes	4E-5	0.007	?	01/08	0.7
LINDOZ											
Pasture			l=.0003	120	0.05	Yes	2E-4	0.005	0.04	10/07	1.8
Grain(b)			l=.0001	240	0.03	Yes	2E-4	0.002	0.02	01/08	0.4

(l) Distinguished 3 different soil compartments.
(m) SPADE2 distinguished 5 different plant compartments.
(n) Two resuspension factors are used in TERNIRBU with units of d^{-1}.
(o) In TERNIRBU, this value is dependent on season.

TABLE II.5. PARAMETERS RELATED TO HUMANS

Model	Inh.(1) (m^3/d)	Ing.(2)	Culinary Losses	F_1	Retention Factor a_1	T_1(d)	T_2(d)	Occup. Factor	Shielding Factor	Dose Conv. Factors
CRLP	24	Scenario(3)	0.5-1	1	0.2	2	120	0	1	Scenario(3)
DOSDIM	24	Scenario	-	1	0.1	2	110	0.33-0.66	0.2	Scenario
HUMOD	22	Scenario	-	?(4)	?	?	?	?	0.16-0.7	Scenario
GENII	23	Other	-	1	0.1	2	110	1	1	Other
ENCONAN	22	Scenario	-	0.7	0.1	3	110	0.68	0.2	Scenario
CHERPAC	48,55(5)	Scenario	.5-1	1	0	-	110	.79-.92	0.23,0.5(6)	Scenario
ECOSYS	29	Scenario	0.75-0.9	0.78	0.06	0.3	90(7)	0.8	0.01-0.3	Scenario
HEDR	23	Other	-	1	0.1	2	110	1	1	Other
PRYMA	23	Scenario	0.4-1	1	0.1	2	110	0.66	0	Scenario
SCHARADLO	20	Scenario	-	0.5-0.8	0	-	100	1	0.5-1	Scenario
SPADE2	?	?	?	(ICRP	model)			?	?	?
TERNIRBU	22	Scenario	0.5-1	0.8	transf.	factors		0.7-0.9	0.2-0.5	Scenario
LINDOZ	24	Other	0.4-1	1	0.15	1.7	91	0.2-0.8	0.1-0.5	Scenario

(1) Inhalation.

(2) Ingestion.

(3) Scenario: Almost all the values were taken from the CB scenario description.
Other: Most of the values were derived from other experiences and not from the scenario description.

(4) Data not supplied by modeler, value unknown.

(5) First value for weekday and second for weekend.

(6) The first factor is fraction of outdoor dose received indoors for exposure to surfaces, the second shielding factor for immersion.

(7) ECOSYS version in Switzerland used a single compartment retention function with a half-time of 110 d.

TABLE II.6. Cs KINETICS IN FARM ANIMALS AND CONTAMINATION OF THEIR PRODUCTS
(A) APPROACHES AND PROCESSES

Model	TR	DM	CM	RT	CU	AD
CLRP		D,C(2),P(1)[+]		n.c.[#]	5/5-0.5	sw
DOSDIM	P,K,H	D(3),C(2)		K,H(.8)	5/6,15-0.5	sw
HUMOD	D,C,P			n.c.	n.c.	sw
GENII	D,C,K,H			n.c.	n.c.	gi
ENCONAN	D,C,K,H		P(4)	n.c.	5/15-0.5	vg
CHERPAC	H	D,C,P,K(1)		D,C(0.3)	5/02-1.0 5/16-0.5	sw
ECOSYS		D(2),C,B, P,K,H(1)		n.c.	5/20-1./0.[@]	vg
HEDR	D,C,K,H			n.c.	n.c.	sw
PRYMA	K,H		D,C(7) P(4)	n.c.	5/15-0.5	vg
SCHRAADLO-T	D,C,P(1)			n.c.	summer 86 -0.8	gi
SPADE2			D,C(5)	n.c.	n.c.	gi
TERNIRBU			D,C(4) P(3)	accounted for in feeding regimes		vg
LINDOZ			D,C,P(2)	n.c.	5/15 -0.5 to 1.0	sw

TR: Transfer factor approach.
DM: Time-dependent approach with exponential retention function of physiological process (number of terms).
CM: Compartmental model defined by a set of linear first-order differential equations (number of compartments).
RT: Loss of radionuclide due to physiological process (fraction of radionuclide transported to milk, meat and egg respectively).
CU: Consumption of uncontaminated feed in May 1986 by dairy cow and cattle/bull (end point, month/day - share of uncontaminted feed).
AD: Dairy cow and cattle feeding regime (sw--constant summer and winter regime, vg--summer regime following vegetation period of individual kinds of feed, const. winter regime, gi--general information only).

[+] D-dairy cow, C-cattle, B-bull, P-pig, K-broiler (chicken), H-hen.

[#] n.c.: Not considered.

[@] In ECOSYS-G a linear decrease of the fraction of uncontaminated feed from April 30 till May 20 has been assumed.

TABLE II.6 (cont.)

(B) MODEL PARAMETERS - GENERAL ITEMS

Model	INHC	SING	MILK	BM	BW
CLRP	n.c.	n.c.	16.9		C(200)
DOSDIM	n.c.	n.c.			
HUMOD	n.c.	n.c.			
GENII	n.c.	n.c.			
ENCONAN	n.c.	n.c.	10.0	P(115)	P(75)
CHERPAC	D(280),P(30) C(80)	D(0.5),C(0.25) K,H(0.01)			P(100)
ECOSYS	n.c.	n.c.			
HEDR	n.c.	n.c.			
CIEMAT	D,C(150)	D(0.5), C(0.2)	10.0	P(115)	C(200) P(75)
SCHRAADLO-T	n.c.	D,C,P(0.5)			
SPADE2	D,C(130)	D,C(0.11)	10.0	D(500)	C(200)
TERNIRBU	D,C(130) P(25)	D(.3),P(.1)	10		C(250) P(60)
LINDOZ	D,C(150) P(60)	D,C(0.5)			

INHC: Inhalation of airborne radionuclide (m3 d^{-1}).
SING: Soil ingestion (kg d^{-1}).
MILK: Milking of dairy cow (1 d^{-1}).
BM: Body mass in a slaughter time (kg).
BW: Weight of muscle tissues or butcher's meat (kg).

(C) MODEL PARAMETERS - TRANSFER FACTOR APPROACH

Model	F_m	F_b	F_p	F_k	F_e
CLRP	0.003	0.005	0.35	n.c.	n.c.
DOSDIM	0.004	0.03	0.25	4.4	0.49
HUMOD	0.005	0.03	0.03	n.c.	n.c.
GENII	0.007	0.03	n.c.	4.4	0.49
ENCONAN	0.003	0.02	n.c.	0.4	0.03
CHERPAC	0.0043	0.028	0.31	4.6	0.75
ECOSYS	0.003	C(0.01) B(0.04)	0.4	4.5	0.3
HEDR	0.007	0.03	n.c.	4.4	0.49
PRYMA	n.c.	n.c.	n.c.	4.4	0.49
SCHRAADLO-T	0.004	0.008	0.04	n.c.	n.c.

F_m: Fraction of the animal's daily intake of the radionuclide that appears in each litre of milk in equilibrium (d l^{-1}).
F_b: Ditto in each kilogram of beef (d kg^{-1}).
F_b: Ditto in each kilogram of pork (d kg^{-1}).
F_k: Ditto in each kilogram of poultry (d kg^{-1}).
F_e: Ditto in each kilogram of egg (d kg^{-1}).

TABLE II.6 (cont.)

(D) MODEL PARAMETERS - RETENTION FUNCTION OF PHYSIOLOGICAL PROCESS

Model	a_1	a_2	a_3	b_1 (d^{-1})	b_2 (d^{-1})	b_3 (d^{-1})
CLRP						
- D	?	?	-	3.00e-1	2.0e-2	-
- C	?	?	-	2.40e-1	2.0e-2	-
- P	1	-	-	2.00e-2	-	-
DOSDIM						
- D	2.0e-3	3.3e-4	4.1e-5	7.45e-1	1.51e-1	1.95e-2
- C	2.2e-4	2.2e-4	-	7.29e-3	1.27	-
CHERPAC						
- D	1.0	-	-	1.73e-1	-	-
- C	1.0	-	-	3.47e-2	-	-
- P	1.0	-	-	6.30e-3	-	-
- K	1.0	-	-	1.89e-2	-	-
ECOSYS						
- D	0.8	0.2	-	4.60e-1	4.60e-2	-
- C	1.0	-	-	2.30e-2	-	-
- B	1.0	-	-	1.40e-2	-	-
- K	1.0	-	-	3.50e-2	-	-
- P	1.0	-	-	2.00e-2	-	-
- H	1.0	-	-	2.30e-1	-	-
SCHRAADLO-T						
- D,C,P	1.0	-	-	2.00e-2	-	-

a_i, b_i: Retention function parameters of physiological process described by the sum: $\Sigma\ a_i*\exp(-b_i t)$.

(E) MODEL PARAMETERS - RATE CONSTANTS IN COMPARTMENTAL MODEL

MODEL	λ_{G1}	F_1	λ_1	λ_2	λ_L	λ_M
ENCONAN						
- P	1.39	0.70	2.31e-2	1.56e-2	n.c.	-
PRYMA						
- D,C	0.668	0.75	0.565	0.253	n.c.	4.0
- P	n.c.	0.70	2.31e-2	1.56e-2	n.c.	-
SPADE2						
- D,C	3.0	0.60	2.0e-2	-	n.c.	6.58e-1
TERNIRBU						
- D,C	7.5e-1	0.60	2.0e-2	-	7.0e-2	7.0e-2
LINDOZ						
- D,C	Two compartments for milk and two compartments for meat (see Section II.4.13)					

λ_{G1}: Rate constant for feed passage through the gastrointestinal tract (d^{-1}).

F_1: Bioavailability, fraction of a radionuclide reaching the body fluids following ingestion (1).

λ_1: Metabolic rate constant of nuclide in unspecified tissues and organs, mostly muscle (d^{-1}).

λ_L: Metabolic rate constant of nuclide in liver (d^{-1}).

λ_M: Metabolic rate constant of nuclide to milk compartment (d^{-1}).

TABLE II.7. VAMP MP/CB PROCESSES IN RELATION TO MODELLING THE TRANSFER IN HUMAN BODY

	Intake		Metabol. in man			Dose assessments					
Models	a	b	c	d	e	f	g	h	i	j	k
CLRP	+	+	+			+	+	+			
DOSDIM	+	+	+			+	+	+		+	
HUMOD	+	+	+			+	+	+			
GENII	+	+		+		+	+	+			
ENCONAN	+	+	+			+	+	+		+	
CHERPAC	+	+	+			+	+	+	+	+	
ECOSYS	+	+	+			+	+	+		+	+
HEDR	+	+				+	+	+			
PRYMA	+	+	+			+	+	+		+	
SCHRAADLO-T	+	+	+			+	+	+			
SPADE2	+	+		+				+			
TERNIRBU	+	+			+	+	+		+	+	
LINDOZ	+	+	+	+		+	+	+			+

a: Inhalation
b: Ingestion
c: Retention function
d: Compartment parallel routes
e: Compartment cross
f: External cloud
g: External deposition
h: Internal intake
i: Use of whole body count
j: Use of occupant facts
k: Age dependent

Appendix III

INDIVIDUAL EVALUATIONS OF MODEL PREDICTIONS FOR SCENARIO CB

III.1. DOSDIM

1. APPLICATION OF DOSDIM MODEL TO CB SCENARIO

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Mol, Belgium

2. GENERAL MODEL DESCRIPTION

2.1. Name of model, model developer, model user.

DOSDIM (DOse DIstribution Model)
P. GOVAERTS - SCK/CEN, Mol (Belgium)
Users : T. Zeevaert
A. Sohier
N. Lewyckyj

2.2. Unique features of model structure.

The DOSDIM model is a compartmental, deterministic, radiological impact assessment model for both routine and accidental atmospheric releases.
For an accidental release, dynamic transfers are used in apposition to a routine release for which equilibrium transfer factors are used. The model itself was constructed to predict best-estimates but parameter values were chosen to be conservative.
Transfers between compartments are described by first-order differential equations.

The following pathways are allowed for in DOSDIM :
- External irradiation from the passing cloud
- External irradiation from deposited materials
- Inhalation/resuspension
- Ingestion of contaminated food.

To determine the contribution of the ingestion pathway, following assumptions are made :

- Both wet and dry depositions are taken into account. For wet deposition, an atmospheric mixing height of 1000 m, a precipitation rate of 1.5 mm/h which is used together with the observed daily rainfall to estimate the length of precipitation event and a wash-out factor for caesium-137 of 1.0 10^{-4} s^{-1} are assumed. For dry deposition, a deposition velocity for ^{137}Cs of 10^{-3} m/s is used.
- If the release occurs in the growing period (May-October), DOSDIM calculates the contribution of both direct deposition and root-uptake. Furthermore the contamination by translocation is calculated for root crops and tubers.
  If the release occurs in the other period (November-April), contamination can only occur by root-uptake [1].
- As indicated in the general scheme of the ingestion pathway (Annex 1), contamination of pasture, fodder, grains, green vegetables, root crops and tubers are calculated.

- Transfers to milk and beef are calculated dynamically using dynamic transfer factors corresponding to equilibrium transfer values, respectively F_m and F_f, of 7.0 10^{-3} d/l and 3.0 10^{-2} d/kg.
- Soil consumption is not considered.
- For pigs, hens and eggs, equilibrium concentration ratios are used. The transfer factor values are taken from [2].
- Whole-body contamination is calculated according to ICRP-56 [3].

2.3. Intended purpose of the model in radiation assessment.

The model was developed to assess the impact to man from routine and accidental atmospheric releases.

2.4. Intended accuracy of the model prediction.

In the initial version of DOSDIM, a conservative bias was introduced for regulatory purposes. However, for the CB-scenario the degree of conservatism was reduced and more realistic i.e. unbiased predictions are aimed at.

2.5. Method used for deriving uncertainty estimates.

At present, uncertainty analysis is not possible with DOSDIM. A code applying a Latin Hypercube Sampling technique (LHS) will be added later.

2.6. References describing detailed documentation of model.

- Commission of the European Communities
  "Seminar on the transfer of radioactive materials in the terrestrial environment subsequent to an accidental release to atmosphere"
  11-15 April 1983, Dublin (Ireland), Volume II, p. 607-637.
- S.C.K./C.E.N.-Mol
  "VAMP Multiple Pathways Assessment - CB
  Response to additional questionnaire on model description."

3. INITIAL COMPARISON OF TEST DATA AND MODEL PREDICTIONS

3.1. Total deposition

The DOSDIM average total deposition for all CB is 7400 Bq/m^2 (compared with 5500 Bq/m^2 observed). The results are compatible with the observations with only slight overprediction.

3.2. Major food items contributing to total diet.

3.2.1. Milk (FIG. 1)

Period 05/86 -> IV87

DOSDIM overpredicts concentrations by, on average, one order of magnitude. This is probably due to :

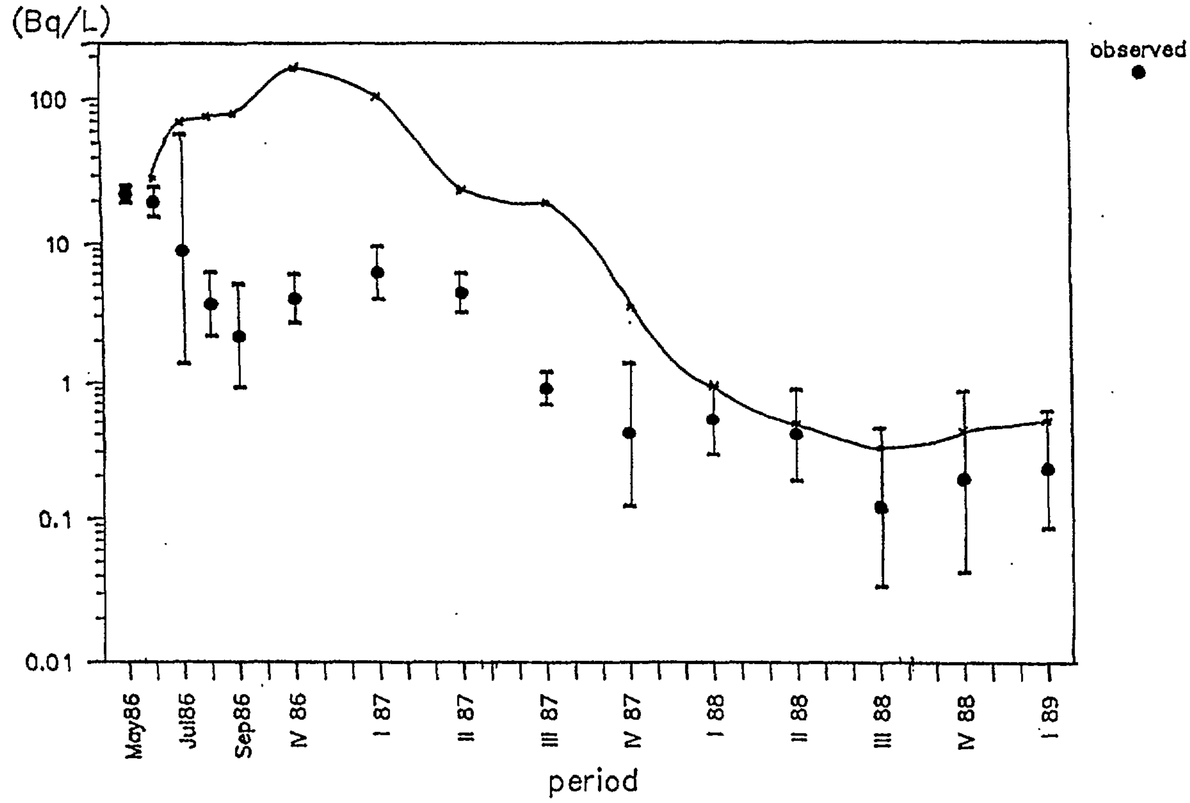

FIG. 1. Cs-137 concentrations in milk.

1. assumptions related to feeding practices, namely all pasture vegetation was cut and stored on the 15/06/86 and the 15/09/86 (no loss due to weathering after harvesting). However from the observations it could be deduced that weathering plays an important role especially during the first months (05/86 -> 10/86).
2. the high value used for the milk transfer coefficient F_m 7.10^{-3} d/l (in BIOMOVS A4 scenario, a best-estimate value of 4.3 10^{-3} d/l has been derived).
3. the high value used for the R/Y ratio. Indeed when using an initial interception of 2.0 m^2/kg (dw) for pasture and an initial deposition of 7400 Bq/m^2, an initial plant contamination of 14800 Bq/kg dw is obtained. However from the data analysis of initial grass contamination (measured at the Institute in AB) a value of 7000 Bq/kg dw was derived (i.e. half the value calculated with DOSDIM) which corresponds to a R/Y value of 1.28 m^2/kg. This seems more realistic and consistent with the results of studies at S.C.K./C.E.N.-Mol (Kirchmann). The value of 2.0 m^2/kg was used as a conservative default.

Period IV87 -> I89

The smaller overprediction observed in this period is probably due to our assumptions about feeding practices, to the high values used for F_m and to the high total deposition. Root-uptake is the only process which must be taken into account.

3.2.2. Beef (FIG. 2)

There seems to be an important discrepancy between our modelling results and the observations with respect to the effective half-life for caesium-137 in beef cattle.

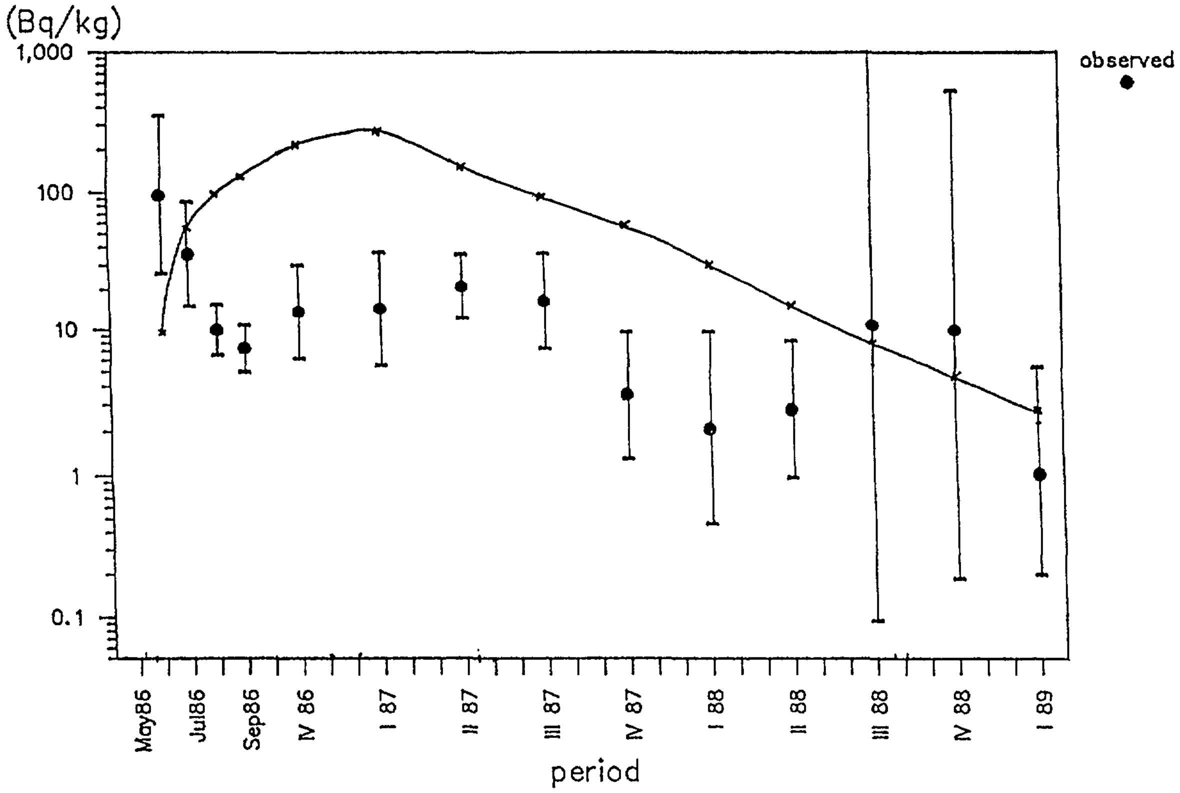

FIG. 2. Cs-137 concentrations in beef.

DOSDIM ignores the fast compartiment of the excretion function ($t_{1/2}$ ~ 2 d). As a result, predicted values show an increase in the first month after the deposition which are in contradiction with observed values.

Between III87 and II88, the same discrepancies between model and observations as for the milk concentrations can be seen, however with a certain delay as compared with the milk because of its longer biological half-life. The probable explanation is a difference in the feeding practice during that time-interval.

3.2.3. Pork (FIG. 3)

The time course of concentrations in pork is very similar to that in milk (equilibrium conditions were assumed in the calculations for pork). Concentrations in pork are overpredicted because of the overprediction in milk concentrations.

3.3. Other items of specific interest.

No comments.

3.4. Whole Body

3.4.1. Mean whole body concentrations. (FIG. 4)

Mean whole body concentrations are overpredicted by up to a factor of 20.

3.4.2. Distribution of whole body concentrations.

Not calculated (not enough time available given the size of the task).

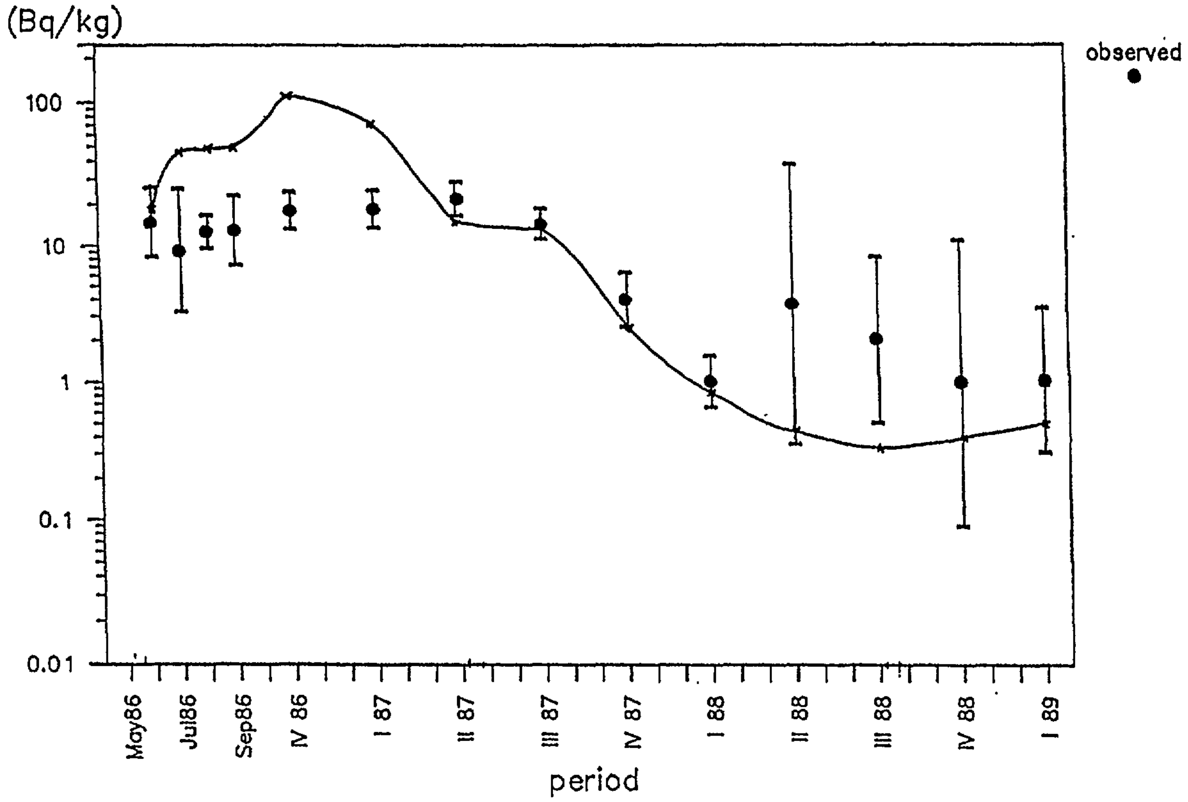

FIG. 3. Cs-137 concentrations in pork.

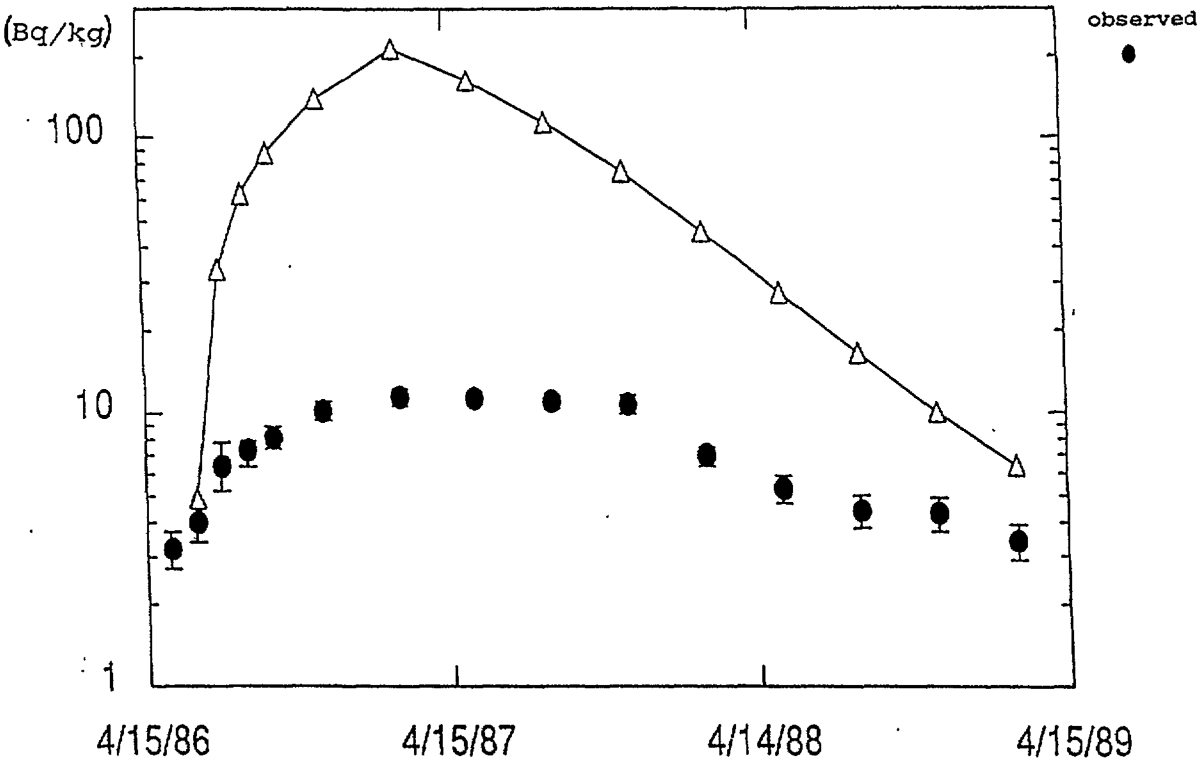

FIG. 4. Cs-137 concentrations in whole-body.

4. EXPLANATION OF MAJOR SOURCES OF MISPREDICTION

4.1. Recommendations for changes to the model.

From suggestions by Dr. Galeriu and by inspection of the observations, DOSDIM performances can be improved by :

- Revising assumptions about feeding practises.
- Allowing for losses by weathering in feed- and food crops during the first months (until 01/11/86).
- Reducing the retention factor (R/Y) to the site-specific value deduced from measurements of grass contamination at the Institute in AB.
- Reducing the F_m value to 4.0 10^{-3} d/l.

Furthermore, we may improve DOSDIM model by :

- Modelling dry and wet retention separately
- Adapting the wet deposition modelling in order to be able to take into account the actual precipitation rate or the daily rainfall rate
- Allowing for decreased concentrations in vegetation by growth dilution
- Taking into account the Leaf Area Index for direct deposition
- Including more detailed modelling of ingestion pathway e.g. including more food and feeding crops and making allowance for various feeding practices
- Adding a fast component to the excretion function for dynamic modelling of the beef compartment.

4.2. Example of how changes improve calculations.

By changing values of F_m to 4.0 10^{-3} d/l and of R/Y ratio to 1.28 m^2/kg for dry pasture, and by taking into account weathering effects, model predictions for milk will be improved as shown in FIG.5. Yet an overprediction by a factor of at most 3 remains until the end of the year '87.

For beef (FIG. 6), the remaining discrepancy until September '86 is probably due to failure to account for the "fast excretion compartment" in beef cattle which causes a lower concentration in the meat to be obtained at the beginning.
After September '86 the predictions are in good agreement with observed values. An overprediction remains by a factor of at most 4 (IV 87). However, these results agree better with the observations than those obtained earlier.

For pork (FIG. 7), the differences between predictions and observations are mainly due to the use of equilibrium parameter values. Modelling of pork contamination was initialy not included in DOSDIM.

For the whole body (FIG. 8), overprediction remains although to a lesser extent, partly due to the overprediction in milk concentrations and to neglecting differences between milk and milk-derived products.

Remarks :

1. Overprediction of caesium concentrations in milk, beef and pork are partly due to the higher contamination at the base of grass than in the upper parts which are eaten by cows.

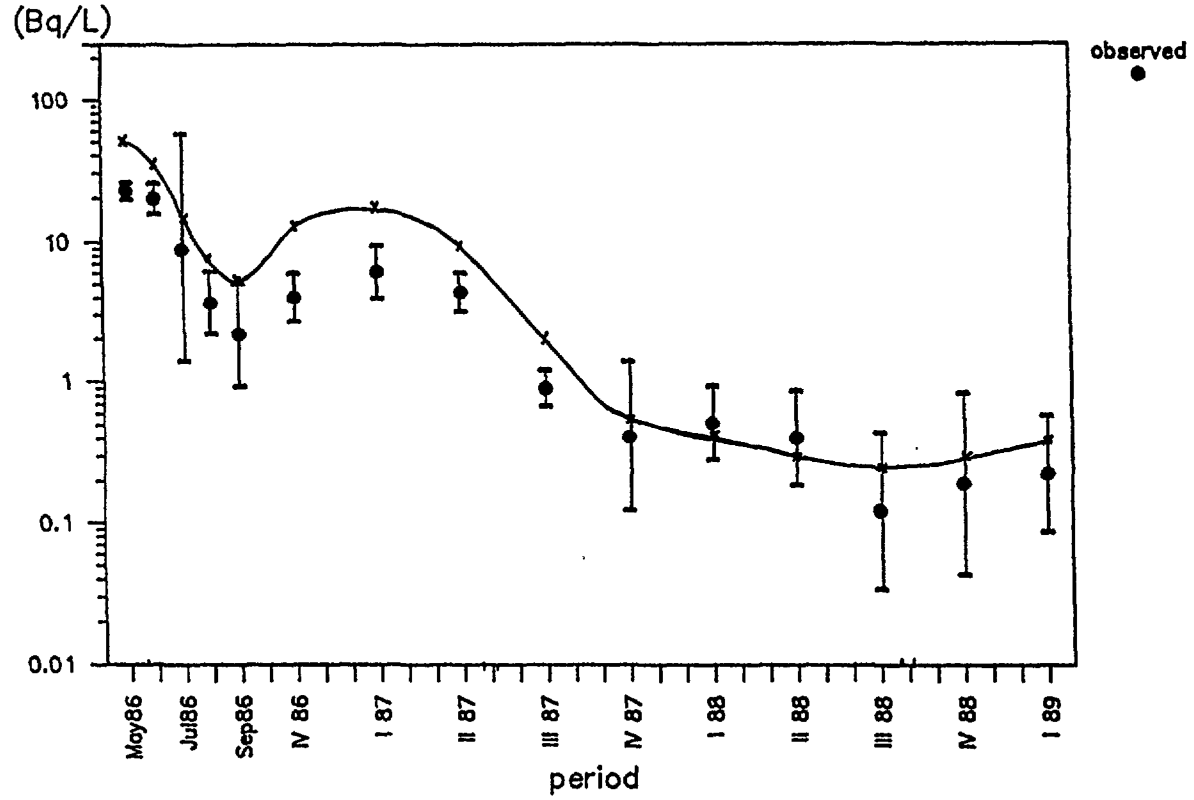

FIG. 5. Cs-137 concentrations in milk.

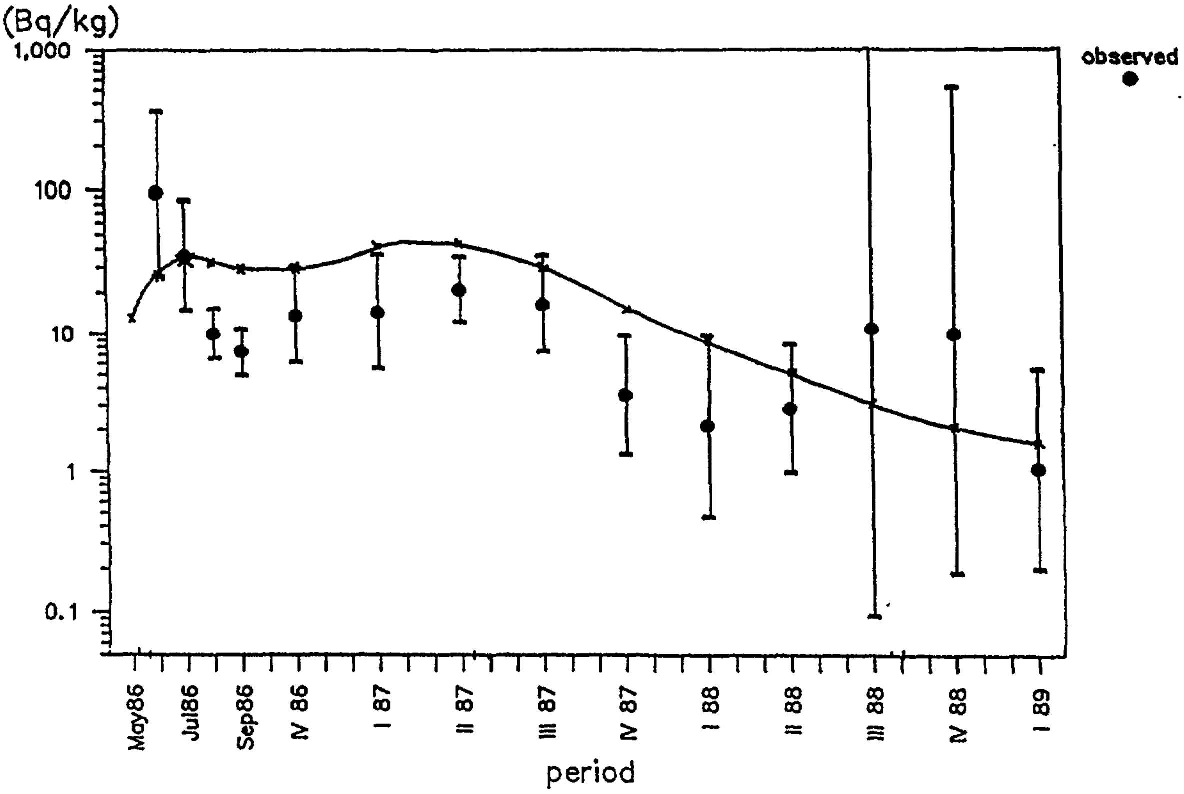

FIG. 6. Cs-137 concentrations in beef.

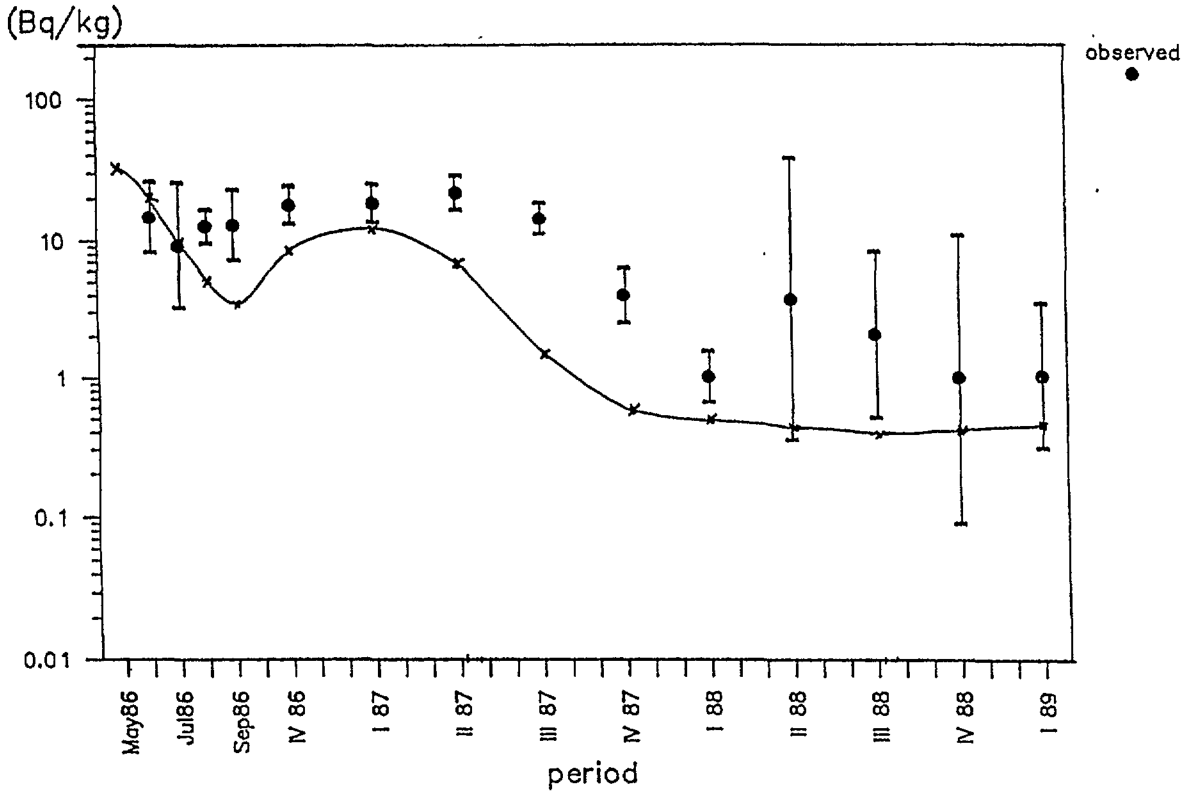

FIG. 7. Cs-137 concentrations in pork.

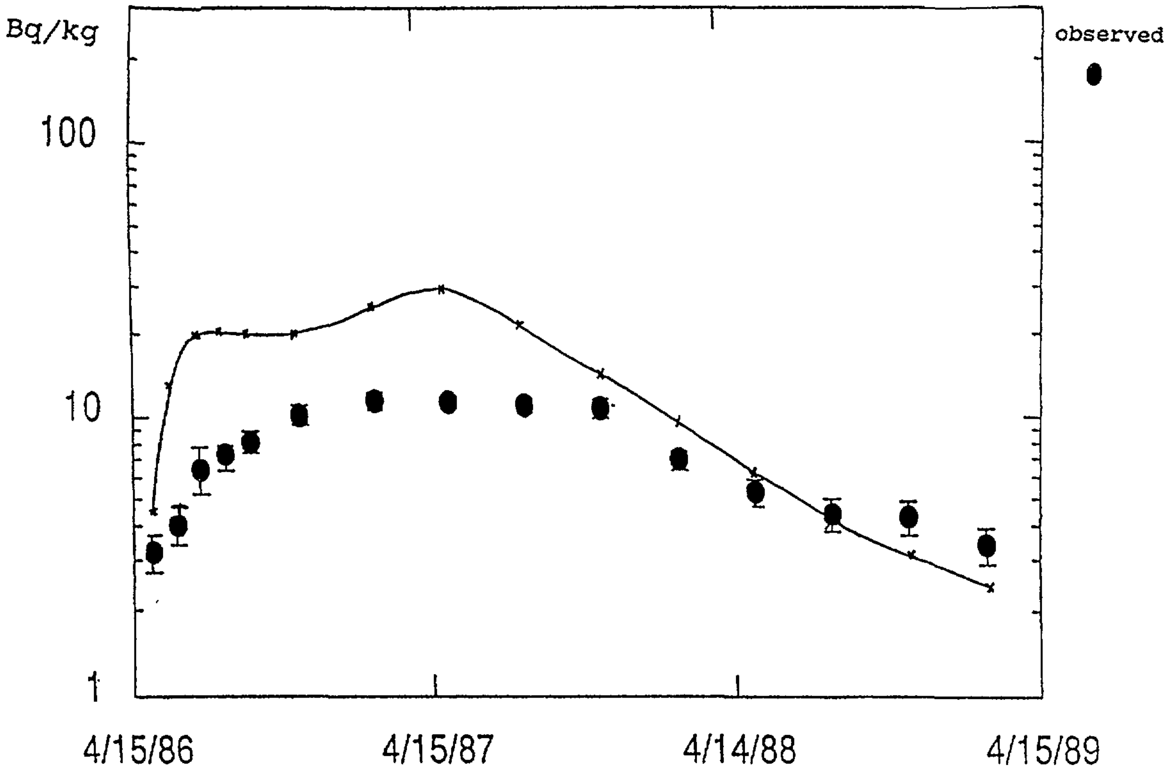

FIG. 8. Cs-137 concentrations in whole-body.

2. The daily quantities said to be fed to cattle are questionnable. Thus cows were fed more than 18 kg dry matter a day and this corresponded to a production of 10 liters of milk whereas, in Belgium, a cow fed daily with an average of 15 kg dry matter produces 20 (or more) liters of milk.
   This suggests that the daily feeding quantities indicated in the scenario description are too high.

5. CONCLUSIONS

When the initial model predictions were compared to the observations, important discrepancies in both magnitudes of the concentrations in several compartments and in their dynamic responses were noted.

Careful analysis of the agricultural practices assumed together with supplementary information about these practices which were submitted later, led to changes in the model and to results in better agreement with the observations.

For beef contamination, a comparison of predicted and observed concentrations in time showed the dynamic response of the model to be poor. This part of DOSDIM will have to be reviewed.
Although modelling pork contamination was not initially included in DOSDIM, an equilibrium model was designed for the sake of participating in the CB-scenario.

The exercise showed that further improvements can be made to DOSDIM, e.g. wet and dry deposition should be treated separately with different retentions, based on LAI. Growth dilution should also be taken into account. In addition, site-specific information must be fed into the model, such as deposition parameters, transfer factors, ...
Finally an uncertainty estimate is necessary in order to be able to quantify the confidence in the model results.

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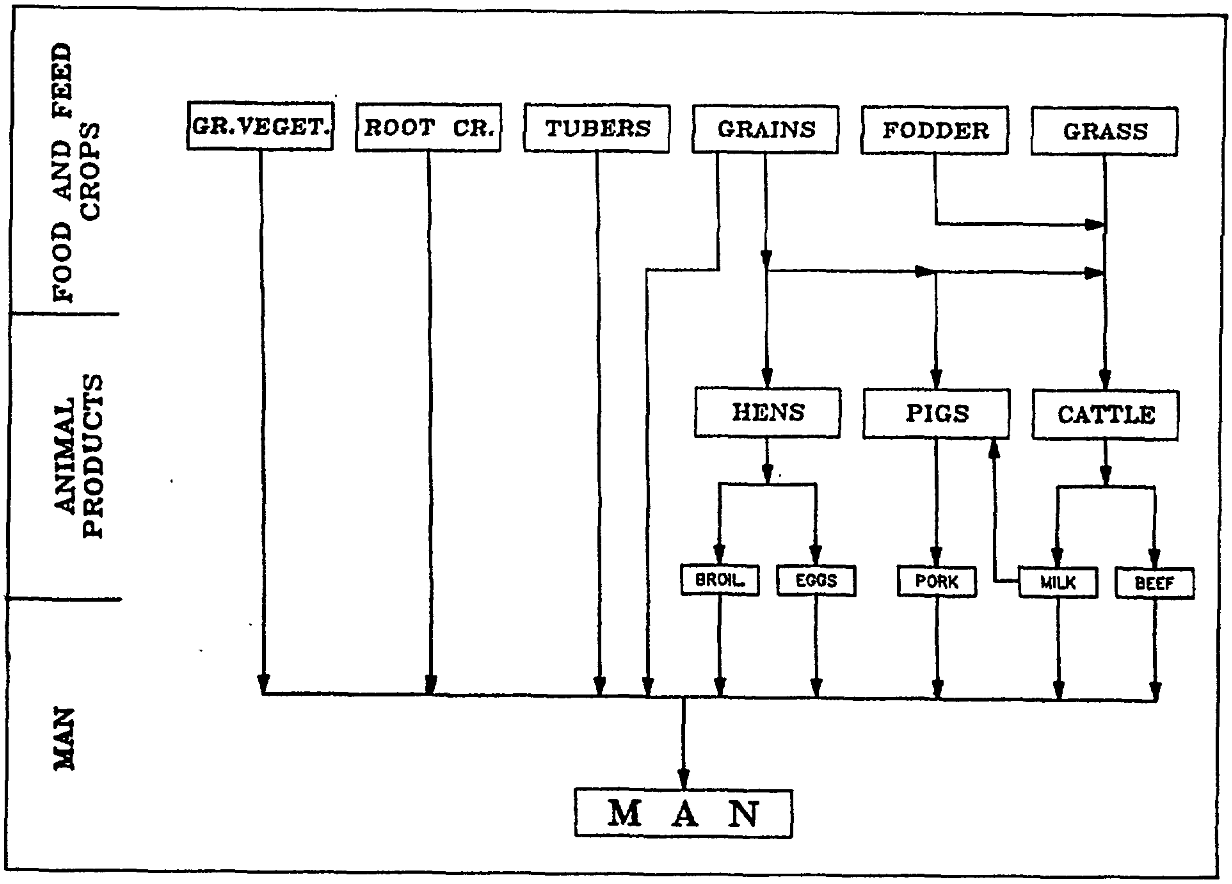
[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook of parameter values for the prediction of radionuclide transfer in the terrestrial and freshwater environments, 2nd Draft, IAEA - 6381W - 1987/03/18 - March 1987.

[3] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Age-dependent doses to members of the public from intake of radionuclides, Annals of the ICRP, Vol. 20 - N° 2 (Publication N° 56 - 1989 - Pergamon Press, Oxford.

Annex 1


FOOD AND FEED CROPS
ANIMAL PRODUCTS
MAN
GR.VEGET.
ROOT CR.
TUBERS
GRAINS
FODDER
GRASS
HENS
PIGS
CATTLE
BROIL.
EGGS
PORK
MILK
BEEF
M A N

III.2. CHERPAC

1. EVALUATION OF CHERPAC PERFORMANCE FOR CB SCENARIO

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2. GENERAL MODEL DESCRIPTION

2.1 The version of CHERPAC (Chalk River Environmental Research Pathways Analysis Code) used in the CB Scenario was developed by P.J. Barry and S-R. Peterson. CHERPAC is still under development. The user is now S-R. Peterson.

2.2 The structure of CHERPAC loosely follows that of the Canadian Standards Association Standard N288.1-M87 (Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities, 1987). It is a time-dependent model that uses inputs of daily air concentrations to calculate average monthly concentrations in the different food chain compartments contributing to ingestion dose. Dose from inhalation and external irradiation from the plume and surfaces are also calculated.

2.3 When completed, CHERPAC will be able to assess dose to the population from routine and accidental releases to the atmosphere and bodies of water.

2.4 Intended accuracy of predictions is to within a factor of 10.

2.5 Uncertainty in the output is estimated statistically using Latin Hypercube Sampling for all parameters.

2.6 The model is presented elsewhere in this document.

3. INITIAL COMPARISON OF TEST DATA AND MODEL PREDICTIONS

The CHERPAC code is still being developed, and although most deadlines for this model validation study have been met, quality-controlled predictions lag behind. Thus the submitted predictions changed during the course of the study. A summary of predictions is shown in Table I.

The original submission of best estimates only (I) met the first deadline. The following changes were made in the second submission (II):

- The estimate of total deposition was lowered from 8000 $Bq\cdot m^{-2}$ to 6500 $Bq\cdot m^{-2}$ because the dry deposition velocity used in CHERPAC is for pasture vegetation and we had been asked to calculate deposition to bare ground. The dry deposition to vegetation was calculated to be 3000 $Bq\cdot m^{-2}$; deposition to bare ground would be about half this value (1500 $Bq\cdot m^{-2}$) and so total deposition was reduced to 6500 $Bq\cdot m^{-2}$.

- The pork model was revised to give an effective steady-state transfer factor from feed to pork of 0.3 rather than the original value of 1.6, which was unrealistically high.

Table I. Summary of all submitted predictions for CHERPAC
Combine Best Estimate III and Uncertainty II for representative results

Date submitted		91 Mar	91 Aug	92 Jan	1992 January		1992 February	
		Best Estimates			1	Uncertainty	11	
		I	II	III	0.025	0.975	0.025	0.975
Deposition (Bq/m2)		8000	6500	6500	820	18000	1100	35000
Leafy Vegs (Bq/kg)	Jun 86	5.5	5.5	7	0.45	38	1.4	100
	Jul 86	6.7	6.7	9.5	0.24	56	1.9	130
	Aug 86	6.9	6.9	10	0.47	53	2	130
	Sep 86	6.9	6.9	10	0.85	38	2	130
	II 87	4.8	4.8	7	0.34	29	1.6	84
	III 87	0.45	0.45	0.65	0.027	1.8	0.12	9.2
	II 88	0.44	0.44	0.65	0.038	3.2	0.11	7.7
	III 88	0.44	0.44	0.64	0.029	2.8	0.12	9
W. Wheat (Bq/kg)	Harv 86	11	11	24	1.8	97	1.4	290
	Harv 87	0.51	0.51	0.86	0.047	4.4	0.055	8.6
	Harv 88	0.5	0.5	0.84	0.051	3	0.052	8.4
Fruit (Bq/kg)	Harv 86	24	24	45	2	186	7.9	525
	Harv 87	12	12	22	1.3	77	3.7	250
	Harv 88	7.7	7.7	14	0.47	63	2.4	160
Milk (Bq/L)	May 86	140	140	370	23	3000	62	3000
	Jun 86	85	85	210	6.3	2000	18	1800
	Jul 86	21	21	50	0.71	820	2.9	660
	Aug 86	5.8	5.8	12	0.11	130	0.8	140
	Sep 86	2.6	2.6	4.4	0.15	140	0.24	38
	IV 86	3.7	3.7	7.1	0.086	55	0.49	69
	I 87	4.8	4.8	9.9	0.3	190	0.73	97
	II 87	2.5	2.5	2	0.13	24	0.19	23
	III 87	1	1	1.5	0.074	8.7	0.22	23
	IV 87	0.9	0.9	1.2	0.07	5.4	0.17	18
	I 88	0.83	0.83	1.1	0.046	10	0.14	17
	II 88	0.66	0.66	0.73	0.043	4.6	0.1	12
	III 88	0.54	0.54	0.7	0.033	4.5	0.1	12
	IV 88	0.54	0.54	0.7	0.041	3	0.1	12
	I 89	0.54	0.54	0.7	0.038	4.2	0.1	12
Beef (Bq/kg)	May 86	210	210	570	26	4300	68	6900
	Jun 86	320	320	810	24	6100	82	10000
	Jul 86	170	170	440	6.7	7200	35	5700
	Aug 86	76	76	190	6.2	2700	14	2600
	Sep 86	33	33	76	2	2000	4.7	1000
	IV 86	14	14	30	1	370	1.8	450
	I 87	16	16	32	0.65	520	1.6	520
	II 87	11	11	13	0.51	110	0.95	220
	III 87	3.9	3.9	5.4	0.3	26	0.77	80
	IV 87	3.2	3.2	4.5	0.24	22	0.63	69
	I 88	2.7	2.7	3.6	0.1	20	0.34	63
	II 88	2.4	2.4	2.7	0.078	14	0.27	50
	III 88	1.8	1.8	2.3	0.07	15	0.23	43
	IV 88	1.8	1.8	2.3	0.068	13	0.24	44
	I 89	1.8	1.8	2.3	0.07	14	0.24	44

Table I. Summary of all submitted predictions for CHERPAC
Combine Best Estimate III and Uncertainty II for representative results

Date submitted		91 Mar	91 Aug	92 Jan	1992 January		1992 February	
		Best Estimates			1	Uncertainty	11	
		I	II	III	0.025	0.975	0.025	0.975
Pork (Bq/kg)	May 86	100	20	54	3.5	420	9	440
	Jun 86	150	29	75	2.7	640	11	600
	Jul 86	130	27	69	2.5	690	9.4	590
	Aug 86	120	23	58	6.3	470	7.4	540
	Sep 86	97	19	49	3.6	670	6	470
	IV 86	52	10	24	0.71	170	2.7	220
	I 87	33	6.5	13	1.1	140	1.5	130
	II 87	34	6.8	13	0.95	99	1.4	130
	III 87	29	5.7	11	1.2	48	1.2	110
	IV 87	19	3.8	7.1	0.4	28	0.7	71
	I 88	5.9	1.2	2	0.22	12	0.28	24
	II 88	3.2	0.64	0.88	0.072	4.8	0.14	11
	III 88	2.8	0.54	0.77	0.068	3.6	0.13	11
	IV 88	2.6	0.52	0.75	0.075	3.2	0.13	11
	I 89	2.5	0.52	0.74	0.077	3.9	0.13	11
Pasture (Bq/kg fw)	May 86	1000	1000	3100	260	20000	330	11000
	Jun 86	290	290	740	32	6900	49	4200
	Jul 86	65	65	170	2.2	4000	9.4	1300
	May 87	2.5	2.5	5.3	0.34	46	0.73	73
	Jul 87	2.4	2.4	5.2	0.12	21	0.86	79
	May 88	1.5	1.5	3.4	0.24	12	0.59	51
	Jul 88	1.5	1.5	3.4	0.26	20	0.59	51
S. Barley (Bq/kg)	Har 86	7.7	7.7	15	1.1	61	0.9	180
	Har 87	0.5	0.5	1	0.055	5.1	0.064	10
	Har 88	0.49	0.49	1	0.061	3.6	0.062	10
Hmn Intake (Bq/kg)	May 86	110	83	260	16	2100	45	2000
	Jun 86	94	66	190	6.3	1700	20	1500
	Jul 86	42	25	74	1.4	1100	8.9	700
	Aug 86	30	18	47	3.9	340	7.4	300
	Sep 86	23	12	34	3.8	700	5.9	240
	IV 86	19	10	29	2	160	4.7	220
	I 87	19	11	30	2.8	370	4.6	240
	II 87	16	8.6	22	2.6	120	3.2	190
	III 87	10	4.1	11	1.4	52	1.8	100
	IV 87	6.3	2.6	6.9	0.75	27	1.1	50
	I 88	3.7	2.2	5.3	0.77	38	0.91	33
	II 88	3.1	1.9	4.6	0.61	19	0.82	32
	III 88	2.5	1.6	3.9	0.47	16	0.67	25
	IV 88	2.3	1.4	3.5	0.45	12	0.61	22
	I 89	2.3	1.4	3.5	0.39	15	0.61	23

Table I. Summary of all submitted predictions for CHERPAC
Combine Best Estimate III and Uncertainty II for representative results

Date submitted		91 Mar	91 Aug	92 Jan	1992 January		1992 February	
			Best Estimates		1	Uncertainty	11	
		I	II	III	0.025	0.975	0.025	0.975
Bod Burd (Bq/kg)	May 86	37	23	60	3.6	480	14	520
	Jun 86	73	50	138	6.5	970	29	1200
	Jul 86	83	56	161	6.2	1500	26	1300
	Aug 86	79	52	151	20	1300	25	1200
	Sep 86	73	46	133	11	1700	24	1100
	IV 86	59	37	104	6	650	19	800
	I 87	46	28	78	6.9	1100	14	580
	II 87	39	23	63	3.8	370	11	450
	III 87	31	17	46	3.4	400	7.1	390
	IV 87	22	11	30	2.3	230	3.9	230
	I 88	15	7.6	20	1.7	120	2.1	140
	II 88	10	5.7	15	1.2	120	2.1	110
	III 88	7.6	4.4	11	0.85	51	1.2	79
	IV 88	5.9	3.5	8.6	0.65	54	0.95	61
	I 89	5	3.1	7.5	0.43	30	0.86	54
Cloud Dose (mSv)		0.000034	0.000034	0.000034	0.000019	0.000058	0.000019	0.000048
Ext. Dose (mSv)	-April 87	0.024	0.024	0.024	0.0036	0.095	0.0066	0.13
	-April 88	0.036	0.036	0.036	0.0048	0.11	0.0098	0.2
	-April 89	0.041	0.041	0.041	0.0045	0.14	0.011	0.23
	lifetime	0.056	0.056	0.056	0.0056	0.2	Not Calcul	Not Calcul
Inhal. Dose (mSv)		0.02	0.01	0.0055	0.0028	0.0091	0.0031	0.0078
Ingest. Dose (mSv)	-April 87	0.2	0.13	0.31	0.033	1.7	0.047	2.1
	-April 88	0.29	0.19	0.42	0.042	2.3	0.071	2.6
	-April 89	0.31	0.21	0.45	0.023	2.6	0.077	2.8
	lifetime	0.47	0.31	0.79	Not Calcul	Not Calcul	Not Calcul	Not Calcul
				92 May				
	fratile							
CCDF for II 1987	97.5			39			Not Calcul	Not Calcul
	90			46			15	890
	50			81			28	1600
	10			110			40	2200
	2.5			120			Not Calcul	Not Calcul
	fratile							
CCDF for I 1989	97.5			5.0			Not Calcul	Not Calcul
	90			6.0			1.9	81
	50			10			3.4	140
	10			17			6.0	210
	2.5			20			Not Calcul	Not Calcul

- The human diet was revised downwards to about 2600 kcal·d^{-1} from the original diet estimated from food production data provided in the input scenario description.
- The inhalation rate was reduced by about a factor of 2 to 23 m^3·d^{-1}. A rate for an extremely active individual was used as a daily average in the original submission.

The third submission (III), along with uncertainty estimates based on random sampling (I), met the final deadline for results, but uncertainty estimates using Latin Hypercube Sampling and revised distributions of parameter values (II) were completed within a month. It is this third submission (III) with its uncertainty estimates (II) that represents the true performance of CHERPAC. The agreement between the "improved" predictions and the observations was not as good, showing that corrections were made independently of the observations. The changes that were made for submission III were:

- To calculate potential deposition from 1 April rather than from 1 May, as in Submission II. This change had a profound effect on the predictions, since air concentrations were highest on 30 April.
- To calculate 100% wet deposition to soil in which leafy vegetables, etc. grew instead of the 10% calculated in Submission II.

The best estimates (submission III) do not change when different methods for estimating uncertainty are used because the best estimates are not the means of the uncertainty estimates: they are the outcome of a single run using a best estimate for each parameter value. The predictions of CHERPAC that will be discussed in the rest of this paper will be best estimates III and uncertainty II.

3.1 Total Deposition

The prediction for total deposition to bare soil was 6500 Bq·m^{-2}, giving a P/O (predicted to observed) ratio of 1.2 and falling well within the 95% confidence interval on the observations. The dry and wet deposition velocities used were those calibrated across all sites in the BIOMOVS Chernobyl scenario (BIOMOVS Technical Report 13, 1991). The integral air concentration used was 28.1 Bq d·m^{-3} which may be as much as a factor of 2 too high. If this were so, we might expect our prediction to fall as low as 3300 Bq·m^{-2}, which is below the lower bound of the observed confidence interval. Yet when the uncertainties in the predictions are taken into account, the predictions and observations would still agree.

3.2 Major Food Items Contributing to Total Diet

3.2.1 Milk

Eight out of 15 predictions at the prescribed times fall within a factor of 2.5[1] of the observations and in only 1 out of 15 do the confidence intervals of predictions and observations fail to overlap (Figure 1). The P/O ratios for the first three months are 16, 11 and 5.6. The uncertainties estimated by CHERPAC (a factor of somewhat more than 10 on either side of the mean) are large. The general trend is predicted well.

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[1] Factors of 2, 2.5 or 3 of the observations are sometimes considered to be a measure of good agreement between predictions and observations.

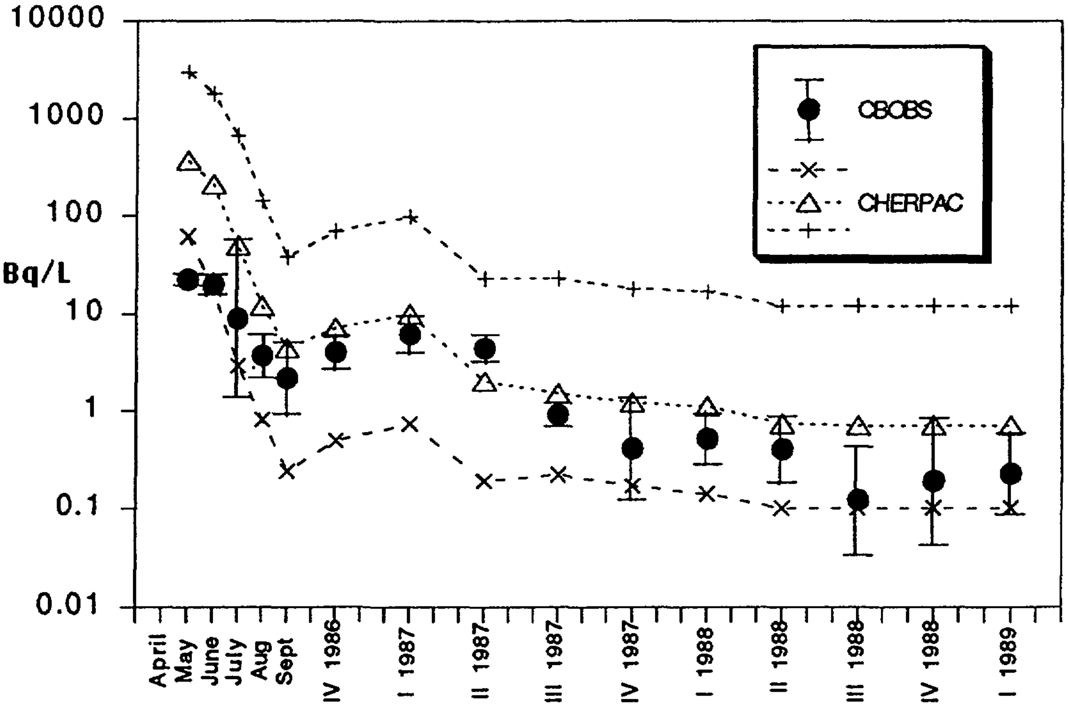

Figure 1. Comparison of observations and predictions for ^{137}Cs concentrations in milk; 95% confidence intervals are shown

3.2.2 Beef

Half of the predictions fall within a factor of 2.5 of the observations, while all of the confidence intervals of predictions and observations overlap (Figure 2) due mostly to large uncertainties (about a factor of 14 on either side of the mean) in the predictions. Predictions for June-September 1986 are high by factors of 8.5-19.

3.2.3 Pork

Due to uncertainty limits of a factor of 9 on either side of the predicted best estimates, all of the confidence intervals of predictions and observations overlap, while 9 of the 14 best estimates fall within a factor of 2 of the observations (Figure 3). As with milk and beef, the larger overpredictions are for May-September 1986 (factors of 3.8-7.5), but after the fourth quarter 1986 the predictions correlate well with the observations.

3.3 Other Items of Specific Interest

In analyzing how well predictions compare with observations for other foodstuffs, Irena Malatova suggested that observed data from adjacent Bohemia (B) be substituted for CB data for pasture vegetation and leafy vegetables. In addition, the geometric mean of the observations should be used instead of the arithmetic mean when many observations are below detection limits (which was the case in 1987 and 1988).

For 1986, the predictions for winter wheat and spring barley are good, with predicted to observed ratios of 1.7 and 0.77 respectively. However, only the predictions for barley fall within the confidence interval placed on

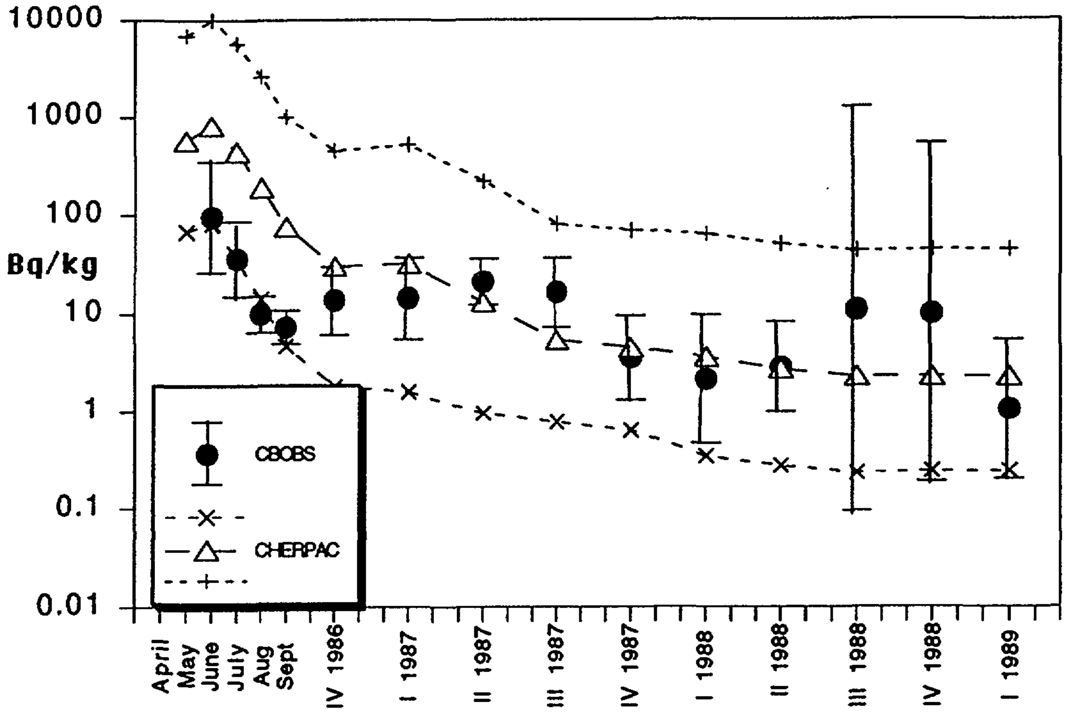

Figure 2. Comparison of observations and predictions for ^{137}Cs concentrations in beef; 95% confidence intervals are shown

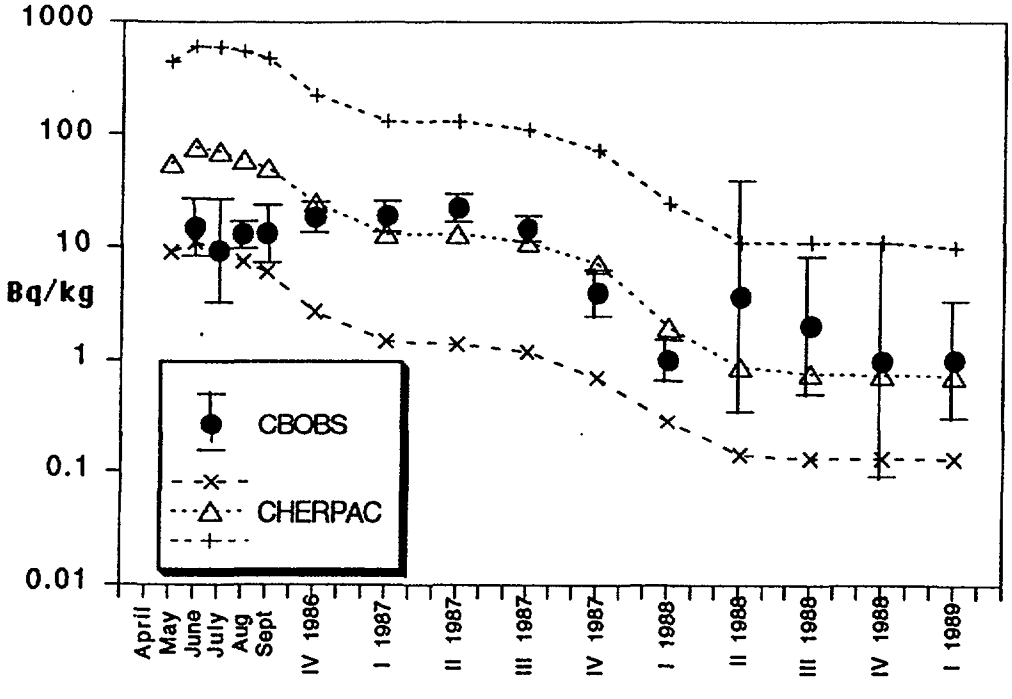

Figure 3. Comparison of observations and predictions for ^{137}Cs concentrations in pork; 95% confidence intervals are shown

the observations. The concentration in pasture vegetation is over-predicted for both May and June by factors ranging from 1.9 to 4.5, whether the data for CB or B are used for comparison, and all predictions fall outside the observed confidence intervals. The concentrations in leafy vegetables are drastically under-estimated by CHERPAC (P/O ~0.05), but concentrations in fruit, although outside the confidence interval on the observations, are predicted to be within a factor of 1.7 of the

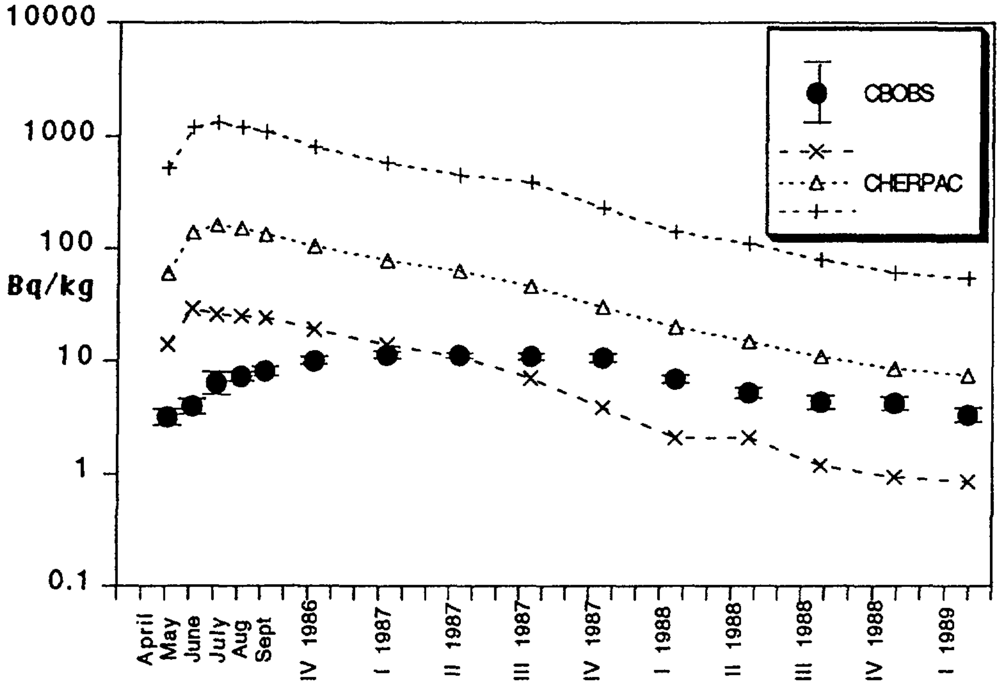

Figure 4. Comparison of observations and predictions for ^{137}Cs body burden; 95% confidence intervals are shown

observations. The confidence intervals on the predictions for all the items above are large and overlap with those on the observations.

The predictions for 1987 and 1988 are in general higher than the observations and fall outside the confidence interval. Yet with both observed geometric and arithmetic means and data from both B and CB available for the analysis, the predictions can be made to look either better or worse depending on the comparison made. Also, the predicted and observed confidence intervals overlap.

3.4 Whole Body Concentrations

3.4.1 Mean Whole Body Concentrations

Predictions for body burden do not reflect the observations until the fourth quarter of 1987, after which all predictions are within a factor of 3 of the observations. In the months May-September 1986, the P/O ratios vary from 16 to 36 (Figure 4). This is consistent with an overprediction of intake by a factor of 25 for 6 June-14 July 1986. The observed values for the first year are below the predicted lower limit of uncertainty, which indicates a major misprediction since the confidence interval on predictions lies within a factor of about 7 from the mean. Furthermore, the shape of the predicted curve is different from the observed until the fourth quarter of 1987.

3.4.2 Distribution of Whole Body Concentrations

The probability of an individual having a certain body burden was calculated by varying those parameter values which directly contribute to body burden (e.g. inhalation rate, ingestion rates, occupancy factors, body weight, rate of loss from the body) while keeping all others at their best estimated values. The uncertainty about the individual body burden was then calculated by using selected combinations of parameter values directly contributing to body burden while varying all the remaining parameter values according to their distributions. Predicted results are higher than the observations by a factor of 7.5 for the second quarter of 1987 (II 1987, Figure 5) and a factor of 3.5 for the first quarter of 1989 (I 1989, Figure 6). The distribution of the values around the basic

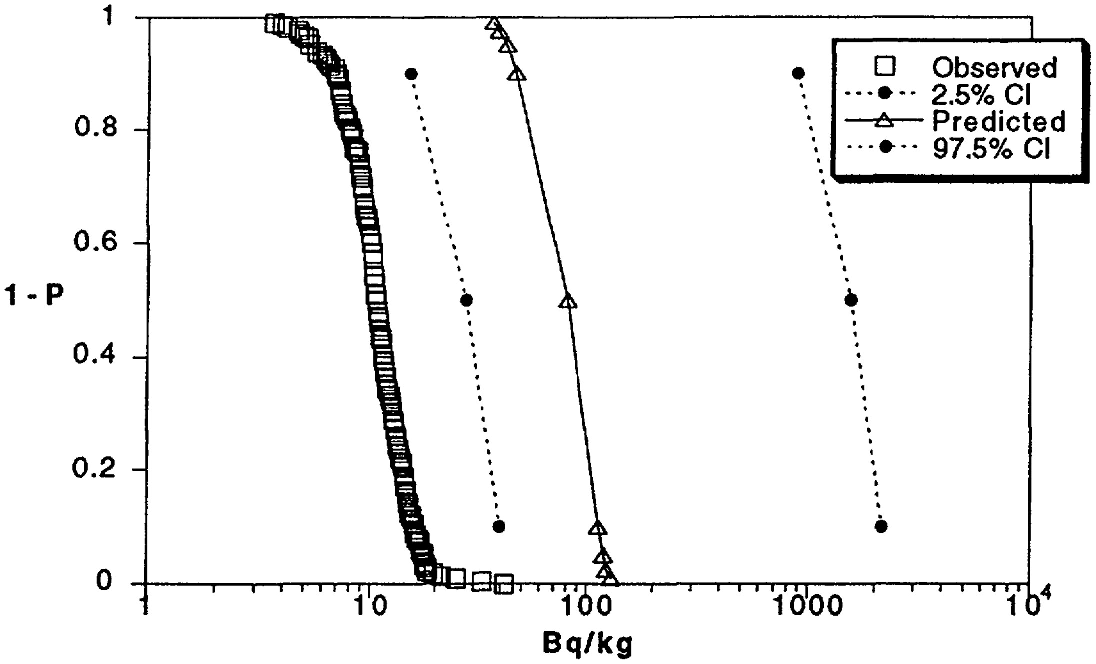

Figure 5. Complementary Cumulative Distribution Function of ^{137}Cs body burden for the second quarter of 1987; predictions and the 95% confidence interval are constrasted with observations

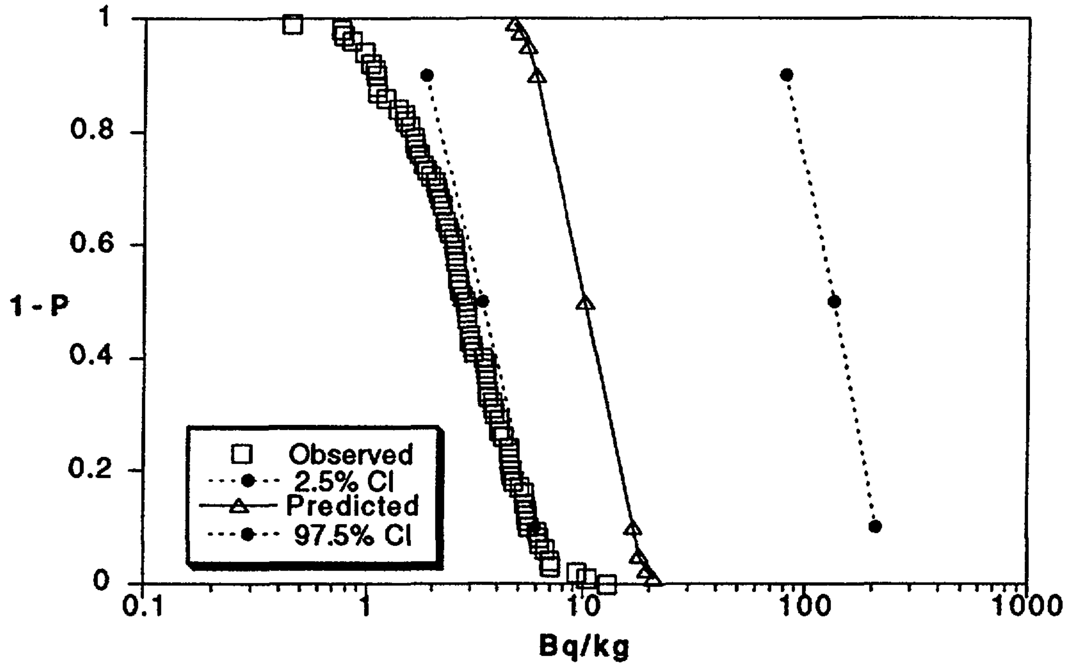

Figure 6. Complementary Cumulative Distribution Function of ^{137}Cs body burden for the first quarter of 1989; predictions and the 95% confidence interval are oontrasted with observations

predicted curve is positively skewed due to the assumed lognormal distribution of many parameters. For II 1987, the 2.5 percentile is more than a factor of 2 higher than the observations, but for I 1989, the 2.5 percentile mostly matches the observations. The predicted body burden curve is parallel to the observed one except at the extremes of the distribution function. This implies that a simple factor could be used to calibrate the model: for example, if food contamination were reduced uniformly, the predicted results would match the observed.

4. EXPLANATION OF MAJOR SOURCES OF MISPREDICATION

The factor of 25 underprediction in leafy vegetables for 1986 is due to having neglected deposition onto growing vegetables. We wrongly assumed that no vegetables would be above ground because it was too early in the year and that the only contamination pathway would have been root uptake. Fruit trees also received direct deposition of fallout to their leaves, so it is purely fortuitous that our predictions for fruit (based on root uptake alone) in 1986 are quite good.

Winter wheat and Spring barley are modelled identically except for harvest date. A small shift in the harvest date for Winter wheat would result in perfect predictions.

The overpredictions for pasture vegetation (i.e. the lawn at the Institute) for May and June 1986 are reduced by about 15 and 30% respectively if the monitoring data for May and June 1986 are adjusted to account for each entire month rather than partial months (May 10-31 and June 1-19). Since our prediction for deposition was good and since CHERPAC had been calibrated for deposition to pasture vegetation using the BIOMOVS Chernobyl data, it is probable that this overprediction is due to using a figure for productivity that is unrealistically low. The figure used (0.543 kg fresh weight$\cdot$m^{-2}) was calculated from the CB production data provided in the scenario description and accepted at face value.

High initial predictions for milk, beef and pork are due in part to overprediction of concentrations in pasture vegetation. They may also be due to modelled feeding regimes being different from actual ones. The feeding information for dairy cows provided in the scenario description for CB was used in CHERPAC. However, careful examination of the data shows that most dairies apparently restricted the feeding of contaminated fodder much more than had been indicated in the scenario description. Actual intakes of radionuclides for May could be low by as much as a factor of 5. If this were so, predictions for May would only be high by a factor of 3. The effect of higher intake of contaminated food would be carried through the first few months. The overprediction of milk in the last two years may be due to overprediction of concentrations in grain and probably pasture vegetation due to high concentration ratios.

In CHERPAC, the diet for beef cows is modelled similarly to that of dairy cows, and it is assumed that both types are on pasture during the summer months (April to October). However, Czechoslovakian beef cattle are not normally allowed out on pasture. Thus their intake of contaminated food is restricted to harvested vegetation, which they receive later than if they had been on pasture. This may explain part of our overprediction for beef.

Initial overpredictions for pork are due to the high concentrations in milk, since in CHERPAC only the milk portion of the diet is assumed to be contaminated until grain is harvested in August.

Finally, although body burden was greatly overpredicted, the real concern is that the shape of the curve for predicted body burden is so different from that observed (Figure 4). The overprediction is caused simply by the predicted diet being much more contaminated than that observed due to nearly consistent overpredictions of concentrations in foodstuffs. The difference in time of the body burden peak is due to CHERPAC's assumption that the CB population ate only contaminated food from the outset. A proportion of uncontaminated food in the early diet due to consumption of stored food would shift the body burden peak more in line with that observed, even though the magnitude of overprediction will not change particularly since decay of ^{137}Cs is negligible.

4.1 Recommendations for Changes to the Model

Deposition to vegetables and fruit trees must be added, and a realistic delay in consumption of foodstuffs after harvest should be introduced.

4.2 Examples of How Changes Improve Calculations

Changes to assumptions had significant effects on predictions, as can be seen in Figures 7-10. In each figure, "Original" refers to the predictions comparable to those in Figures 1-4. There is a significant difference between these two sets of predictions, however: those for Figures 1-4 are results averaged over all of CB, as requested in the scenario description, while those for Figures 5-8 are for site AB alone. These predictions are higher than the ones averaged for CB because of the higher rainfall at AB. Comparing model results for one site is quicker than handling data from all sites and the results are as valid, but the difference between AB data and CB averaged data should be clear.

The results labelled "Airfeed" in Figures 7-10 were obtained by assuming that the daily air concentration was 75% of its original value (to fall in

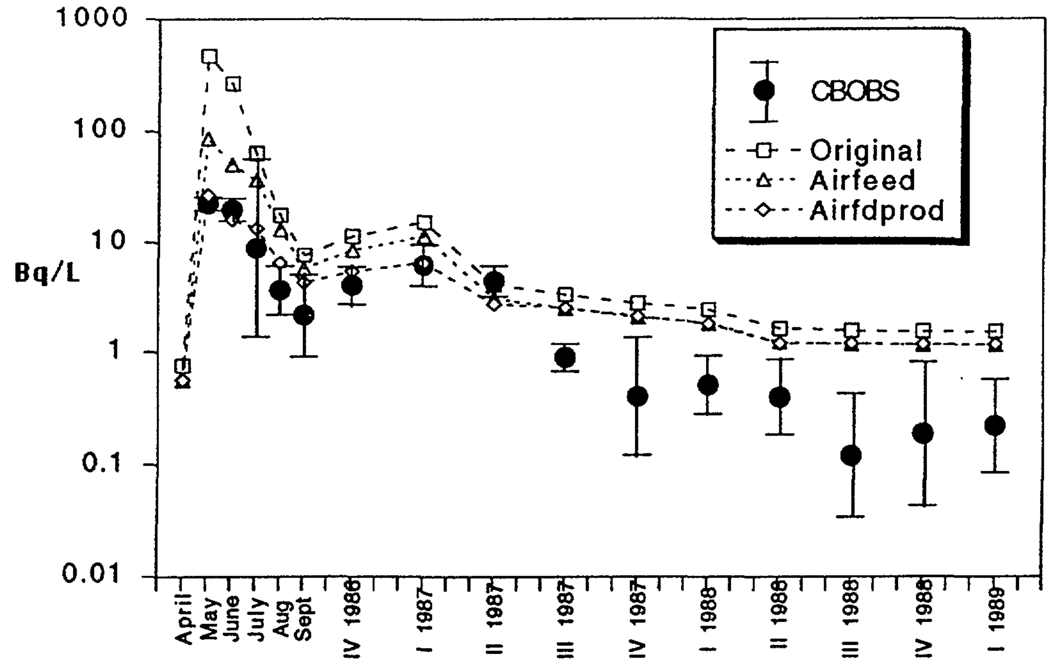

Figure 7. Comparison of observations and predictions for ^{137}Cs concentrations in milk; the submitted best estimate prediction is contrasted with predictions resulting from changed assumptions about site-specific input data

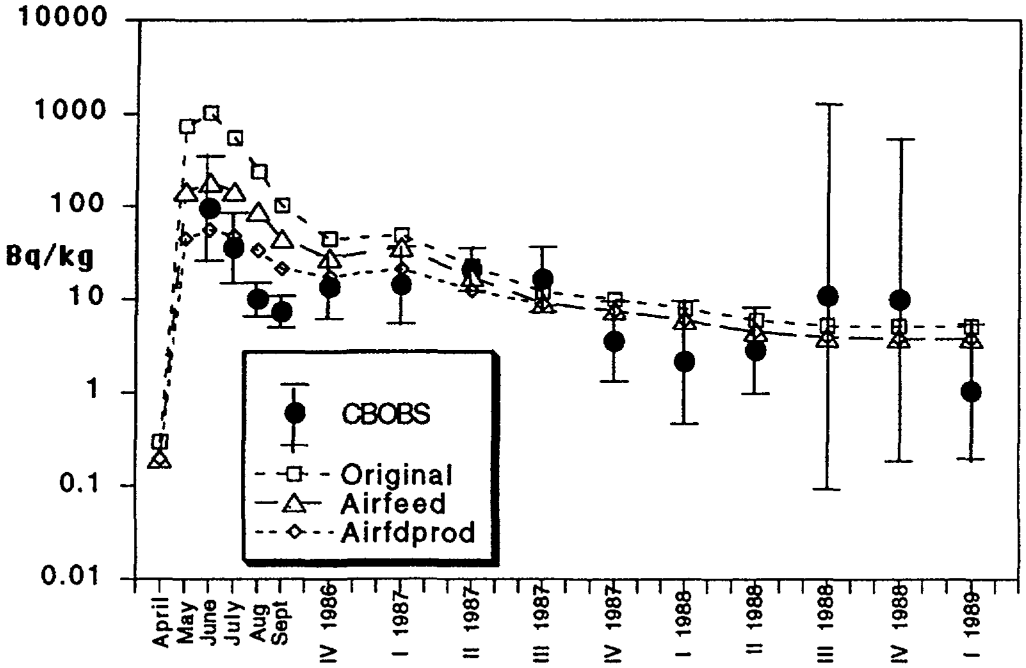

Figure 8. Comparison of observations and predictions for ^{137}Cs concentrations in beef; the submitted best estimate prediction is contrasted with predictions resulting from changed assumptions about site-specific input data

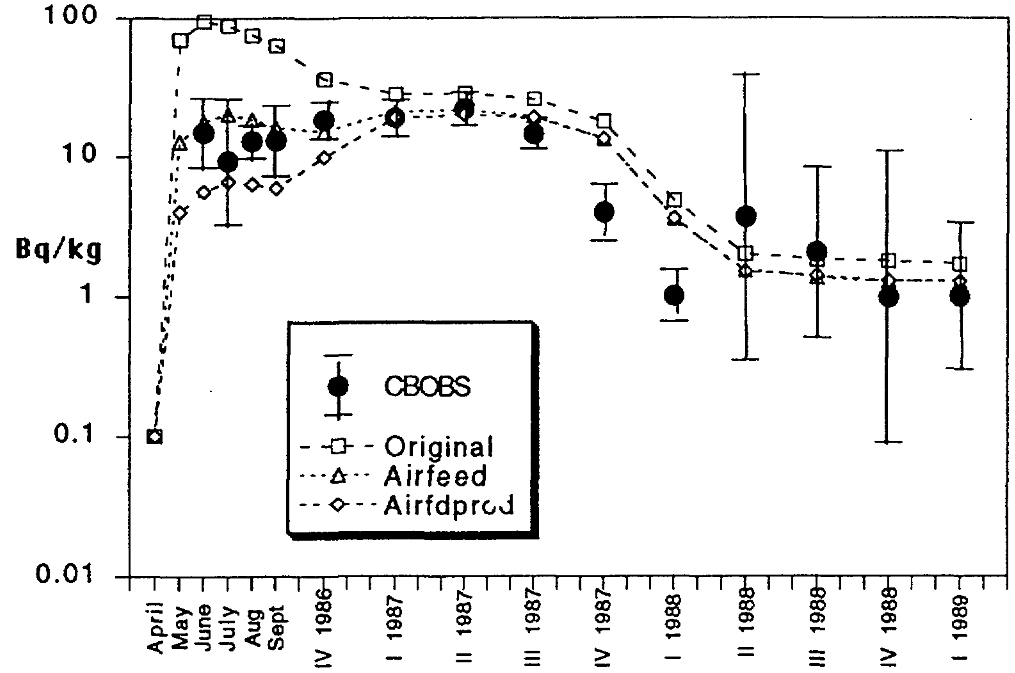

Figure 9. Comparison of observations and predictions for ^{137}Cs concentrations in pork; the submitted best estimate prediction is contrasted with predictions resulting from changed assumptions about site-specific input data

line with the best estimate of Heinz Mueller, in "Documentation of Input and Observation Data Used in Scenario CB") and that intake of contaminated pasture comprised only 15% of the total diet for May and 30% of the total for June. The 25% reduction in air concentration will simply reduce all concentrations by 25%, but the change in the feeding regimes will affect the initial dynamic response of concentrations in milk, beef, pork and whole bodies. The improvement is striking in the predictions for pork

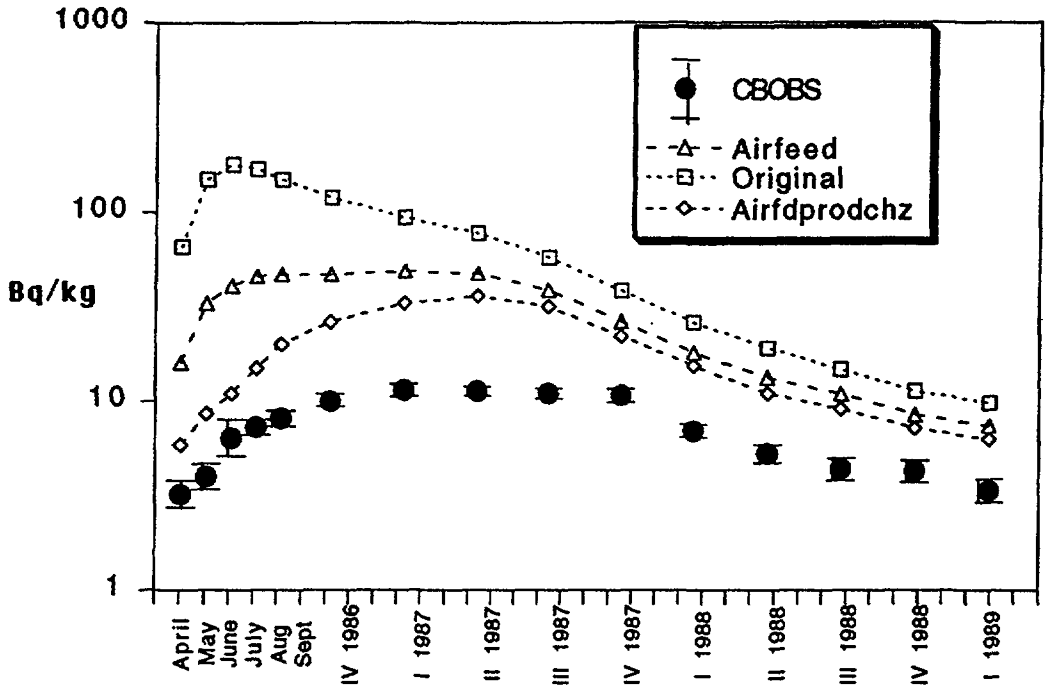

Figure 10. Comparison of observations and predictions for ^{137}Cs body burden; the submitted best estimate prediction is contrasted with predictions resulting from changed assumptions about site-specific input data

(Figure 9). Also, the body burden predictions are much improved (Figure 10).

In Figures 7, 8 and 9, "Airfdprod" refers to "Airfeed" plus an increase in pasture productivity from 0.543 to 1.8 kg fw·m^{-2}, which is the productivity necessary in CHERPAC to make predictions equal to observations of pasture vegetation. Increased productivity greatly improves the initial predictions for milk and beef, although the magnitude of the dip in observations in August and September is not reproduced. There is no effect on the predictions of the last two years since productivity is only important when converting from area to mass after deposition and is not considered in root uptake. These lower predictions of concentrations in milk mean that the initial predictions of concentrations in pork are lower than observations.

Finally, in Figure 10, "Airfdprodchz" adds a storage factor for cheese to "Airfdprod". The assumption is that 90% of all milk is made into cheese and is ingested after a year's storage. This is a gross and unrealistic assumption, but the resulting curve does resemble the observed, which suggests that a more realistic diet early on might be appropriate.

5. CONCLUSIONS

The CB scenario provided an excellent data set against which to compare many different predictions, especially body burden over time. It is still just one site, however, and since it is a site that seems to have anomalously low concentrations in food and body burden given the high air concentrations, lowering our various transfer parameters to achieve P/O ratios closer to unity does not seem justified, especially since the predicted/observed ratios are so variable with time that no linear correction is possible. As has been shown, with more knowledge of harvesting and feeding regimes we can better approximate the observations. These changes in assumptions have improved the dynamics of the first few months only: the dynamics of the last two years are reproduced quite well. No changes to the parameter values for Cs-137 transfer are contemplated for CHERPAC, since it is quite probable that the necessary corrections may be found in the parameter values and assumptions associated with the situation in CB. Introduction of a storage factor for human food would adjust the dynamics of our body burden predictions to be in line with the observations.

Our uncertainties are based on sampling from distributions of parameter values for most input, but they do not, for example, include uncertainty in the observed air concentrations or in the percentage of contaminated forage ingested by cows. They are large, particularly for milk and beef, over the first few months after the accident but they probably do not reflect our real uncertainty. In fact, having calibrated the air-forage-milk/beef pathways to the BIOMOVS Chernobyl scenario, we have high confidence in our best estimates for milk and beef for the first six months once uncertainties in air concentrations and cow intake are reduced. The real uncertainty may lie in the choice of and distributions of parameter values for uncertainty analysis. Presently they are global values from the literature, encompassing experimental, bomb fallout and Chernobyl values, and the distributions reflect the user's unfamiliarity with the data. Although it may be appropriate to restrict the parameter values to those observed for Chernobyl cesium world-wide, it is still important to use global values since, at the time the uncertainty was calculated, the identity of CB as Central Bohemia was unknown. An effort will be made to re-analyze the distributions for those parameters to which the model is very sensitive (at 6 months post-accident in descending order of importance: washout velocity, weathering loss rate, dry deposition velocity and productivity). Also, it is inappropriate to propogate through the model uncertainties based on large distributions for washout and dry deposition velocities, when measured deposition is supplied as input.

III.3. HUMOD

1. EVALUATION OF HUMOD MODEL'S PERFORMANCE FOR CB SCENARIO

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2. General model description

2.1. Name of model, model developer, model user.

The name of the model is HUMOD, this model was developped by Erbang Hu. The users are Erbang Hu, Xingzeng Liu, and Heyuan Zhang.

2.2. Unique features of model structure

HUMOD is a equilibrium compartmental model, which was developped to calculate for CB scenario. In the model, internal exposure due to inhalation and ingestion as well as the external exposure from the passing cloud and deposited ground activity are included. But the main part of the model is for simulation of ingestion pathway.

Only concentration factor or transfer coefficient are considered between each compartment. So the model is simple and easy to use.

2.3. Intended purpose of model in radiation assessment

HUMOD was developped from the model given in US、NRC Regulatory Guide 1.109, Which is used to assess the consequence of radioactivity routine releases. Here some modification was performed in order to suit for the accident situation.

2.4. Intended accuracy of the model prediction

We had not developped an assessment model for accident release before this Co-ordinate Research Programme. In this first model, some assumptions were arbitrarily made. We don't know its accuracy. But from the CB calculation, we can improve the model and perform some analysis about it (see section 4).

2. 5. Method used for deriving uncertainty estimates

LHS method was used to estimate the uncertainty of the model for calculation CB Scenario. Due to our lack of the knownlege about the ranges of so many input data and default parameters, our results may not represent the real situation and we did not submit the confidence bounds of each prediction endpoint.

3. Initial comparison of test data and model prediction

3. 1. Total deposition

The initial prediction of deposition we submitted is 4340 Bq. m^{-2}, But it's the value for bare soil surface activity in the end of 1988. In 1986 the value is 4900Bq. m^{-2}, which results a p/0 ratio of 0. 89.

From CB-Scenario and other analysis we know the concentration is high for input to calculate the endpoint value. If the model and parameters are appropriate the deposition should be an overestimate. Our model uses daily air concentration and daily rain as input. Only dry deposition is considered in the first few days when daily air concentration is high because no rain occures in the 14 stations. This may be different from the real situation.

3. 2. Major food items contributing to total diet

3. 2. 1. Milk

The predictions of milk in 1986 are compatible with the observed data, and in the other years are lagely overestimate (See Figure 1). In 1986, direct deposition contributed the most to the contamination of plant species; in the other years, root uptake play a more important role than the direct deposition. Due to an error of an input parameter, the root uptake is overestimated. The root uptake in the n-th day after contaimination can be expressed as in our model:

$$Cn_{(root)} = C_{(n-1)} \cdot e^{-\lambda r \Delta tn} + C_{soil} \quad Biv/Ps \qquad (1)$$

The parameter Biv should be a concentration factor related to the growth of the plant biomass. In the initial prediction we submitted a constant Biv was used.

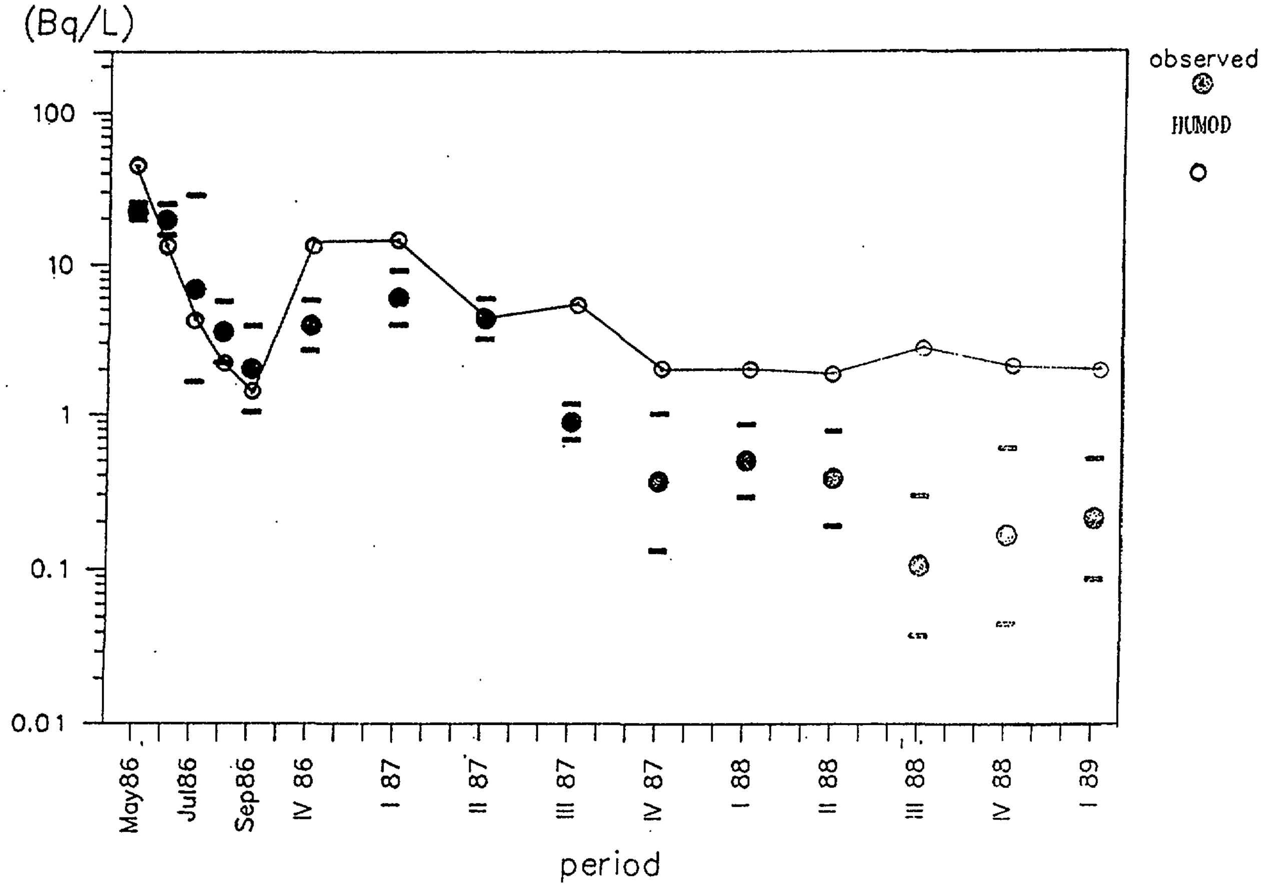

FIG. 1. Cs-137 concentrations in milk.

The high concentration in plant species causes the overestimate of concentration in animal products. If we use $(\frac{dy}{dt})_n/Ymax$ to multiply the second term of equ. (1) to modify the model and assume a constant growing rate of plant, the results will be better. Table 1 shows the initial predictions and the modified model prediction.

Another parameter causes the misprediction of contamination in plant species is the biological removal of Cs-137. In the first month, the Cs-137 half-life is appropriate to give a value of 14 days, but for the latter periods, it should be longer.

This was not included in our model, only a 14 days of half-life for weathering removal of Cs-137 from the plant was applied. This deviated results can be seen from our modified model prediction (see Table 1). In the initial prediction this was not seen due to the overestimate in the latter periods.

Tab—1 comparison prediction and observation data of milk

period	observation data	initial prediction result max(p/o, o/p)		modified model prediction result max(p/o,o/p)	
May 86	22.4	47.1	2.1	51.0	2.3
Jun 86	19.7	13.5	1.4	49.3	2.5
Jul 86	6.89	4.27	1.7	11.3	1.6
Aug 86	3.57	2.09	1.7	2.96	1.2
Sep 86	2.02	1.44	1.4	0.68	2.9
Ⅳ 86	3.94	14.0	3.6	1.70	2.3
Ⅰ 87	6.01	14.8	2.5	2.34	2.6
Ⅱ 87	4.33	5.23	1.2	1.57	2.8
Ⅲ 87	0.89	5.84	6.6	1.19	1.3
Ⅳ 87	0.36	2.77	7.7	0.49	1.4
Ⅰ 88	0.5	2.77	5.25	0.14	3.6
Ⅱ 88	0.38	2.58	6.8	1.23	1.6
Ⅲ 88	0.11	3.16	28.7	0.28	2.5
Ⅳ 88	0.16	2.68	16.6	0.09	1.8
Ⅰ 89	0.21	2.68	12.7	0.13	1.6

3.2.2. Beef

The model for beef is the same as for milk. only feed practice and transfer coeffcient are different. So the same deviation occured in our initial prediction(see Figure 2).

3.2.3. Pork

For pork, we assumed a unresonable feeding practice in the initial prediction, i. e. , contaminated food was used to feed the pig untill the fall of 1986. This caused serious underestimation of the results(see Figure 3).

3.3. Other items of specific interest

We followed the rule in Section 3.2 to modify the model. The results are as listrd in tsble 2.

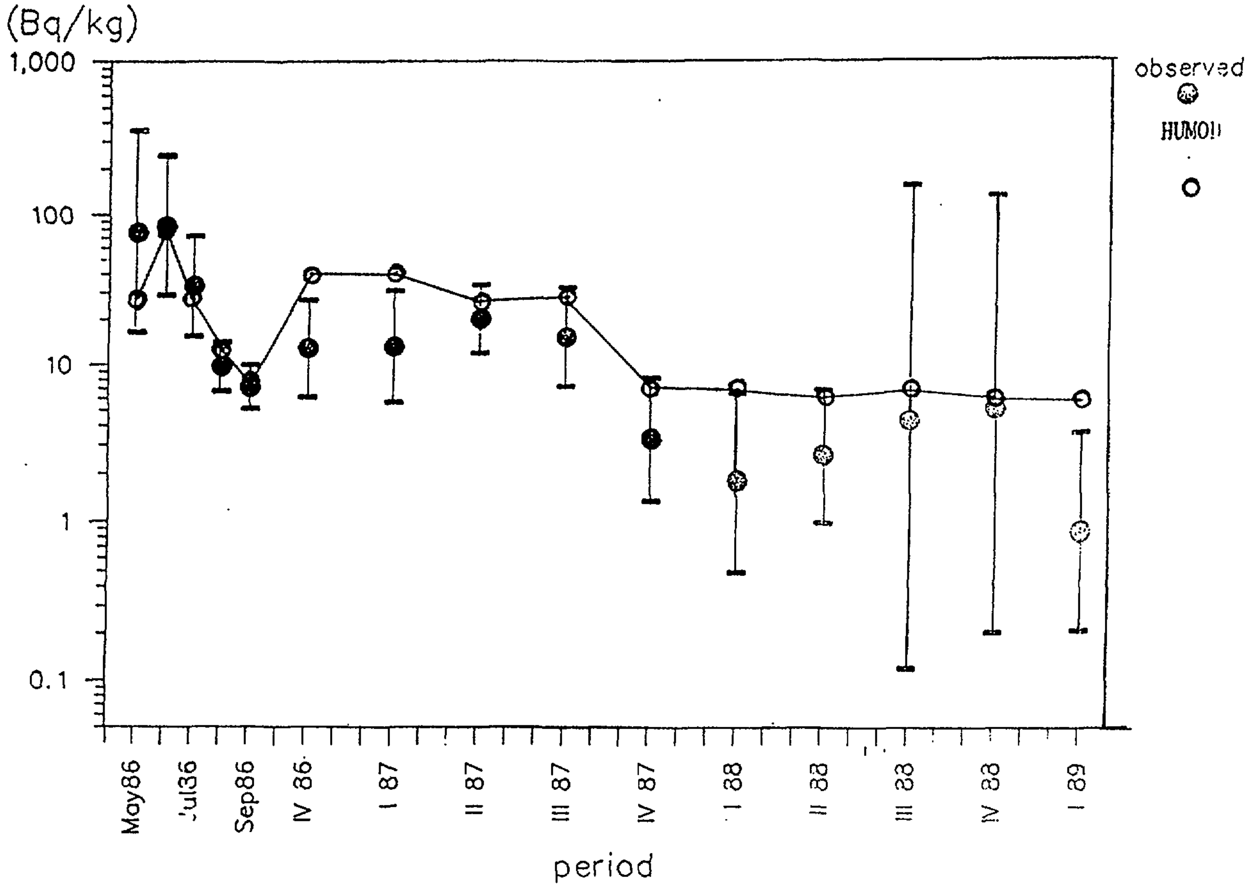

FIG. 2. Cs-137 concentrations in beef.

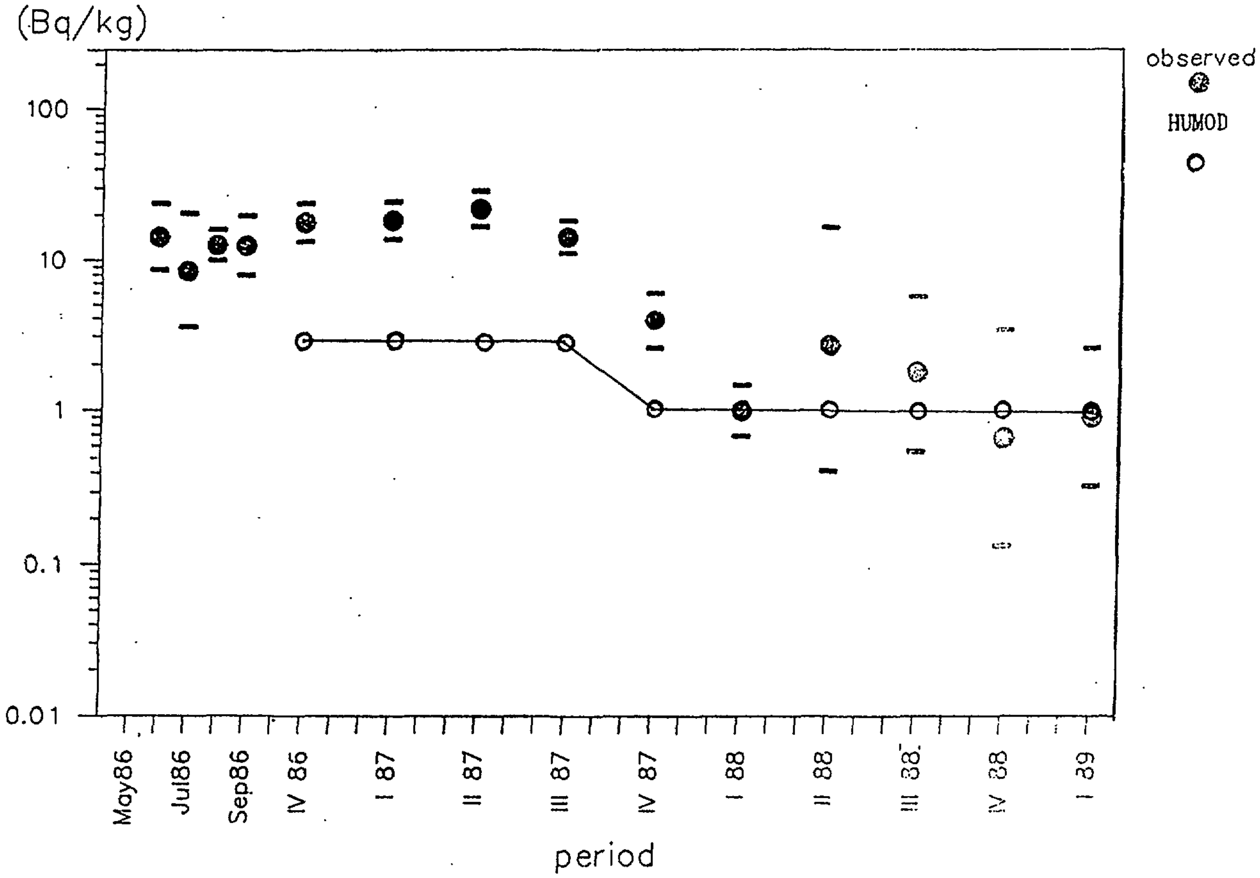

FIG. 3. Cs-137 concentrations in pork.

table 2

leafy	Veg.	prediction	max(p/o,o/p)
IV	86	3.24	1.05
	87	0.49	2.7
	88	0.43	2.3
wheat			
	86	23.3	1.75
	87	0.51	2.55
	88	0.44	2.10

3.4. whole body concentration

The whole body concentrations are grossly overestimated (see Figure 5). The p/0 ratio is in a factor of 4. We do not know the main source of misprediction, because so many food types are used, and maybe some types of food contribute to the contamination are not included, and maybe the quantity of some types of food deviate the reality.

4. Explanation of major sources of misprediction

The major sources of misprediction include (1) overestimation of plant root uptake, (2) weathering removal of Cs-137 from plants, and (3) true feeding practice for animals.

4.1. Recommandations for changes to the model

From description of section 3, it may be concluded that the following changes may improve the model performance:

a): Apply a more practical biological removal process.

b): Use a factor related to the growth of plant to simulate the root uptake;

c): Use more real feeding practice data.

4. 2. Examples of how changes improve calculations

If a factor related to the growth of plant is used to simulate the root uptake, the results for 1987 and 1988 will be better. After modified, we used the feeding practice provided by Mr. Hinton to calculate for the milk concentration. The results are given in Fig 4.

And the results show a fast decrease in the later period of 1986. This is due to the inappropriate biological removal assumption. If a half-life of 14 days is used for the first month and 30 days is used for the later periods, the underestimste will be eliminated.

5. Conclusion

This is the first time for us to calculate for off- site accident consequence. From participation in the co-ordinated research programme we learned a lot.

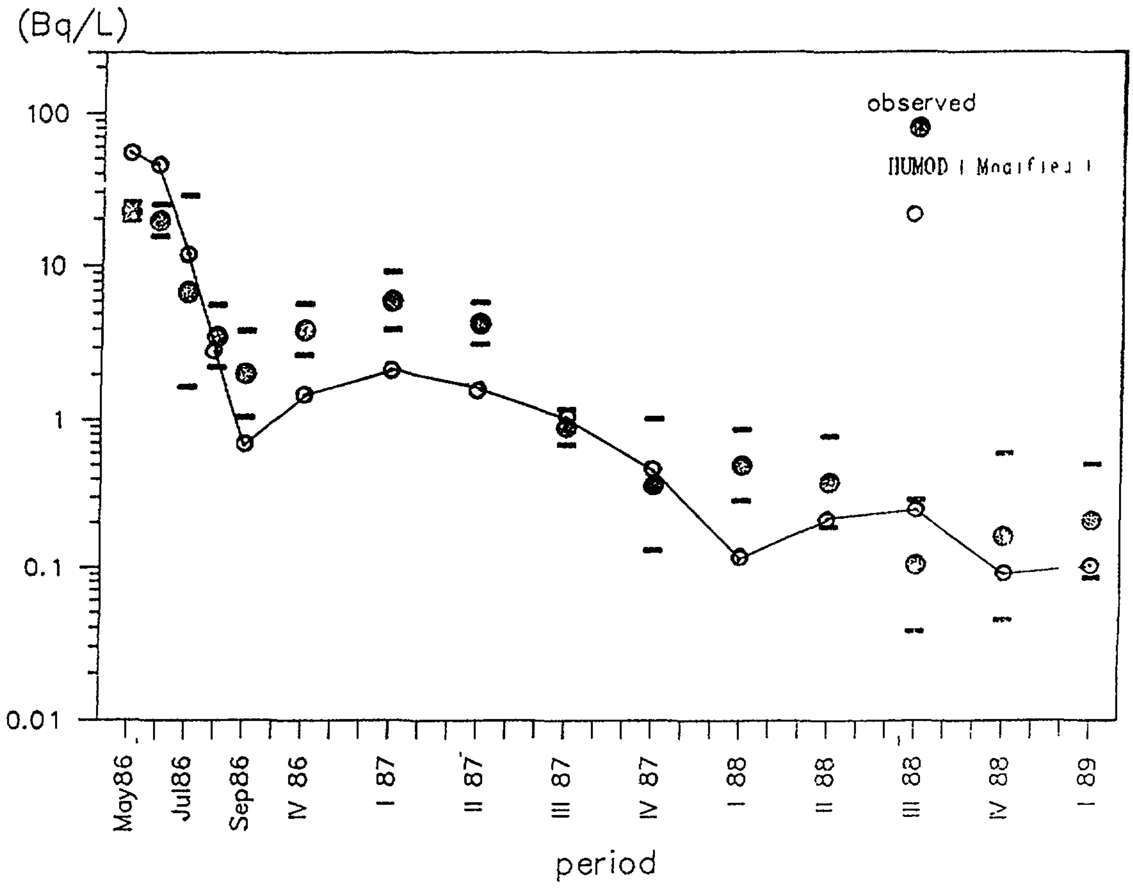

FIG. 4. Cs-137 concentrations in milk.

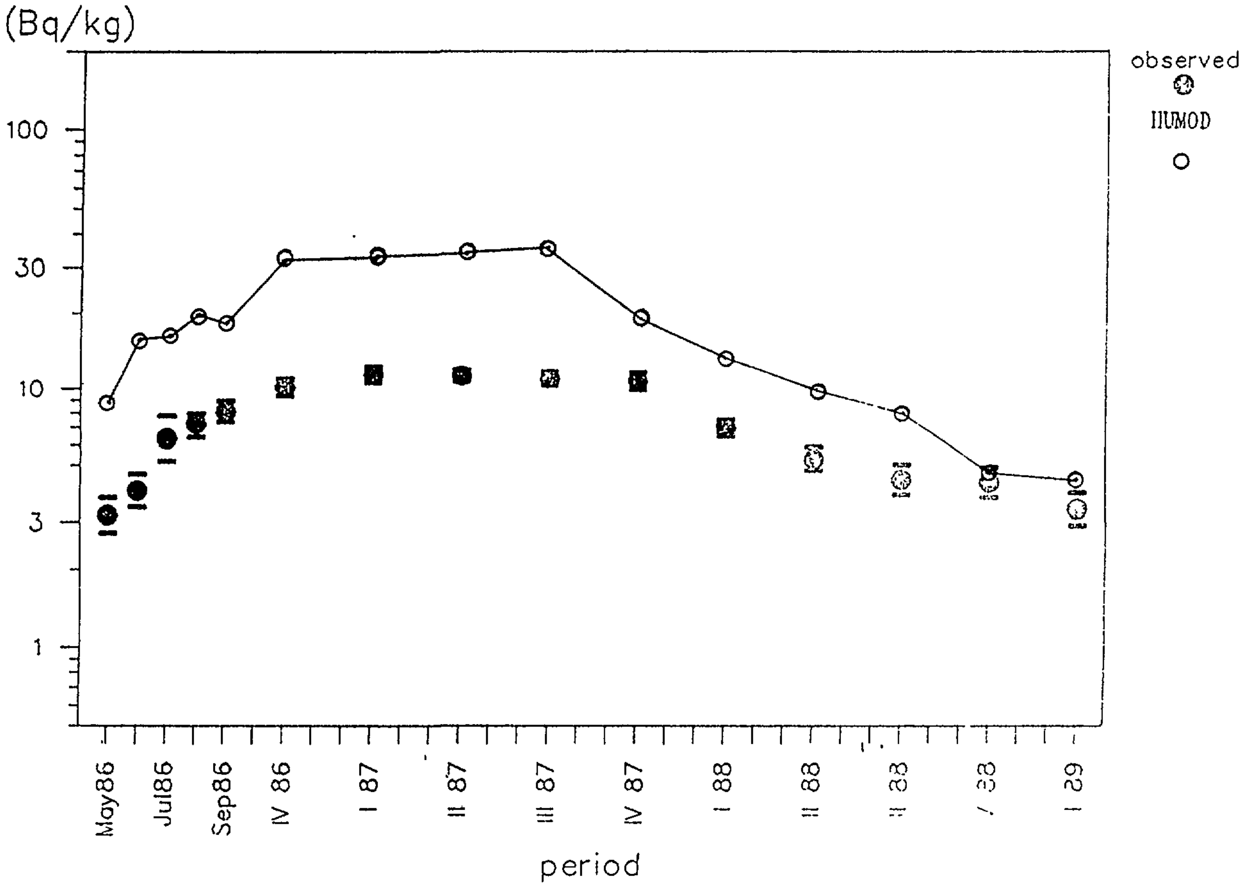

FIG. 5. Cs-137 concentrations in whole body.

This made possible for us to study the model carefully and improve it for practical use.

Although we did not derive the uncertainty of the model successfully due to lack of knownlege about the uncertainty of the input data and parameters, yet we learned the LHS method and we can use it in radiologocal protection field.

The activities in the Co-ordinted Research Programme do us a good help in our work. In China, the first nuclear power plant is available and we will do some work in this field. we think we'll do better.

III.4. SCHRAADLO-T

1. APPLICATION OF SCHRAADLO-T PERFORMANCE FOR CB SCENARIO

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2. General model description

The model SCHRAADLO was developed by J. Horyna to assess the environmental impact of nuclear facilities. It is a time dependent compartmental model.

The model is driven by daily air concentration and daily precipitation rate. The output are time dependent concentrations in soil, different types of meat and plants, milk and whole body.

The model SCHRAADLO-T is a modification of the model used e.g. in the BIOMOVS A4 exercises. Some parameters of the model have been modified according to the "Chernobyl" experiences.

It can be used for accidental as well as for routine releases. Intended accuracy is to give best estimate results. Uncertainty in the output is estimated using Monte Carlo analysis. The present version of the model has not been published. The previous one is possible to find in "Jaderná energie" 36 (1990) p. 467 - 471.

3. Comparison of test data and model predictions

The P/O ratios for calculated quantities are given in Table 1 and 2.

3.1 Total deposition

The calculated average total deposition was in good agreement to the observedwith only 10% of overestimation. the calculated mean value is within the confidence limit of the observed.

Table 1: Summary of results predicted by the model

	Deposition		L.Vegetables		Cereals		Pasture grass*	
	P/O	C.I.	P/O	C.I.	P/O	C.I.	P/O	C.I.
1986	1.1	+	1.4	+	1	+	1.2 - 0.8	+
1987			0.7	n.a.	5	-	n.a.	
1988			n.a.		3.3	-	n.a.	

P/O - predicted to observed ratio
C.I.- confidence interval of observations
\+ indicates prediction falls with C.I.
\- prediction is out of C.I.
* - data given for harvest in May (1.2) and June (0.8)
n.a.- not available data

Table 2: Summary of time series of results predicted by the model

	Milk		Beef		Pork		W.B.C.	
	P/O	C.I.	P/O	C.I.	P/O	C.I.	P/O	C.I.
May 1986	2.2	-	n.a.	n.a.	n.a.	n.a.	1.7	-
Jun	1.6	-	0.4	+	1.7	+	2.8	-
Aug	1.1	+	1.5	+	1.6	-	1.7	-
Sep	1.4	+	1.4	+	1.4	+	1.6	-
IV 1986	4	-	1.3	+	1.1	+	1.4	-
I 1987	2.8	-	1.8	+	1.1	+	1.8	-
II 1987	1.4	+	0.6	+	0.7	+	1.6	-
III 1987	4.5	-	0.6	+	0.6	+	1.4	-
IV 1987	2.7	+	0.9	+	1.3	+	0.8	+
I 1988	0.8	+	0.4	+	4	-	0.7	-
II 1988	1.0	+	0.3	-	1.1	+	0.7	-
III 1988	2.5	+	0.5	+	1.5	+	0.6	-
IV 1988	1.6	+	0.8	+	3	+	0.4	-
I 1989	1.3	+	0.5	+	2.9	+	0.4	-

mean P/O 2.2 0.8 1.7 1.3
W. B. C. - whole body concentration (Bq/kg)

3.2 Major food items contributing to total diet

3.2.1. Milk

The mean value of P/O is 2.2. The 55 % of predictions are within confidence interval.

It is interesting to remark that the predictions of milk concetrations with mean P/O ratio of 2.2 is better than the predictions of W.B.C. with the mean P/O of 1.4 and only 9 % of predictions is within confidence interval. It may be the consequence of less frequent sampling of milk .

3.2.2. Beef

The best results were obtained for beef. The mean P/O is 0.9 and all results are in the confidence interval.

3.2.3. Pork

Despite the fact that porks are feed for an important part with milk, the time evolution of the concentration is not very closed to that in milk. the mean P/ O is 1.7 and 80 % of results are within confidence interval.

3.3. Other comments

As can be seen from Table 1 there were good results for leafy vegetables, grass and cereals in 1986 with the P/O s within the range 0.8 - 1.4. The concentration in cereals were overpredicted in the next years.

There is indicated also the confirmance of predictions with the confidence intervals of observations given in the report of IHE in November 1991 (version No. 4) as can be seen from Table 1 and 2 . Our P/O ratios has not been revised since January 1991.

The time dependence of P/O has shown that the used model tends to overpredict concentrations of ^{137}Cs. The most significant differences has occcured in May 1986 and during the year of 1988.

4. Explanation of major sources of misprediction

The potential sources of differences between model predictions and observations are mentioned below:

Air:

The mean airborne contamination of the CB region was measured by 3 sampling stations. The value of 26 Bq.d/m^3 given by the scenario CB was the highest one. The uneven distribution of airborne contamination may be also expected according to the published wind trajectories, measured soil contamination as well as by the map shown in the UNSCEAR report. The filtering factor of 0.8 (activity concentration of indoor air divided by outdoor concentration) has been assumed. The overestimating of WBC in May 1986 also suggests that the time integrated concentration given in the scenario CB is too high.

Soil:

According to measured samples of soil taken at 151 sites it is possible to divide results into 3 groups:

1. Sites with the Cs 134 depositions below detection limit of 20 Bq/m^2. From it follows that some 9% of the CB region has not been influenced by the Chernobyl fallout containing Cs 134. The contamination of these samples by Cs 137 is also very low. From the pre-Chernobyl data on soil contamination on undisturbed land, the large number of samples with the surface activity below 300 Bq/m^2 is difficult to explain.

One reason for these results may be that some soil samples were spoiled during preparation. Accepting this explanation it is possible to delete data on these samples from input data set. The GSD of soil contamination will decrease from the value of 4 to 3.7 and the mean value increases from 4.7 to 5.2 kBq/m^2.

2. Sites with contamination below 3 kBq/m^2. It indicates that there were no precipitations during Chernobyl cloud arrival at 30th April. It includes 50% of sites.

It seems that the area in question was much less influenced by precipitations than it follows from results of uneven situated weather stations.

3. Sites with contamination above 3kBq/m^2.

The used approach in assessing of the surface contamination is to consider the given data on mean daily concentration of Cs and mean daily precipitation rate. The activity deposited by rain depends on the precipitation rate and airborne concentration, the differences between mean and instantaneous values may be the mean source of uncertainty of the calculated deposited activity.

Cereals:

The worst over-prediction has occured for the concentration in cereals (winter wheat) after 1986. The effect of various soil properties has not been taken into account and the conservative concetration factors (soil-plant) from regulatory guides of various origin have been used. The results are conservative(overpredicted).

Milk and beef:

It has been supposed a voluntary limitation of cattle feeding by green plants depending on the stored feed availability in such a way that the direct contamination of stored feed was the main source of milk contamination till the middle of May.

It is probable that the share of green fodder at the beginning of May 1986 was much lower as supposed in the CB scenario. The unknown feeding practises at the begining of May is the main source of uncertainities in predictions of milk as well as beef contamination. Unfortunately such data were not supposed to be important for screening of environmental contamination to take protective measures.

Another source of differences between calculated and predicted contamination is, that samples were taken only for the specific days and not all dairies were sampled.

Unfortunately no beef samples were taken in May and the sampling frequency below 10/month seems too low to obtain representative mean values for the CB region during 1986.

The mean values for the 3d and 4th quarter 1988 seems to be unreasonable high in comparison to the preceeding values as well as to the values obtained in neibourghing areas(B,B-CB). The high value of GSD for the period in question in comparison to GSD in other periods supports the suspicion on the quality of data.

Whole body concentration:

Although the P/O ratios for the whole body concentrations are good (mean P/O is 1.3 with a maximum of 2.8), the predictions did not fall with the narrow confidence interval caused by high number of measurements. There is a tendency of the model to the underestimation with increasing time.

It is interesting with the fact that the concentrations in foodstuffs are overestimated with the exception of beef. Here it should be noted, that the WBC in 1989 is the same level as in the May 1986.

The most simple explanations are that not all food chains are included in the model or the decontamination during food processing is not modelled properly.

Because the P/O for W.B.C. tends to decrease with time despite that the P/O for foodstuffs is increasing, the acceptable explanation is that there is an unknown source of contamination not included in the model, e.g. wild grown plants, mushrooms or the delayed consumption of food produced in 1986.

The course of the cumulative distribution functions as presented in Fig. 2 does not seem to differ significantly in various years.

5. Conclusions

The predicted and observed values of the concentrations of Cs-137 have agreed reasonable.

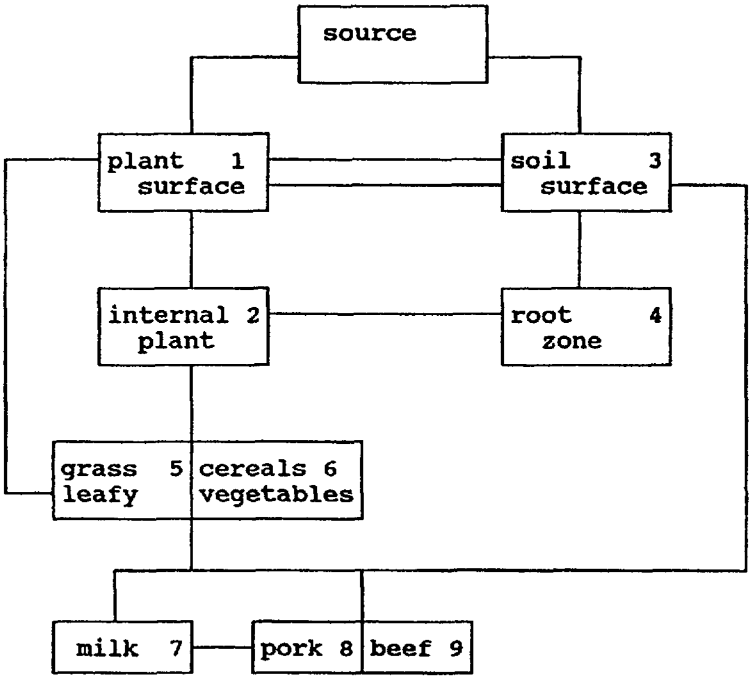

FIG. 1. Flow chart through the terrestrial food chain.

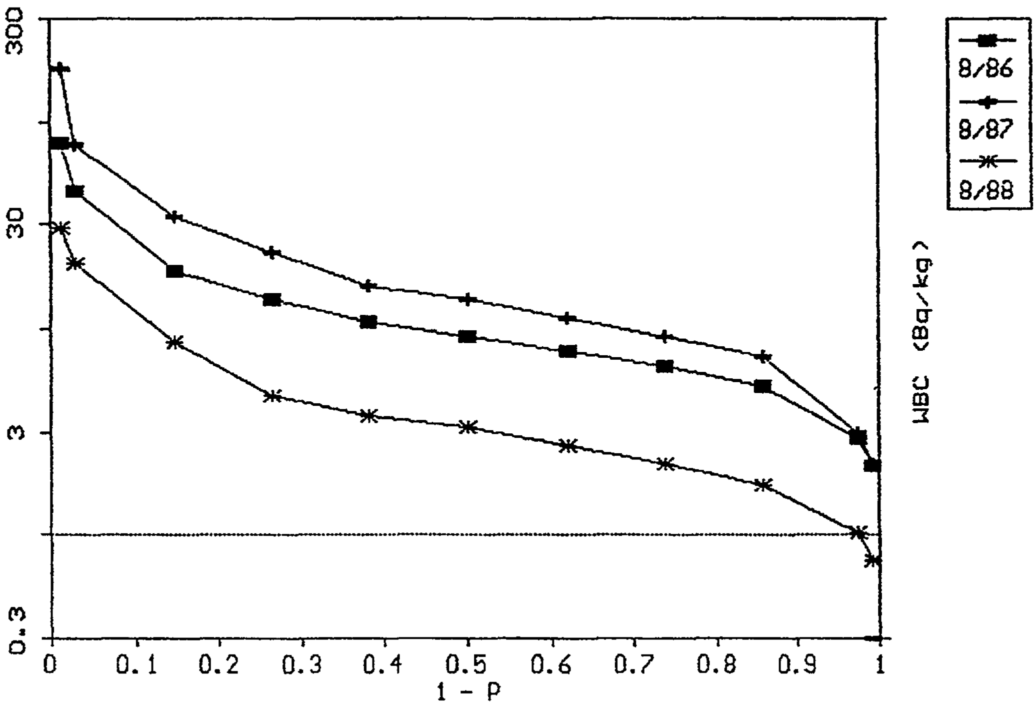

FIG. 2. Cumulative distribution of WBC.

The weak point of the model is its dynamics. It is not only the problem of model structure, but also the problem of input data interpretation including the risk of not detecting input data error. Taking into account proper timing of harvest of cereals and hay, as well as the beginning of fresh/stored feed consumption has been of special importance due to the fact, that the Chernobyl accident happened at time of the fast development of plants. It is very difficult to obtain such informations for a specific site. Including more pathways in the model does not decrease the final uncertainty of the WBC due to increasing number of uncertain parameters of the model.

It has appeared that data not significant for the purpose of screening of environmental contamination after the accident will be of special importance for predictions of the accident impact based on model calculations.

III.5. ENCONAN

1. EVALUATION OF ENCONAN PERFORMANCE FOR CB EXERCISE

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National Institute of Public Health,
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2. General model description

2.1. Name of model, model developer, model user

ENCONAN (ENvironmental COntamination ANalysis) - model of foodchain contamination and of assessment of committed dose effective equivalent by inhalation and ingestion after an accident at nuclear facilities for cesium radioisotopes.

Author and user of model: Viktor Kliment

ACAN - submodel for computation of activity in tissues and organs, excretion quantities and daily excretion rates by inhalation, ingestion and injection after single and steady intake of radionuclides.

Author and user of submodel: Viktor Kliment

EXTIRR - submodel for computation of cloud and ground exposure.

Author of submodel: Zdenek Prouza, National Institute of Public Health, Prague, CSFR

2.2. Unique features of model structure

Deterministic type of prediction only. Method of concentration factors with exception of pork contamination, method of system analysis.

2.3. Intended purpose of the model in the radiation assessment

The intended purposes of the model are the following:
- predictions of mean annual concentration of Cs-137 in major agriculture products (cereal, potato, vegetable, fruit and fora-

ge) and time course of mean concentration of Cs-137 in animal food products (milk, beef, pork, egg, poultry),

- time course of whole body concentration of Cs-137,
- ingestion, inhalation and external irradiation (from ground and cloud) doses.

2.4. Intended accuracy of the model predictions

The intended accuracy is believed to be one order of magnitude.

2.5. Method used for deriving uncertainty estimates

Model gives deterministic type of prediction only.

3. Initial comparison of test data and model predictions

3.1. Total deposition

In the model the total deposition is used as input information.

3.2. Major food items contributing to total diet

The model values of mean specific activities calculated for harvested products and of annual time integrals for the principal kinds of animal food products are presented together with 95% confidence interval bounds about arithmetic mean of observed data available for Central-Bohemian Region in Table I. The model can hardly be expected to embrace all the components of the human foodchain pathway. This particularly applies to certain kinds of less important produce or animal food products for which no information on the soil-to-plant or feed-to-meat transfer coefficients or daily feed quantities is available. In these instances attempts were made at qualified assessments of activity by analogs. Nevertheless, these kinds of food could hardly significantly affected the total dose to man, because of their relatively minor importance in the human diet.

TABLE I

COMPARISON OF PREDICTED AND OBSERVED (MEAN AND 95% CONFIDENCE INTERVAL RESPECTIVELY) VALUES OF SPECIFIC ACTIVITY IN PRINCIPAL KINDS OF AGRICULTURAL PRODUCTS AND OF ANNUAL TIME INTEGRAL OF SPECIFIC ACTIVITY IN COMMON FOOD PRODUCTS PRODUCED IN CB REGION IN CONSECUTIVE YEARS AFTER THE ACCIDENT

(P - predicted, O - observed values)

Product		Specific activity [Bq.kg^{-1}]		
		1.y	2.y	3.y
Vheat	P	12.0	0.31	0.23
	O	10.5-16.9	0.05-0.34	N/A
Barley	P	6.5	0.29	0.29
	P	7.2-52.1	0.17-0.27	N/A
Potato	P	2.7	0.6	0.4
Vegetable	P	3.4	2.4	1.5
Fruit	P	28.0	2.5	1.6
	O	20.7-33.0	N/A	0.41-9.6
Ensilaged hay	P	503	21.1	1.4
	O	37.5-1100	0.76-223	N/A
Silage	P	315	13.2	0.90
	O	12.0-209	0.46-266	N/A
Ensilaged crops	P	0.62	0.20	0.20
	O	1.72-10.4	0.07-1.86	N/A
		Time integral [kBq.d.(kg,L^{-1})]		
		1.y	2.y	3.y
Milk	P	5.26	0.39	0.028
	O	2.42	0.44	0.060
Beef	P	14.12	2.99	0.164
	O	5.32	3.17	0.730
Pork	P	6.49	3.83	0.187
	O	6.03	2.95	0.270

Notes. Fruit and vegetable model values are weighted means by respective consumption rates.
Ensilaged crops - a mixture of maize and sugar beet.
Ensilaged hay - a mixture of clover, alfalfa and pasture grass after dehumidifying (72% of dry matter).
Silage - a similar mixture to ensilaged hay but with 45% of dry matter.
The symbol "N/A" indicates the lack of sufficient quantities of samples for the given product or a group of products.

3.2.1. Milk

The dynamics of Cs-137 concentrations in milk is presented in Fig. 1. Comparison of the data in Table I and Fig. 1 shows a good agreement between the predicted and the observed values. Differences between these values are well within the range of 0.3 - 3 which is commonly considered to be acceptable (IAEA [2]).

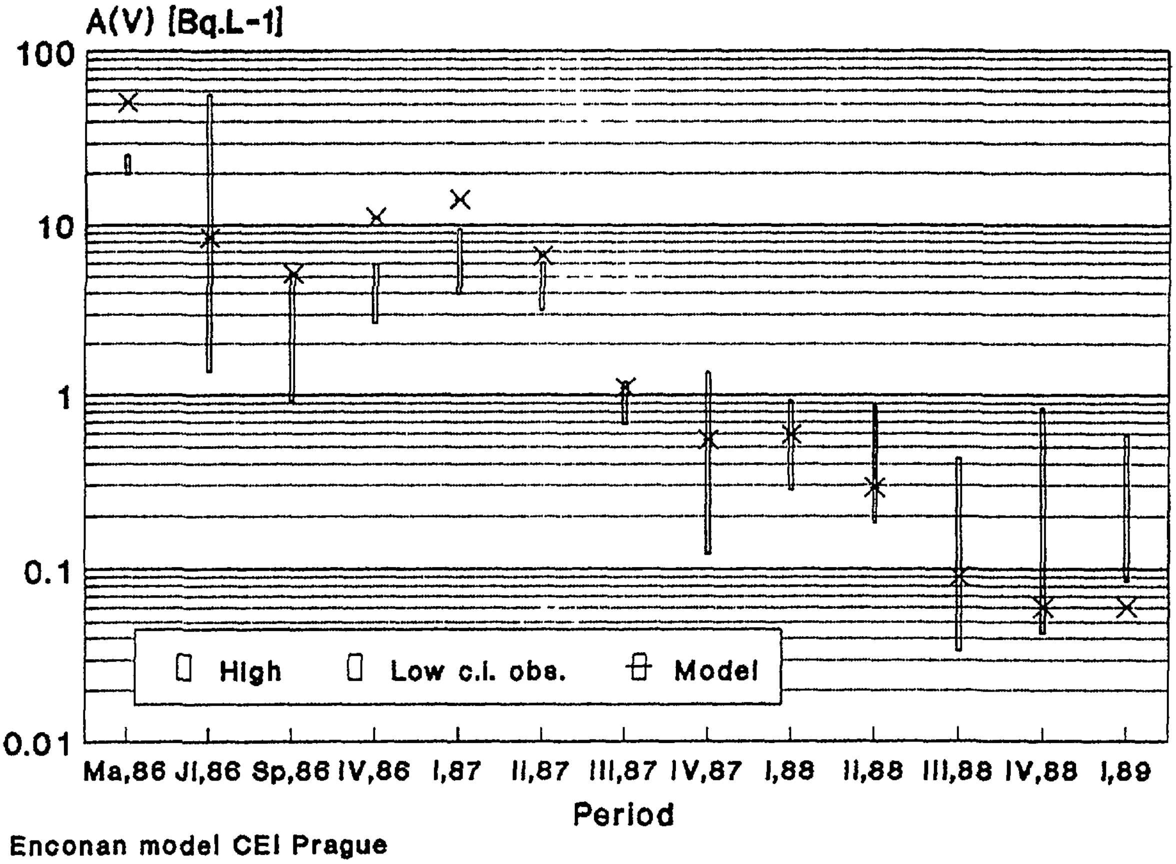

Fig. 1. Cs-137 Concentrations in Milk VAMP/MPA - CB Scenario

3.2.2. Beef, pork

The dynamics of Cs-137 concentrations in beef and pork are presented in Fig. 2 and 3. Comparison of model predictions and observed data shows a good agreement between them in the first and the second years after the accident. In the third year the predicted concentrations of Cs-137 in beef are slightly lower, than observed data.

3.4. Vhole body concentrations

3.4.1. Mean whole body concentrations

The total monthly intakes of Cs-137 ingested by the adult population are shown in Fig. 4, using both transport model and observed data (CSFR data are published by Kliment and Bučina [3]) consistent with the food consumption model.

The model predictions for Cs-137 whole body concentrations are presented in Fig. 5. The calculated values are 1.5 - 2 times higher then observed data during the first and second years

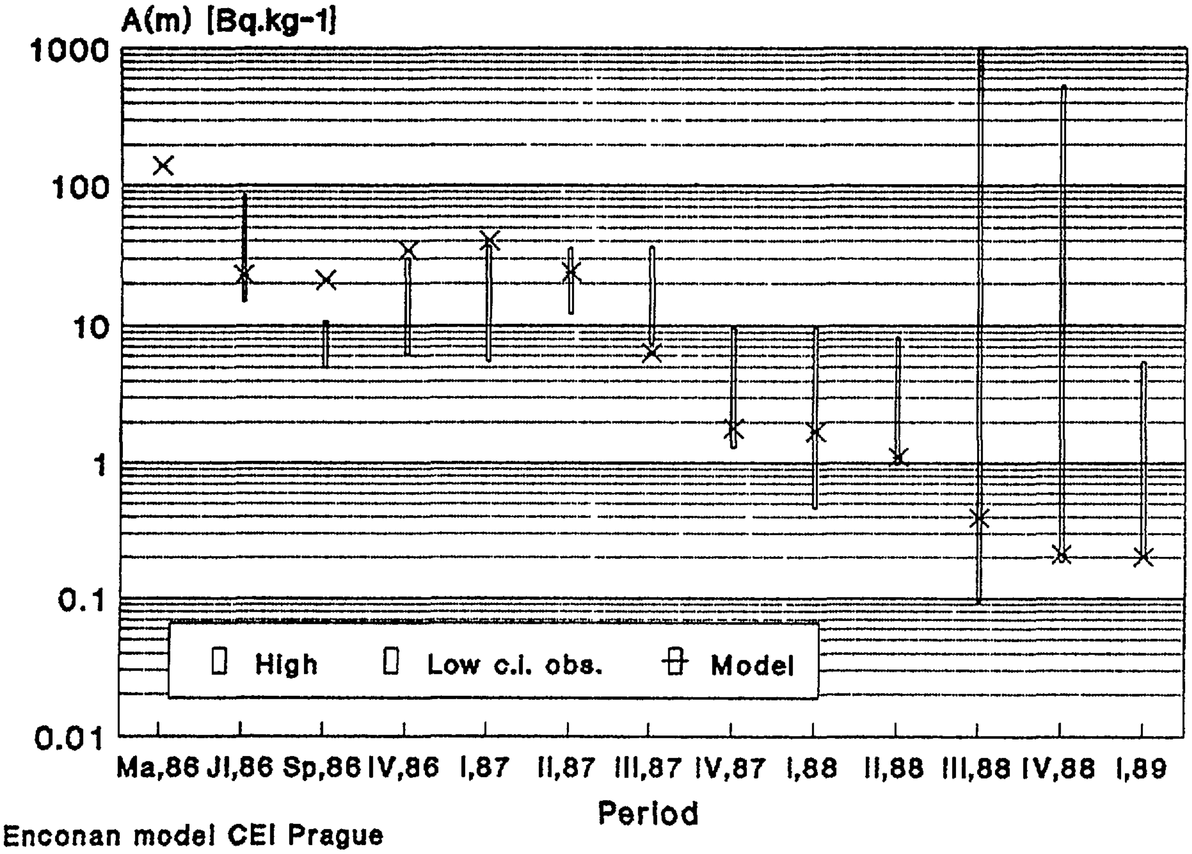

Fig. 2. Cs-137 Concentrations in Beef VAMP/MPA - CB Scenario

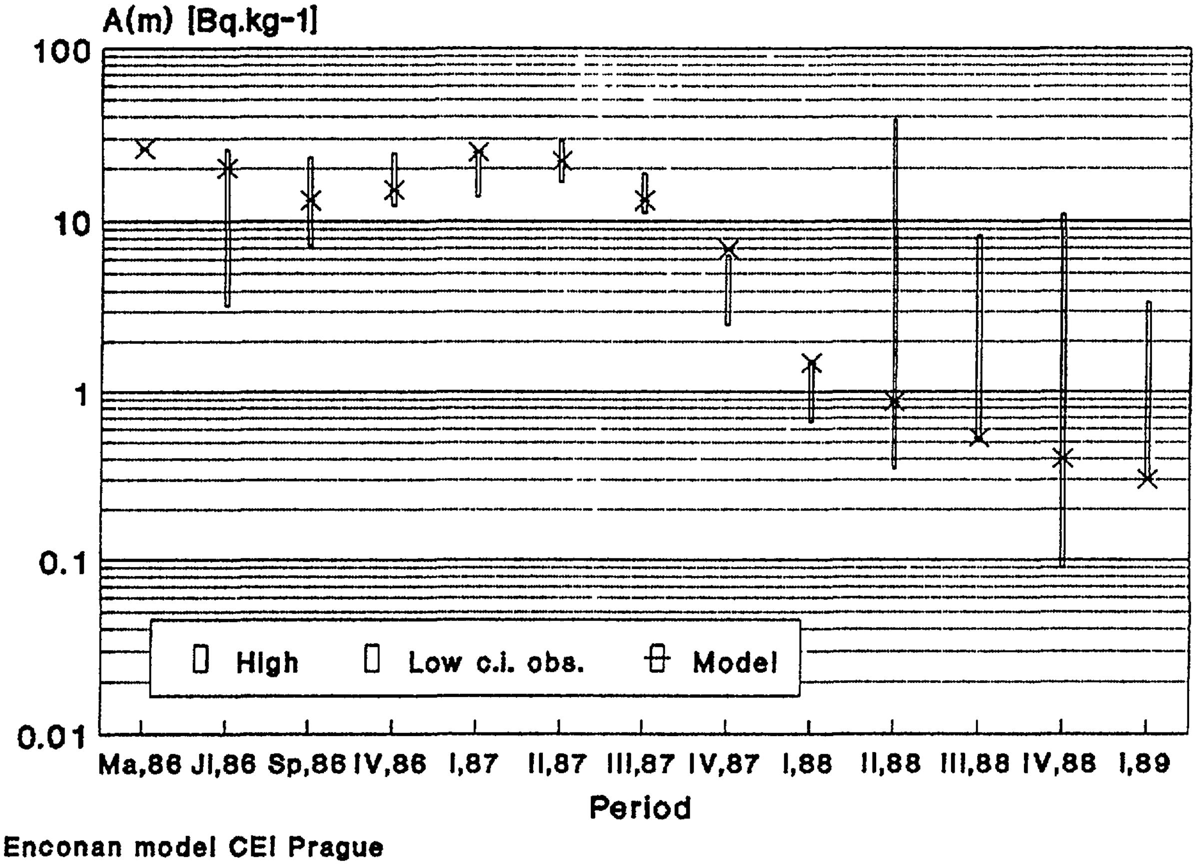

Fig. 3. Cs-137 Concentrations in Pork VAMP/MPA - CB Scenario

after the accident and are slightly lower (80% of observed value) in third year.

4. Explanation of major sources of mispredictions

4.1. Feeding practice

An additional assessment of model outcomes should take into account that the composition of feed need not necessarily be constant during the feeding period. A relatively common practice is to mix together stored fodder and feed grain irrespective of the year of harvest. Feeding practices may also reflect an actual shortage of regular feed, e.g. at the end of the winter feeding period, which may result in the use of alternative feed. These and other practices may become a cause of overestimates in model values at the beginning of the observation period and of their underestimates in subsequent years.

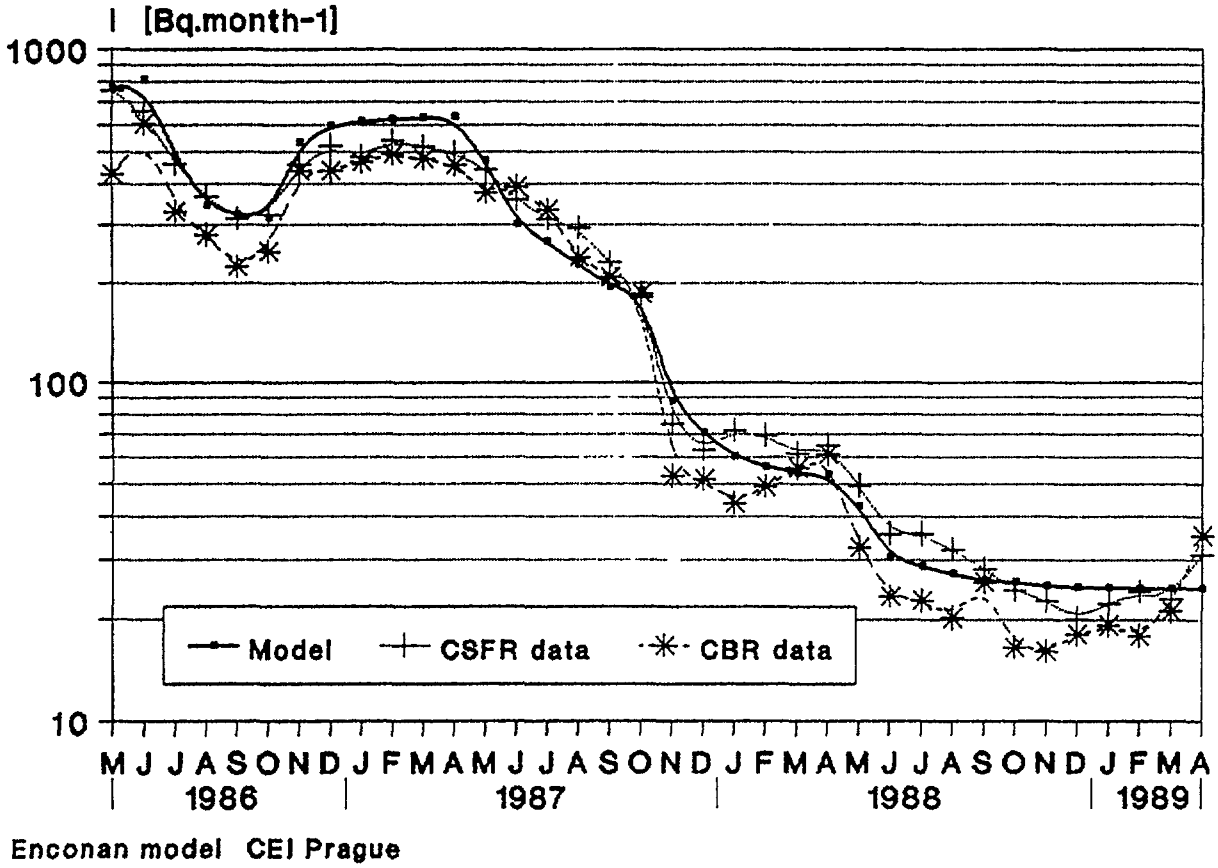

Fig. 4. Total intake of Cs-137 by adults VAMP/MPA - CB Scenario

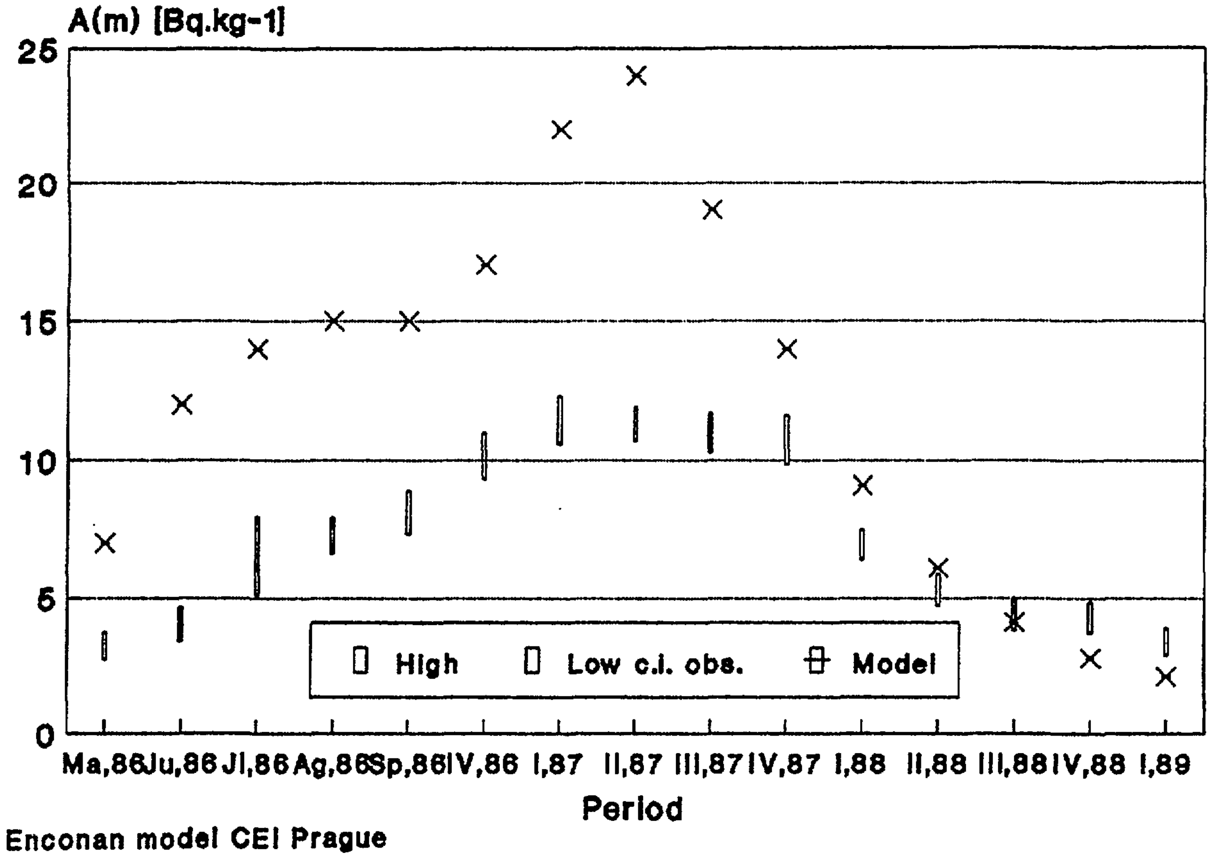

Fig. 5. Cs-137 Vhole Body Concentrations VAMP/MPA - CB Scenario

4.2. Cs retention

The curves in Fig. 5 clearly document the fact that the model retention values in the first phase after the accident are distinctly higher than the corresponding values from whole body measurments. The most plausible explanation for the two months of the observation period (May and June 1986) lies in the implied regulatory countermeasures taken by both producers and consumers of the agricultural products.

The discrepancy also seen in later months until the summer of 1987 is probably associated with the problem discussed several times before, i.e. the hypothetically assumed completeness of resorption of cesium in not fully soluble droplets through the intestinal walls in man.

In another study concerned with Cs-137 transport modeling in pig (Kliment [4]), i.e. animals whose physiology is close to that of man, the cesium value of bioavailability was estimated at f_1=0.7. If used in human model calculations this value will yield a time course of retention (Fig. 5) that is distinctly different from the values for the complete resorption hypothesis but it is evident that the difference between the calculated and observed values has been improved although not fully eliminated.

4.3. Food consumption model

The food consumption rates originate from trade balance data (FSB [1]). At least two factors may lead to their overestimation:

- consumption of home-produced food estimates from questionnaire surveys of households,
- food bought but not fully consumed due to planned feeding to domestic animals or due to premature spoilage by mouldening or rotting.

Consumption values for pasteurized milk and milk products, or for flour products are as a rule derived from quantities of the original raw material. However, for the actual human intake of the radionuclide it is necessary to be familiar with their distribution into products of dairy and milling processing. The distribution for cesium (Kliment and Bučina [3]) is described in Table II and III and the data reported here in Table IV are already effective consumption values calculated from the physical consumption of food multiplied by the respective distribution

TABLE II

DISTRIBUTION OF CESIUM IN THE MILK BY-PRODUCTS

(f_M is the ratio of specific or volume activity in the product and in the consumption milk)

Product	Annual consumption [kg, L] converted to milk	Annual consumption [kg, L] converted to product	f_M
consumption milk	111.1	111.1	1.00
cream	4.5	4.5	0.53
curd	26.0	3.7	1.06
cheeses	52.5	6.3	1.06
frozen products	1.5	2.8	0.53
milk powder	30.5	3.2	9.50
evaporated milk	4.5	1.7	2.56
other	17.8	17.8	1.00

TABLE III

DISTRIBUTION OF CESIUM IN THE BY-PRODUCTS OF WHEAT MILLING
(f_P is the ratio of specific activity of the milling product and in the wheat before milling)

Product	Ash [%]	Weight contribution [%]	f_P
semolina	0.45-0.48	2	0.40
wholemeal flour	0.40-0.45	17	0.43
medium flour	0.50-0.55	27	0.49
fine-ground flour	0.70-0.75	4	0.49
bread flour	0.90-1.70	19	0.67
edible fraction	0.40-1.70	69	0.52
feeding fraction	1.6 -3.3	31	2.06

TABLE IV

ANNUAL CONSUMPTION OF PRINCIPAL KINDS OF FOOD PRODUCTS BY ADULTS IN CZECHOSLOVAKIA

Food	Consumption [kg,L]	Food	Consumption [kg,L]
Milk {5}	178.8	Fruit {2}	45.0
Beef {1}	21.5	Potato	80.0
Pork {1}	39.5	Vegetable {3}	75.0
Poultry	12.0	Egg {4}	17.3
Other meat {1}	3.7	Fat	26.0
Wheat {5}	46.3	Sugar	37.5
Rye {5}	14.1	Other foodstuffs	7.1

Notes. 1 - in net weight including viscera.
2 - without fruits of tropical and subtropical zones.
3 - comprise 2% leafy harvested in June, 21% leafy harvested in Autumn, 37% fruit and 40% root vegetable.
4 - in net weight.
5 - effective consumption (related to milk and grain) given by physical consumption value multiplied by Cs distribution factor into food and feed component (0.72 for milk, 0.36 for wheat and 0.50 for rye).

factor (i.e. the ratio of specific activities of dairy products to pasteurized milk or of flour products to whole grain before milling).

5. Conclusions and recommendation

The transport model presented in this study appears to reflect the situation to a reasonable degree of accuracy. As shown above, the problems involved also lie in the reliability of information concerning farming technology (namely evaluation of the vegetation period and feeding practice) and in the food consumption model.

The ENCONAN model was reconstructed in 1990. It is now widely used for other radionuclides as well.

In all models used for exercise on CB scenario there is one large imperfection. This is the transport of contaminant by the fruit pathway. Information on the interception of aerosols and/or vapours on the leaves of fruit trees and shrubs is insufficient, as is the data concerned with root transport.

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[1] FEDERAL STATISTICAL BUREAU CSFR, Statistical Yearbook (in Czech), SNTL, Prague (1987).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Evaluating the Reliability of Predictions Made Using Environmental Transfer Models, IAEA-SS-100, Vienna (1989).

[3] KLIMENT, V., BUČINA, I., Contamination of Food in Czechoslovakia by Caesium Radioisotopes from the Chernobyl Accident, J. Environ. Radioactivity 12 (1990) 167-178.

[4] KLIMENT, V., Contamination of Pork by Caesium radioisotopes, J. Environ. Radioactivity 13 (1991) 117-124.

III.6. TERNIRBU

1. EVALUATION OF MODEL PERFORMANCE FOR SCENARIO CB

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National Research Institute for Radiobiology and Radiohygiene,
Budapest, Hungary

2. GENERAL MODEL DESCRIPTION

2.1. Model name

TERNIRBU (***Ter***restrial model for the ***N***ational Research ***I***nstitute of ***R***adiobiology and Radiohygiene, ***Bu***dapest)

2.2. Unique features of model structure

The model consists of systems of ordinary differential equations with linear and nonlinear terms. It contains 77 parameters, the values of all can be changed at any time depending on the scenario evaluations. It can therefore take account of any countermeasures implemented during the period of interest and other irregular changes.

2.3. Intended purpose of the model

Used for predicting the radiological consequence of accidental releases of radionuclides.

2.4.Intended accuracy of model predictions

Intended to make realistic predictions of doses.

2.5. Method used for deriving uncertainty estimates

Ranges of parameter values were usually based on values taken from the literature but in cases where few values are available the lower value of the range was taken as 20-30% of the best estimate and the upper value was taken as 3 to 5 times the best estimate. A triangular distribution of values was assumed between the range limits. Uncertainty estimates were generated by Monte-Carlo sampling from distributions of all parameters.

2.6. References

[1] KANYÁR, B., FÜLÖP, N., Use of models to assess the radionuclide concentrations in the environment in different ecological relations (in Hungarian), Research Report No. PK-9.50, issued by the Hungarian Technical Development Committee, Budapest (1990).

[2] KANYÁR, B., FÜLÖP, N., Modelling the Variation of the Radioactive Contamination of the Terrestrial Food Chain Due to the Seasonality and Measures, Proc. of the Austrian-Italian-Hungarian Regional IRPA, Obergurgl, Austria, 1993 (to be issued).

[3] KANYÁR, B., NIELSEN, S.P., User's Guide of the Program TAMDYN, BIOMOVS Techn. Rep. No. 4, Stockholm (1989).

3. INITIAL COMPARISON OF TEST DATA AND MODEL PREDICTIONS

3.1. Total deposition

Total deposition predicted from air concentrations was overestimated by a factor of 1.9 mostly because of using too large a value for the dry deposition velocity. The value used was a default in the absence of particle size information.

3.2. Major food items contributing to total diet

In addition to the overestimation of concentration in milk, beef and pork because deposition was overestimated, the concentrations in these food items were also overestimated because fractional absorption from the GI-tract into blood (0.6 for cattle) was too high in the first year. Later, following changes in availability with time, the same value might have been too low. This factor also contributes to the relatively fast predicted loss of Cs-137 from milk and beef during 1988 and 1989. Also contributing to the same error is an overestimate of the both transfer of Cs-137 from muscle to blood and its excretions in urine.

3.3. Other items of specific interest

The overestimation of deposition also contributed too high a concentration to fruit and grain. However, transfer to winter wheat was further grossly overestimated by choosing too high values for transfer parameters from relatively poorly known faiting descripting translocation in plants. For the same cause but in the opposite directions, was the gross underestimate of concentration in fruit.

3.4. Whole body concentrations

The main dietary contributions to whole body concentrations were milk, beef and bakers ware. Time dependent behavior of concentrations in whole body follows the corresponding concentrations in these dietary items.

4. EXPLANATION OF MAJOR SOURCES OF MISPREDICTION

Major sources of mispredictions and errors were

(a) Use of inappropriate velocity of dry deposition because particle sizes were not specified. Starting with the measured soil deposition given as alternative input to air concentration would have given better predictions of levels in foodstuffs.
(b) In the model pasture was plaughed in August 1987 so that concentrations in foodstuffs from root uptake and soil resuspension in 1988 were too low.
(c) Values chosen for the transfer factors determining concentrations in the bodies of men and other animals were too high.
(d) Whole body concentrations in May and June 1986 were too high because the intakes from inhalation were overestimated due to failure to take account of the occupation factor and decreased air concentrations indoors.
(e) Concentrations to the whole body concentrations from foodstuffs in the winter of 1986/87 were too high of overestimated concentration in milk, beef and bread.
(f) Time integrated dose rates were incorrectly calculated by hand from the time integrated air concentrations. The original values should be multiplied by 2.

4.1. Recommendations for changes to the model

- Obtain better values of transfer parameters for fruit and grain.
- Be careful when modelling special operations such as ploughing, closing feeding regimes and consumption rates.
- Obtain better values for metabolic processes for cattle and man.

4.2. Examples of how changes improve predictions

As examples, Figures 1 and 2 show the recalculated concentrations in milk and whole body made after correcting the errors and the parameter values.

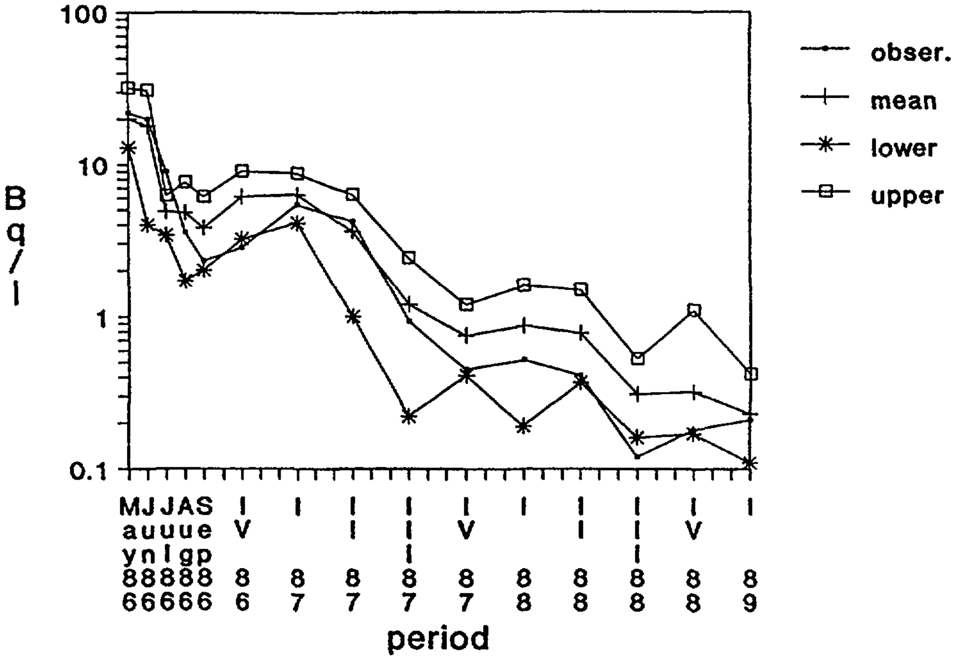

Figure 1. Cs-137 concentration in milk.

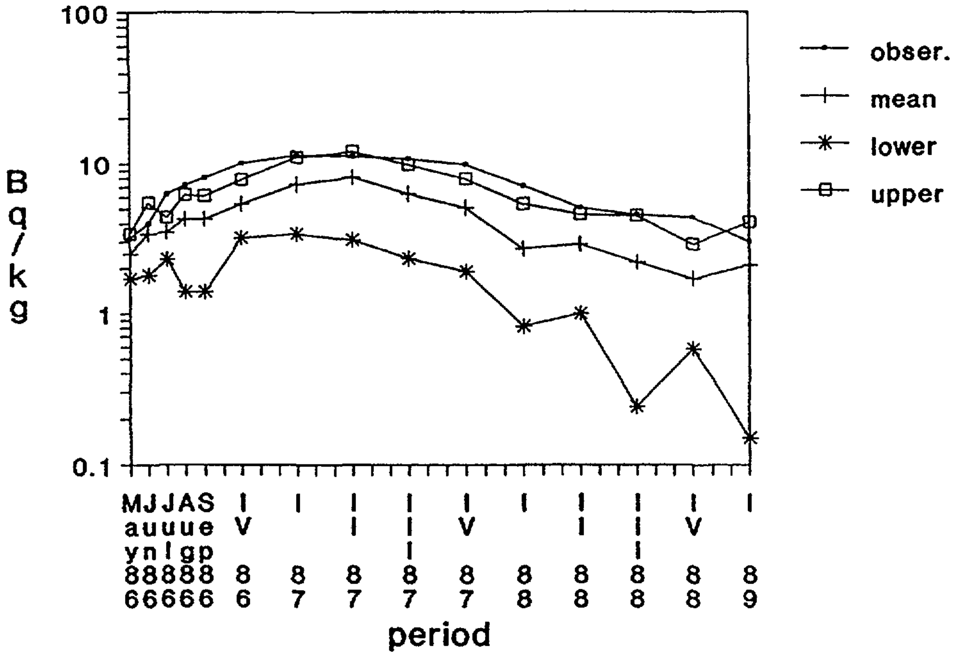

Figure 2. Cs-137 concentration in whole body.

5. CONCLUSION, SUMMARY OF LESSONS LEARNED FROM SCENARIO CB

- The necessity for a clear description and a right interpretation of the input data are very important to avoid mispredictions.
- The scenario is to be studied more carefully before any assessments.
- The whole model as well as parts of it are to be tested over various situation and different radionuclides.
- The parameter sensitivity and correlation analysis might give contributions to improve the model.

III.7. ECOSYS-G

1. INDIVIDUAL EVALUATION OF MODEL PERFORMANCE FOR CB SCENARIO

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2. General Model description

2.1 Name of model: ECOSYS (version ECOSYS-87)

Model developers: authors

2.2 Unique features of model structure

The time-dependent radioecological simulation model ECOSYS-87 has been developed in order to assess the radiological consequences of short-term depositions of radionuclides. Internal exposure via inhalation and ingestion as well as the external exposure from the passing cloud and from radioactivity deposited on the ground are included in the model. The ingestion dose is calculated as a function of time considering 18 plant species, 11 animal food products and 18 processed products. During the model development much work has been spent to model the dependence of radionuclide transfer in food chains on the season in which the deposition occurs.

2.3 Intended purpose of the model in radiation assessment

ECOSYS has been developed for the fast assessment of radiation exposure via all relevant pathways in order to answer questions relevant for decision makers in emergency situations. Therefore not only those foodstuffs which are most relevant for the average population are treated in ECOSYS but also those which might be relevant only for a few people (critical groups). The program system is organized in a way to allow the simulation of many different radioecological situations and dose affecting countermeasures.

2.4 Intended accuracy of the model predictions

For being used as a tool for decision making the intended accuracy is to give best estimate results. Nevertheless, in cases where decisions about parameters are doubtful those were used which are more likely to not underestimate the doses. This seems to introduce in some cases a certain bias to overestimation of doses. A general estimation how accurate a best-estimate model should be, can not be given since the expected accuracy of the results depends to a high degree on the informations available in a specific situation; moreover it is dependent on the type of result and on the time for which it is predicted.

2.5 Method used for deriving uncertainty estimates

ECOSYS-87 has been developed as a deterministic model. The uncertainty estimates given for the VAMP CB scenario calculations were derived by personal judgement of the authors considering

- general radioecological experience
- experience with a former stochastic version of the ECOSYS model
- experience with comparisons of predictions and measurements after the Chernobyl accident.

For the revised calculations such an uncertainty estimation was not performed since subjective judgement is adulterated if the "true" results are known. Without knowing the results, about the same factors up and down as in the initial calculations would have been estimated in most cases. Only in some cases where more informations on the scenario were available in the meantime, the uncertainty ranges would have been somewhat smaller.
In the meantime ECOSYS-87 has been extended for application of Monte-Carlo technique for uncertainty estimations.

2.6 References describing detailed documentation of model

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The Dynamic Radioecological Model ECOSYS - A Tool for the Management of Nuclear Accidents' Consequences. IVth International Symposium of Radioecology "The Impact of Nuclear Origin Accidents on Environment", Cadarache, March 14th - 19th, 1988

Pröhl G.:
Modellierung der Radionuklidausbreitung in Nahrungsketten nach Deposition von Strontium-90, Cäsium-137 und Jod-131 auf landwirtschaftlich genutzte Flächen. GSF-Report 29/90 (1990)

Müller H., Pröhl G.:
ECOSYS-87: A Dynamic Model for Assessing Radiological Consequences of Nuclear Accidents.
Health Physics 64(3), 232-252; 1993

3. Initial comparison of test data and model predictions

3.1 Total deposition

The assessment task as given in the "revised and completed scenario description of test scenario CB (February 1991)" was to estimate the average total deposition (wet and dry) in the entire region CB. We estimated a mean value of 7.2 kBq/m^2 basing on the mean measured contamination of bare soil and an assumed additional dry deposition to other surfaces. It turned out that no observed data exist except the measured deposition values on bare soil. So, irrespective of comparing our estimation with the arithmetic mean of 4.76 kBq/m^2, or with the estimate of version IV of 5.57 kBq/m^2 (assuming a log-normal distribution which is the result of long discussions on statistical procedures) we can not learn anything about model performance from this part of the exercise.

3.2 Major food items contributing to total diet

3.2.1 Milk

Figure 1 shows the comparison of predicted and observed concentrations in milk. The following observations become obvious:

a) In May 1986 the model overpredicts by a factor of about 4.

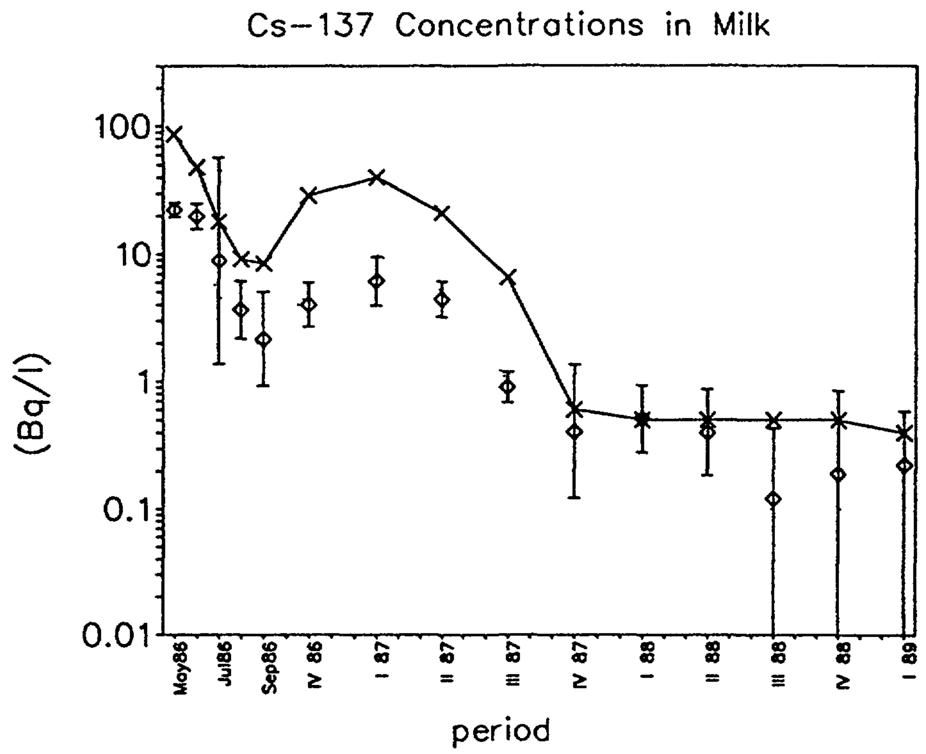

Fig.1: Comparison of observed and initially predicted ("X" with estimated 95% confidence interval "...") Cs-137 concentrations in milk

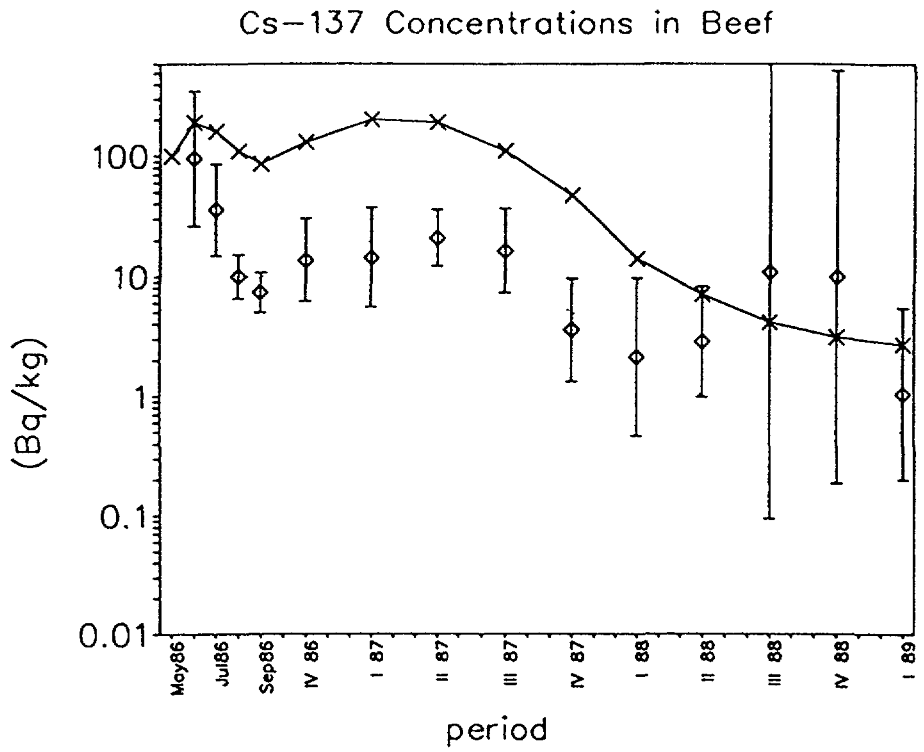

Fig.2: Comparison of observed and initially predicted ("X" with estimated 95% confidence interval "...") Cs-137 concentrations in beef

b) The overprediction is somewhat less during summer 1986.

c) During winter 1986/87 until summer 1987 the overprediction increases to about a factor of 7.

d) From autumn 1987 until summer 1988 there is good agreement, thereafter there is again a (not very pronounced) overprediction.

3.2.2 Beef

The comparison of predicted and observed data (Fig.2) shows similar (dis-)-agreement as for milk, but the overprediction in 1986/87 is still higher (up to about one order of magnitude); in 1988/89 neither over- nor underprediction can be seen due to the big variability and uncertainty of the observations.

3.2.3 Pork

The comparison of predicted and observed Cs-137 concentrations in pork (Fig.3) shows much better agreement than for beef but until 1988 there is also overprediction by a factor of about 2 to 3. Again in 1988/89 neither under- nor overprediction can be seen due to variability and uncertainty of the observations.

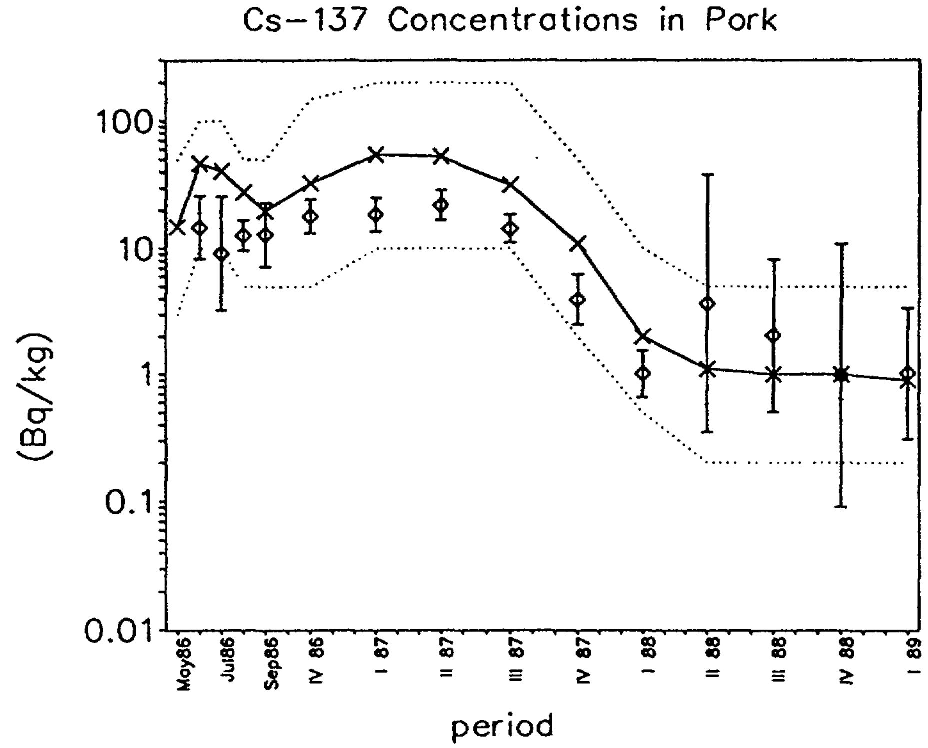

Fig.3: Comparison of observed and initially predicted ("X" with estimated 95% confidence interval "...") Cs-137 concentrations in pork

3.3 Other items of specific interest

In the following tables predicted and observed Cs-137 concentrations are compared by giving the P/O ratio (i.e. mean value of initial model prediction divided by the arithmetic mean of observations as given in version IV of observed data). Moreover, in the column "Remark" a qualitative indication on the agreement of predicted and observed data is given:

"+" means that the predicted mean value is within the 95% confidence interval of the arithmetic mean of observations,

"O" means that the prediction is outside the 95% confidence interval of the observed mean but the estimated 95% confidence interval of model predictions overlaps with the 95% confidence interval of mean observed values, and

"-" means that the estimated 95% confidence interval of model predictions is completely outside the 95% confidence interval of mean observed values.

3.3.1 Grain

The 1986 activity concentration (which was dominated by leaf contamination and translocation) has been overestimated in winter wheat while in spring barley there is good agreement. In 1987 (when only root uptake is effective) there is some overestimation in both types of grain.

Period	Winter wheat		Spring barley	
	P/O	Remark	P/O	Remark
harvest 1986	2.8	0	1.2	+
harvest 1987	3.1	0	1.9	0
harvest 1988	no data		no data	

3.3.2 Fruit

The fruit model of ECOSYS failed to a high degree for the CB region. In 1986 there is considerable overestimation (this made fruit to one of the most relevant foodstuffs during the first year in our calculations). In 1988 the observed values are a factor of 7 above the predicted ones.

Period	Fruit	
	P/O	Remark
harvest 1986	5.3	0
harvest 1987	no data	
harvest 1988	.15	0

3.3.3 Leafy vegetables

The assessment task was the prediction of mean monthly Cs concentrations in leafy vegetables in 1986. In the observed data only numbers for "harvest 1986" are available; due to the large temporal variablity in 1986 a comparison makes no sense. For 1987 a mean observed value for B region is given (0.635 Bq/kg). The predicted value is a factor of 2 below this value, but due the rather large uncertainties of the observed data no conclusions can be drawn from this comparison.

3.3.4 Animal Feed

Pasture vegetation

The assessment task was the prediction of the mean activity in pasture vegetation in May and July in the years 1986 through 1988. In the version IV of observed data only concentration in May and June 1986 are given. Therefore in the following table the P/O ratio has been calculated for May and June 1986 taking the June values (280 Bq/kg) of the initial ECOSYS calculations. Since there is considerable difference in observed values between

CB and whole B region (which is not surprising since there is large variation with time, so inhomogeneous sampling results in large variation of observed data), both sets of data have been used for comparison. From this comparison it can be concluded that the model performed well during the 2 month period. Nothing can be concluded about later times due to missing observed data.

Period	Pasture veg. [CB]		Pasture veg. [B]	
	P/O	Remark	P/O	Remark
May 1986	2.0	0	.88	+
June 1986	1.0	+	1.7	0

Silage

In the initial calculations for the CB scenario we did the wrong assumption that silage is prepared from pasture vegetation (the calculations were done before the revised scenario description was available which had an indication on the type of silage in the table of feeding rates). Therefore, and because of the low reliability of the observed data (for CB a value of 51.8 Bq/kg is given for harvest 1986, for whole B region 11,700 Bq/kg; this indicates that the composition of silage is not well defined) a comparison of predicted and observed data makes no sense.

Ensilaged Hay

The observed data of ensilaged hay can be compared with our "silage" which is made from pasture vegetation. Again a comparison with both CB and B data is made due to the large variability of observed data:

Period	Ensilaged hay[CB]		Ensilaged hay [B]	
	P/O	Remark	P/O	Remark
harvest 1986	.54	+	.27	0
harvest 1987	.13	+	.33	+

There seems to be some underestimation but due to the large variability of the observed data no general conclusions can be drawn from this comparison.

3.4 Whole body concentrations

3.4.1 Mean whole body concentrations

The comparison of predicted and observed Cs-137 concentrations in whole body is given in Fig.4. There is substantial overprediction from the begin-

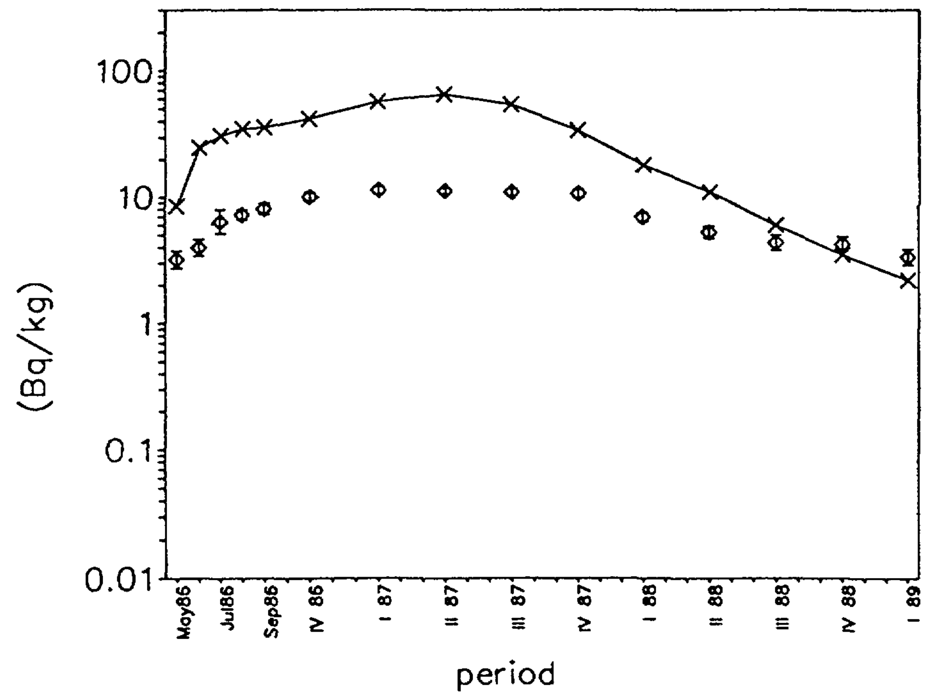

Fig.4: Comparison of observed and initially predicted ("X" with estimated 95% confidence interval "...") Cs-137 concentrations in whole body

ning until mid 1988 (in most cases by a factor of 4 to 6). In 1988/89 it becomes obvious that the predicted curve decreases faster than the observed one.

3.4.2 Distribution of whole body concentrations

The distributions of whole body concentrations within the population have not been calculated by us for the VAMP exercise since our model is calculating only individual doses. In the limited time we could spend for the VAMP exercise it was not possible to expand our programs to all questions given in the assessment tasks.

4. Explanation of major sources of mispredictions

4.1 Recommendations for changes to the model

The following facts have been identified as major sources of mispredictions:

a) Our assumption in the initial calculations that silage is prepared from pasture grass lead to a high overprediction of activity in milk and beef especially during the winter 1986/87; due to feeding whey the activity in pork was influenced too. In the revised calculations only ensilaged hay is made from pasture vegetation and "silage" is assumed to be 2/3 maize and 1/3 beet leaves.

b) The model applied in ECOSYS for fruits gave a significant overprediction of Cs concentration in fruit in the harvest 1986 and hence of the activity intake by humans from autumn 1986 till autumn 1987. From the existing informations it can not be decided what the reson for the overprediction was. One possible reason is that the leaves of fruit trees were not as far developed as it is the default assumption of ECOSYS; since there was no information available, no adaption to the local conditions of CB has been made. In the revised calculations it is assumed that the development of leaf area is delayed by 10 days. But this alone is not sufficient to give reasonable agreement of predicted and observed data; so in addition a reduction of the translocation factor by a factor of 4 has been assumed in the revised calculations. This does not mean that we consider the fruit model to be o.k. now, but it was done to prevent fruit from being a dominating foodstuff for whole body Cs-137 concentration. The development of a better fruit model remains still one of the most important tasks.

c) The beginning of feeding fresh pasture vegetation was assumed too early in the initial calculations (it started on May 1st and reached full summer feeding on May 20). According to the evaluations of observed data by S.R.Petersen/P.Barry we assumed in the revised calculations that summer feeding started on May 1st with linearly increasing feeding rates until on June 30 full summer feeding is reached. The assumption of this feeding regime influences the contamination of milk, beef, pork and whole body very much during the summer 1986.

d) The time-integrated activity concentration in air as given in the CB scenario description seems to be too high for mean CB conditions; this is concluded from several other sources of information. Moreover the initial assumption of linear increase of Cs concentration in air from 29.4.86, 20:00 until 30.4.86, 10:00 might be an overestimation. Therefore in the revised calculations a time integrated Cs-137 concentration in air of 500 Bqh/m^3 is assumed (this is a 35% reduction as compared to the initial calculations) while keeping the total deposition to bare soil constant.

e) We assume that the variations of total deposition within the CB area are mainly caused by variations in precipitation during the cloud passage, i.e. high contaminations are due to high precipitation. It is known that the interception fraction of wet deposited material by plants is lower for high amounts of precipitation. Therefore the relationship between total deposition and initial contamination of plants is not linear. This causes also a non-linear relationship between total deposition and milk contamination, whole body content and doses. This causes that calculations based on mean deposition with mean amount of rainfall leads to an overestimation of all these predictions until spring 1987 (thereafter the dominating pathway is root uptake which is not influenced by the precipitation-interception relationship). To account for this effect, in the revised calculations a higher amount of precipitation (1mm instead of 0.35 mm) has been assumed.

4.2 Examples of how changes improve calculations

The revised calculations with changes of parameters and assumptions as given above result in the activity concentrations in milk, beef, pork and whole body as given in Figs. 5 - 8. The situation seems now much better but the following problems still exist:

In **milk** there is still some overprediction (factor 2.5) in winter 1986/87. This might be partly a result of the feeding practice given in the CB scenario description: the amount of dry matter fed to dairy cattle seems to

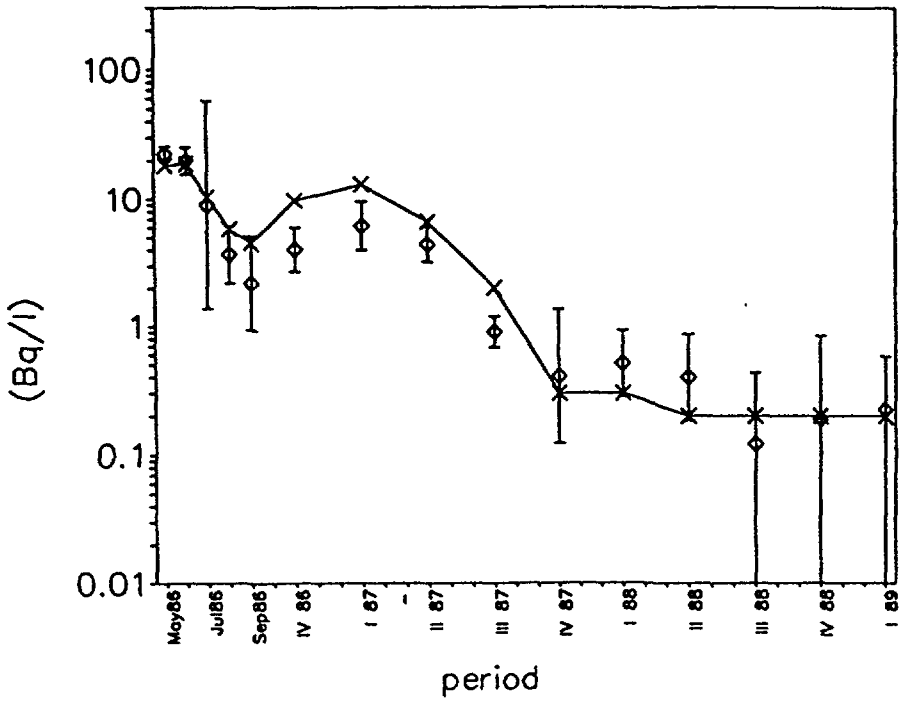

Fig.5: Comparison of observed and revised predicted ("X") Cs-137 concentrations in milk

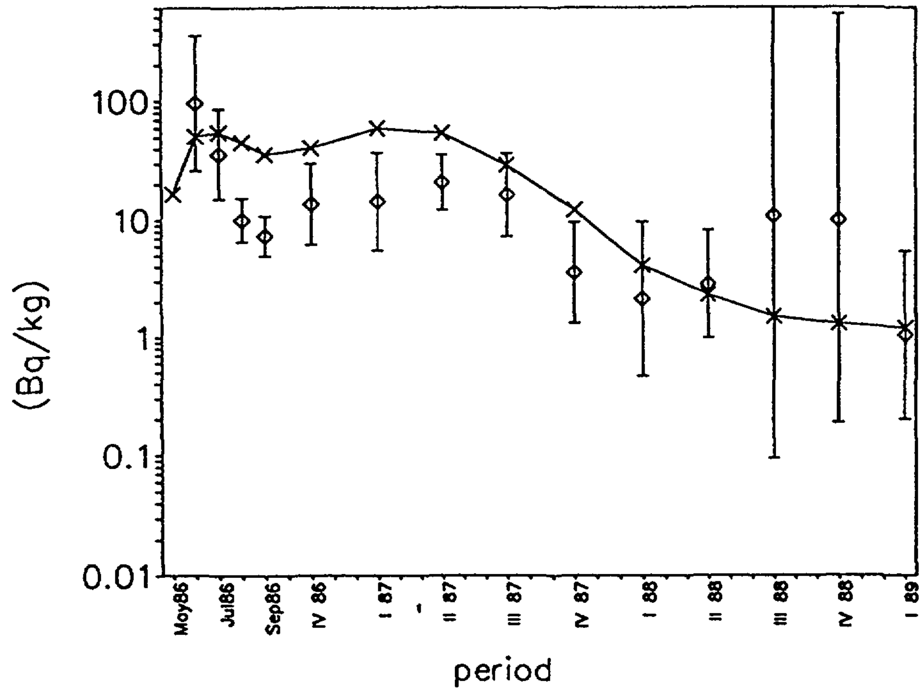

Fig.6: Comparison of observed and revised predicted ("X") Cs-137 concentrations in beef

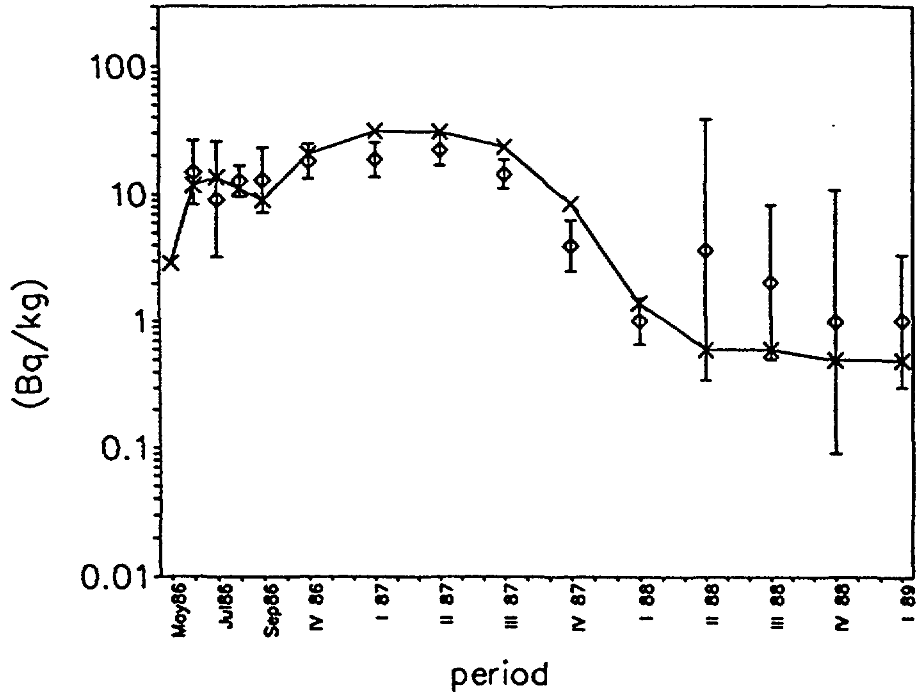

Fig.7: Comparison of observed and revised predicted ("X") Cs-137 concentrations in pork

be very high as compared to the mean milk yield. Unfortunately there is no possibility to investigate in more detail the reasons for the overprediction since the observed data on animal feed is too poor. In 1988/89 the P/O-ratio looks good.

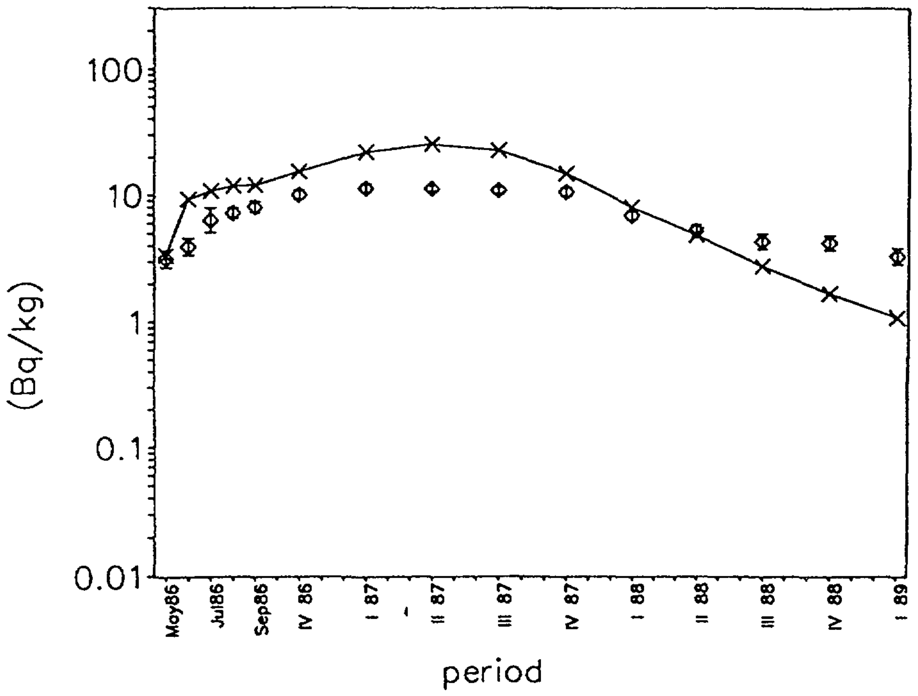

Fig.8: Comparison of observed and revised predicted ("X") Cs-137 concentrations in whole body

For **beef** the situation is similar as for milk but the overprediction from summer 1986 to summer 1987 is higher. Again we can only speculate about the reasons for it: there might be a wrong assumption of composition of feed or the storage times are much higher than assumed (but the latter is not supported by the agreement of the time of activity decrease in 1987/88). Also our assumption that 1/3 of beef is from cattle and 2/3 is from bulls might be not correct. In 1988/89 the agreement of observed and predicted data seems to be satisfactory as far as the uncertainty ranges of observed data allow such a statement.

The agreement of predicted and observed data for **pork** is quite satisfactory. The differences in 1986/87 are less than a factor of about 2. In 1988/89 there might be a slight underprediction (perhaps due to feeding of some fodder stored since 1986?) but this is not proved due to the large uncertainty estimates of observed data.

The comparison of predicted and observed Cs-137 concentrations in **whole body** shows two important facts: The predicted values are about a factor of 2 too high from July 1986 to 3rd quarter of 1987, and after this there is much faster decrease in the predicted data as compared to the observed. The overprediction in the first 1.5 years is of similar magnitude than that for milk, but undoubtedly milk is not the only foodstuff contributing to whole body concentration. The overprediction in summer 1986 could be easily explained by reduced consumption of milk and fresh vegetables during the first months after the Chernobyl accident. The informations available on vegetables etc. do not allow to draw conclusions about the model performance for vegetables and other foodstuffs. The overprediction until end of 1987 and underprediction thereafter indicates that there are larger time periods for storage and processing for some important foodstuffs. So we did a further calculation with some larger storage and processing times for animal fodder as far as they seemed reasonable but this didn't solve the problem to a considerable amount. Better success was achieved with assuming a longer storage time of cereals (50 % of the consumed grain is from the harvest one year ago; see Fig.9). This assumption is surely not unrealistic, even a storage time of two years for some fraction of the consumed grain (which would lead to a much better fit in IV/88 and I/89) could be an explanation, but since we do not have information about the real storage times in CB, we have to consider such calculations as merely speculative games. A further reason could be that the root uptake factor for some relevant vegetable foodstuffs is assumed too small; but since this seems to be not the case for cereals (which are one of the most contributing non-animal foodstuffs) there is no indication which proves

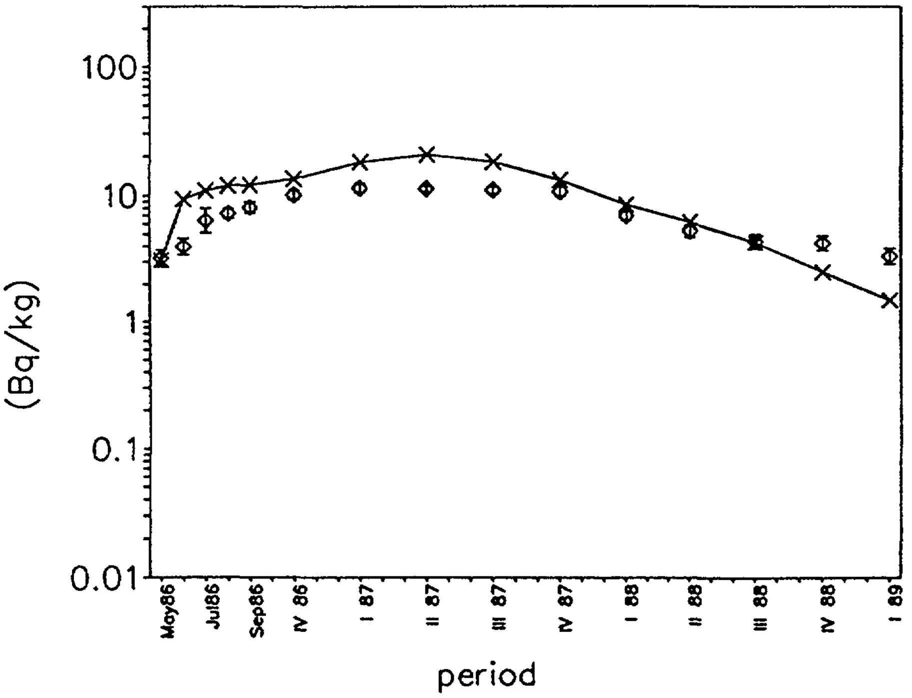

Fig.9: Comparison of observed and predicted ("X") Cs-137 concentrations in whole body; same situation as for Fig.8, but with the assumption that 50% of the consumed grain is stored for one year.

this supposition. A further possibility for the steeper decrease of predicted whole body activity is that people eat some foodstuffs which have a very slow reduction in contamination level and which have not been considered in the calculations (this might be e.g. mushrooms, wild berries, game, or fish etc.). A few kilogramms per year could be sufficient for explaining the differences. But again the informations available (or not available) do not sustain this assumption.

5. Conclusions

a) Several discrepancies between model prediction and observations still remain after the revised calculations. We do not see how the observations available can help to further clarify the reasons for it. Of course, it would be possible to adjust some more model parameters in order to get a fairly good agreement (as it was done in Fi.9), but this wouldn't help to learn about the processes and to improve the general model performance.

b) In the adaptation of radioecological models to regions with different conditions there is risk of misinterpretation of informations (as it was with composition of silage). The more detailed informations are given, the larger is the risk that some informations are overseen.

c) The Chernobyl accident happened at a time where due to the fast development of vegetation there is large uncertainty caused by a wrong assumption of the stage of the plants' development. This is especially important for crops other than pasture grass. It is very difficult to get appropriate informations for a specific location and time (of course, this is no problem for models which do not consider the time dependence of plant growth). The time of the Chernobyl accident makes also the assumption of the beginning and intensity of summer feeding practices a very sensitive one.

d) It is very difficult to get appropriate sets of observed data for model testing. Even for the CB scenario, where very good work has been done by the colleagues providing the data and where a lot of work has been spent for statistical treatment of the data, there are only relatively few data which can be used for learning about model performance (see above). Data measured for screening purposes most often are not appropriate for model validation since the necessary boundary conditions are not known. For emergency management strategies should be developed for taking representative samples in order to have a feedback to the models and to be able to improve model predictions of foodstuff contamination and doses made in the first phase after an accident.

III.8. CLRP

1. INDIVIDUAL EVALUATION OF MODEL PERFORMANCE FOR SCENARIO CB

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2. General Model Description

2.1 Model Name: CLRP - Concentration Levels Rapid Predictions

2.2 Unique features of model structure

Dynamic processes in the model include foliar interception, weathering; plant growth and root uptake, leaching and radioactive decay. The model considers seasonal changes in the biomass of vegetation and animal diets, also specific plowing and crop-harvest dates. Human dietary data are included to permit calculation of time -dependent radionuclide ingestion rates for adult, youngster 10 years old and child 1 years old.

The CLRP model has been designed as a set of Lotus 3.1 worksheets that simulate the transport of radionuclide through agricultural ecosystems to humans.

All dynamic processes are described by exponential formulas and are solved numerically.

2.3 Intended purpose of the model in radiation assessment

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 cooperation with U.S. Environmental Protection Agency. The aim of this project was to examine the fate of long-lived radionuclides in the terrestrial ecosystem. Concentrations of Cs-137 and Cs-134 in the particular components of terrestrial ecosystem e.g. soil, vegetation, animal tissues and animal products are calculated as a function of time following deposition from the atmosphere. Based on this data the whole body contents of radionuclide as a function of time is calculated and dose to a specific organ for the radionuclide may be estimated as an integral of the resultant dose rate over a sufficient period. In addition, the model allows estimation of inhalation dose from time integrated air concentration and external dose from total deposition using simple conversion factors. The program is designed to allow the simulation of many different radiological situations (chronic or acute releases) and dose affecting countermeasure's.

2.4 Intended accuracy of the model prediction

CLRP model is deterministic and yields single estimates of specified variables.

Intended performance of the model is standard that specifies that model should not under-predict the true value by more than factor of three. Justification of standard model performance has been done based on post-chernobyl data of Poland. Further modification of the CLRP model will be made to run model with stochastic subroutine that enable to perform an uncertainty analysis.

2.5 Method used for deriving uncertainty estimates

The uncertainty estimates given for the CB scenario were derived by personal judgement of the authors considering experience with comparisons of predictions and measurements after the Chernobyl accident (on basis post-chernobyl data in Poland) and general radioecological experience. For the revised calculation the uncertainty ranges were kept the same to avoid subjective judgement as the true values of the results had been known.

3. Initial comparison of test data and model prediction

3.1. Total deposition

The change from initial results (P/O = 0.6 and not within confidence interval) and final results (P/O=0.99 and within confidence interval) is caused by the fact that used values for dry deposition velocity give as result the deposition on vegetation surface (mainly grass). Using correction factor (DEPOSITION TO BARE SOIL/DRY DEPOSITION ON VEGETATION) equal to 2.8, the mean dry deposition to bare soil for whole CB equal to 3.75 kBqm^{-2} and subsequently mean total deposition for CB equal to 5,5 kBqm^{-2} was obtained. However in our opinion, this correction does not improved prediction of total deposition for particular subregions of CB because of lack some detailed information about weather conditions and aerosol distribution in the period of interest. The initially and finally predicted values for total deposition are presented in Table A. The detailed explanations of the miss-prediction is presented in the section 4.

3.2 Major food items contributing to total diet

The comparison of predicted (both initially and finally) concentrations in milk; beef and pork are compared to observed values and are presented in Figure 1; 2 and 3 respectively. In each figure the initial prediction values are drown as a low contrast line with diamonds together with upper and lower 95% subjective confidence intervals. The final prediction values are graphed as higher contrast line with squares and observed values are graphed as unconnected thick dots with attached 95% confidence limits. Predicted to observed ratios (P/O) as well as indications if predicted values falls with confidence interval are shown in Tables 1 and 2 respectively.

3.2.1 Milk

There is over-prediction in initial calculations by a factor of about 10 during summer 1986 and even more in autumn 1986. In the subsequent years 1987 and 1989, the over-predictions increases reaching the value up to 50 in the III-th QUARTER of 1988. The results improved remarkably after correction the numeric error of retention function for dairy cow and beef cow and changing a cows' diet (see section 4), but we have got some under-predictions of the results by a factor of about 0.5 in summer 1986 and by a factor of about 0.8 in 1987. One possible explanation can be that a factor of bio-availability in the cow model was too low (0.13) and second that there was under-prediction for pasture grass (P/O=0.6) and silage(P/O = 0.3). Unfortunately, in the version IV of observed data only concentration in May and June 1986 are given and there is considerable difference in observed values between CB and B region.

Table A.

Comparison of initially and finally predicted values of ^{137}Cs total deposition for region CB

SUBREGION	TOTAL ^{137}Cs DEPOSITION TO BARE SOIL Arithmetic mean for subregion [kBq m^{-2}] OBSERVED VALUES	TOTAL ^{137}Cs DEPOSITION DRY* + WET [kBq m^{-2}] INITIAL PREDICTION	The predicted to observed values P/O INITIAL PREDICTION	TOTAL ^{137}Cs DEPOSITION DRY* + WET [kBq m^{-2}] FINAL PREDICTION	The predicted to observed values P/O FINAL PREDICTION
AB	5.82	5.5	*0,9*	7.9	*1.4*
BN	22.05	7.5	*0,3*	9.9	*0.45*
BE	1.73	1.6	*0,9*	4.0	*2.3*
KL	0.23	1.8	*7,8*	4.2	*18.3*
KO	2.11	1.7	*0,8*	4.1	*1.95*
KH	9.82	1.9	*0,3*	5.3	*0.54*
ME	2.54	1.4	*0,6*	3.8	*1.5*
MB	3.12	3.6	*1,2*	6.0	*1.9*
NB	4.34	3.1	*0,7*	5.5	*1.3*
PH	7.10	3.9	*0,5*	6.3	*0.9*
PZ	2.74	4.1	*1,5*	6.5	*2.4*
PB	0.90	1.4	*1,6*	3.8	*4.2*
RA	1.60	1.9	*1,2*	4.3	*2.7*
The mean value for whole region CB	**5.57^{+}**	**3.1**	*0.56*	**5.5**	*0.99*

*The total dry deposition calculated for the whole region CB on the vegetation surface was equal to 1.34 [kBq m^{-2}]

$^{+}$The arithmetic mean of 5.57 kBqm^{-2} with 95% confidence interval bounds (lower 4.05 kBqm^{-2}; upper 7.66 kBqm^{-2}} was finally evaluated for whole region CB

The over-prediction of milk in May 1986 (P/O = 1.3) might be caused by the fact that feeding restrictions were introduced in CB until mid-May, but assumption of these restrictions was no sufficient to improve predictions for milk.

3.2.2 Beef

The comparison of predicted and observed data (Figure 2 and Tables 1,2) gives similar discrepancy for initially predicted data for beef as for milk, but finally predicted results after cows model correction shows under-prediction in May 1985 by factor of 0.3 and over-prediction by factor less than two in autumn 1986 and winter 1987 as well as slightly under prediction in the rest of 1987. In 1988/89 it is difficult to notify any over and under predictions due to the big variability and uncertainty of observations.

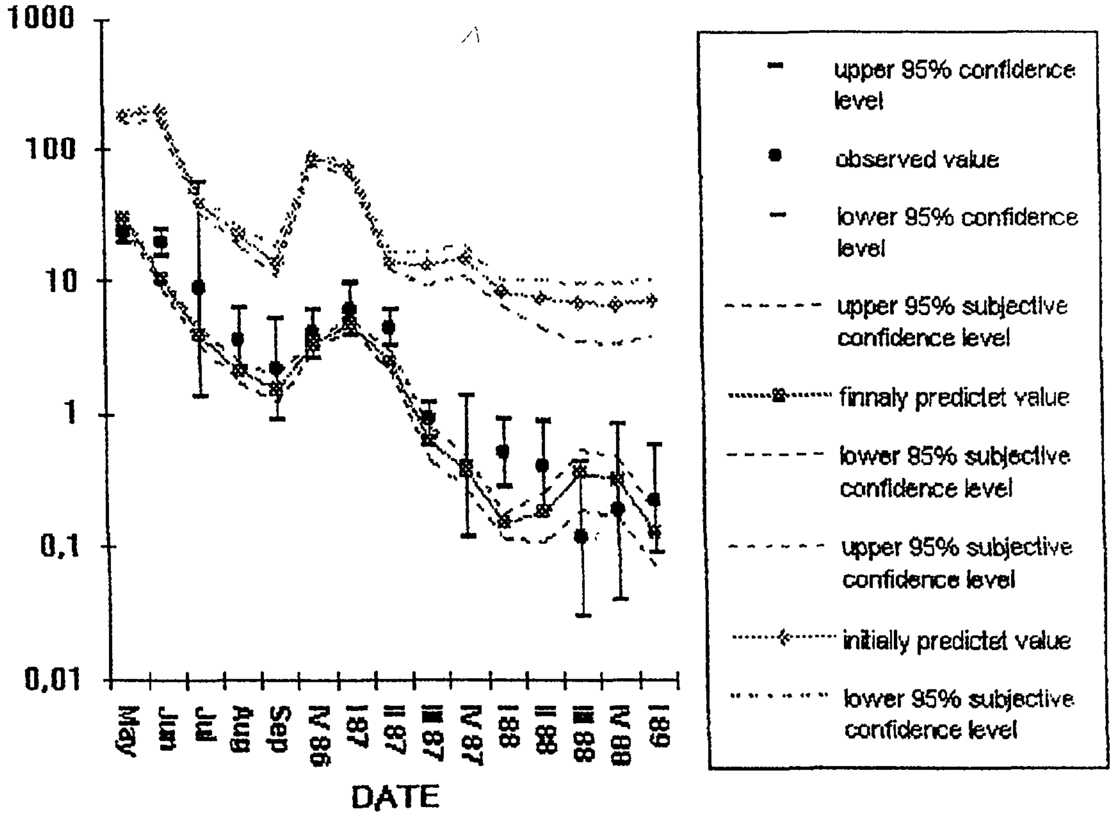

Fig. 1. A comparison of model predictions against observations for the concentration of Cs-137 in MILK in region CB

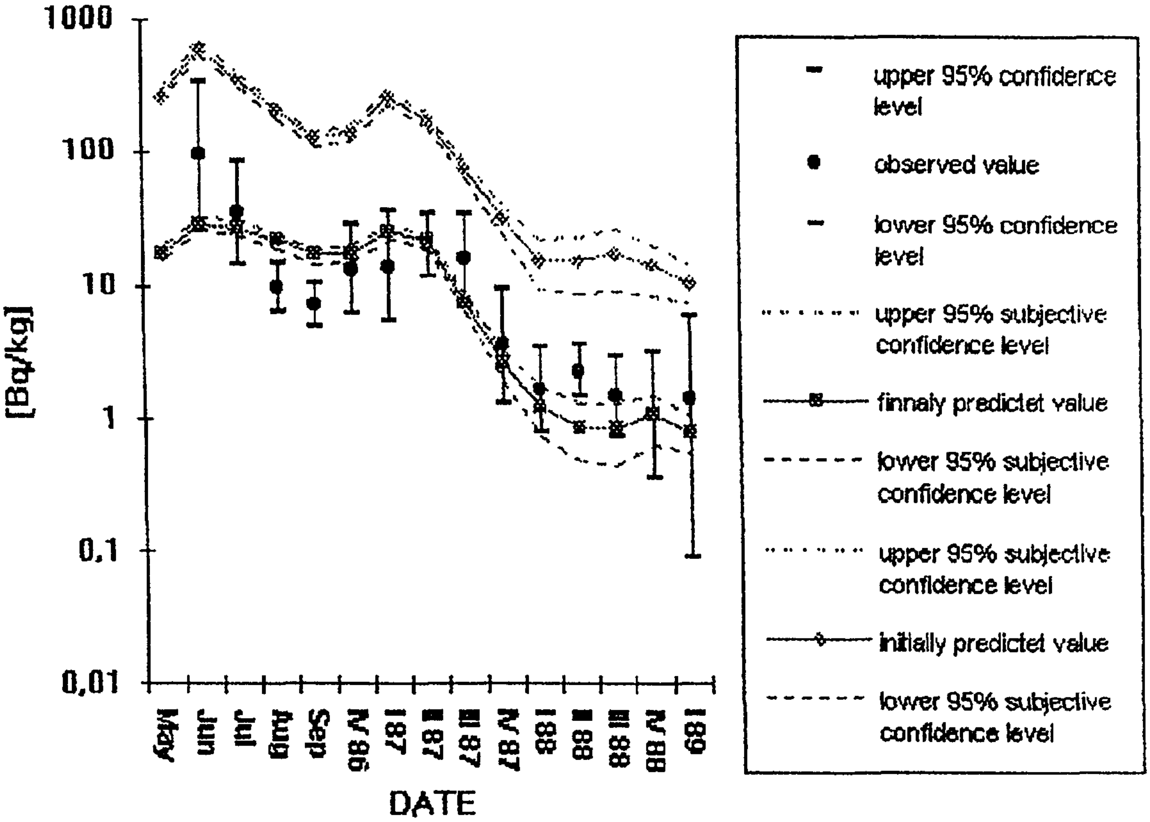

Fig. 2. A comparison of model predictions against observations for the concentration of Cs-137 in BEEF in region CB

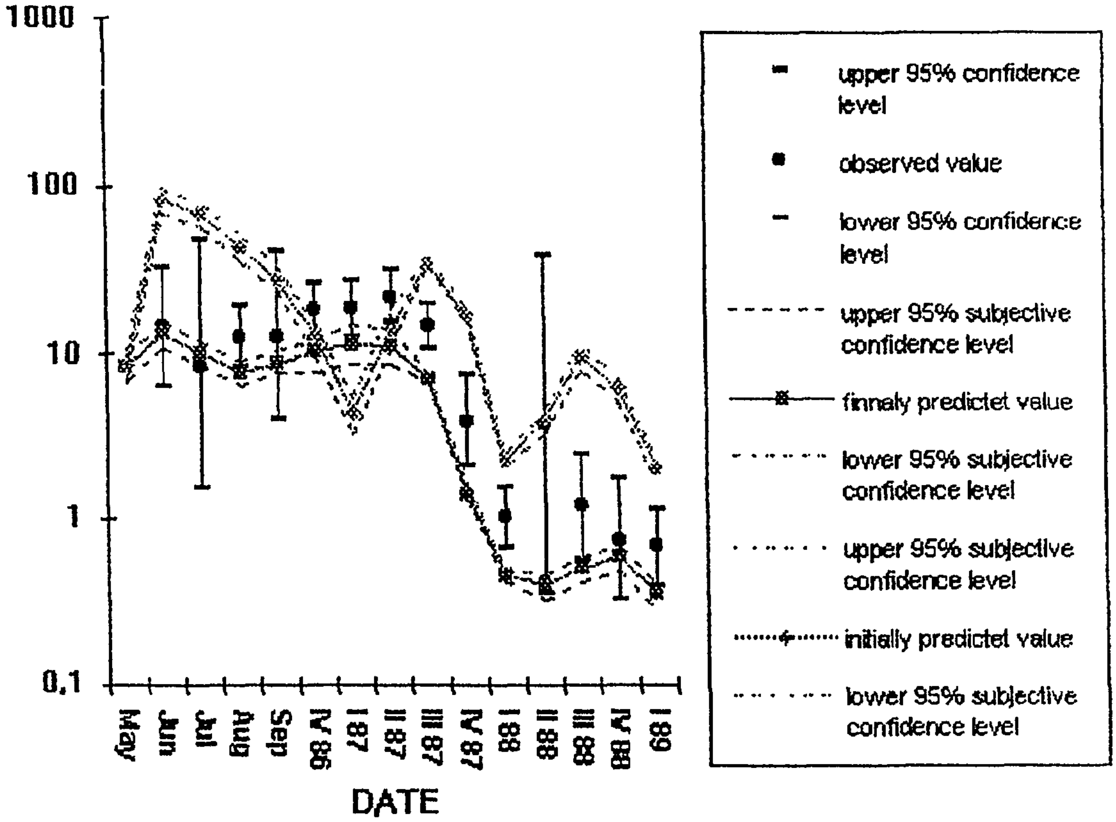

Fig.3. A comparison of model predictions against observations for the concentration of Cs-137 in PORK in region CB

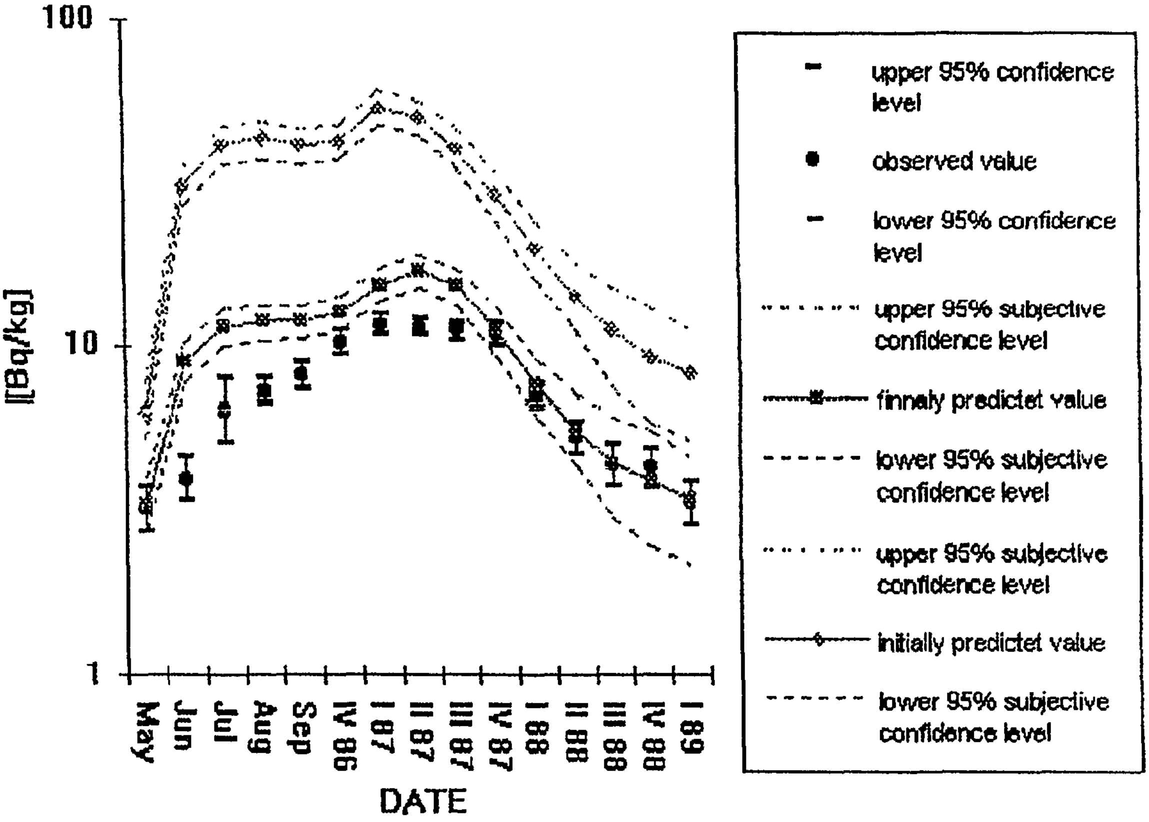

Fig. 4. A comparison of model predictions against observations for the concentration of Cs-137 in WBC in region CB

Table 1. Summary of the results initially predicted by the model

Date	MILK		BEEF		PORK		WBC	
	P/O	C	P/O	C	P/O	C	P/O	C
1986 May	8	NO	-	-	-	YES	2 0	NO
June	10	NO	6	NO	5 7	YES	7 8	NO
July	4	NO	10	NO	8 0	YES	6 4	NO
August	6	NO	21	NO	3 4	NO	5 9	NO
September	6	NO	18	NO	2 2	YES	5 1	NO
IV	22	NO	10	NO	0 7	NO	4 2	NO
1987 I	12	NO	18	NO	0 2	NO	5 6	NO
II	3	NO	9	NO	0 6	NO	4 4	NO
III	14	NO	5	NO	2 4	NO	3 6	NO
IV	37	NO	10	NO	4 4	NO	2 7	NO
1988 I	16	NO	10	NO	2 2	NO	2 9	NO
II	18	NO	7	NO	1 1	YES	2 7	NO
III	56	NO	12	NO	8 1	NO*	3 5	NO
IV	34	NO	14	NO	8 4	YES*	2 2	NO
1989 · I	32	NO	8	NO	2 9	NO*	2 4	NO

DATE	L VEG		W WHEAT		S BARLEY		SILAGE		EN HEY		P GRASS	
	P/O	C	P/O	C	P/O	C	P/O	C	P/O	C	P/O	C
1986	not comparable		0,8	NO	0 9	YES	0 6	YES	1 3	YES	0 8	YES
1987	not comparable		27	NO	18	NO	0 07	YES	0 8	YES	no observed data	

Table 2. Summary of the results finally predicted by the model

Date	MILK		BEEF		PORK		WBC	
	P/O	C	P/O	C	P/O	C	P/O	C
1986 May	1 3	NO	-	-	-	-	1 0	YES
June	0 5	NO	0 3	YES	0 9	YES	2 2	YES
July	0 4	YES	0 8	YES	1 2	YES	1 8	NO
August	0 6	NO	2 2	NO	0 6	NO	1 6	NO
September	0 7	YES	2 4	NO	0 7	YES	1 5	NO
IV	0 8	YES	1 3	YES	0 6	NO	1 2	NO
1987 I	0 8	YES	1 8	YES	0 6	NO	1 3	NO
II	0 6	NO	1 1	YES	0 5	NO	1 5	NO
III	0 7	NO	0 5	YES	0 5	NO	1 4	NO
IV	0 9	YES	0 7	YES	0 4	NO	1 0	YES
1988 I	0 3	NO	0 7	YES*	0 4	NO	1 1	NO
II	0 5	NO	0 4	NO*	0 1	YES	1 0	YES
III	3	YES	0 6	YES*	0 4	NO*	1 0	YES
IV	1 7	YES	1 0	YES*	0 8	YES*	0 9	YES
1989 I	0 6	YES	0 6	YES*	0 5	NO*	1 0	YES

DATE	L VEG		W WHEAT		S BARLEY		SILAGE		EN HEY		P GRASS	
	P/O	C	P/O	C	P/O	C	P/O	C	P/O	C	P/O	C
1986	not comparable		0 7	NO	0 6	YES	1 3	YES	1 3	YES	0 6	NO
1987	not comparable		2 4	YES	1 6	NO	0 3	YES	0 8	YES	no observed data	

Yes indicates prediction falls with confidence interval, NO that it does not *Test data of [CB-B]

3.2.3 Pork

The comparison of predicted and observed Cs-137 concentrations in milk and pork (Figures 1, 3; Tables 1,2) shows that milk prediction have strong influence on concentration Cs-137 in pork as whey is the most important component for pig's diet in CB scenario. Therefore, there is also over-prediction in initially calculated data by a factor of 6 in June 1986 and by a factor of 8 in July 1986. In addition the dynamic response of the initial pig model was poor due to simplification in feeding regime of pigs (see section 4) .

3.3 Other items of specific interest

3.3.1 Grain

The predicted and observed Cs-137 concentrations in 1986 for winter wheat and spring barley are presented in Tables 1,2 . There is slightly underestimation both for initially and finally predicted values for harvest 1986 (P/O equal to 0.8, 0.7 respectively). In 1987 and following years, when only root uptake and resuspension had influence on plant contamination, there is overestimation of the results by factor of 27,18 in initially predicted results and overestimation of factor two in finally predicted results. Further analysis of grain contamination is presented in section 4.

3.3.2. Fruits

The predictions for fruits show necessity of reexamination of fruits' model. It will have little effect on the while body due to quantities ingested.

3.3.3 Leafy vegetables

The task of the validation was to predict the monthly mean of Cs-137 concentration in leafy vegetables. In the observed values only a one number for "harvest 1986" and for "harvest 1987" are available. Also the observed values consisted of a mixture of washed and unwashed vegetables and they seemed to be not representative for the initial contamination. Additionally we could observe different ^{137}Cs concentrations depending on the type of leafy vegetables as lettuce, cabbage; spinach and other. Also the agricultural practice e.g. plant in an open area or in a green house and the date of harvest (especially in 1986 when surface contamination is important) can change the leafy vegetables contamination.

Therefore it seems that yearly averages over all types of leafy vegetables are absolutely not representative and say almost noting about the model performance. The comparison of predicted (initially and finally) as well as observed values is presented in Table 3. We can see how yearly average changes depending on type of vegetable and date of harvest and agriculture practices. Therefore, from point of view the model validation, it seems to be more valuable to carry out a comparison between particular plants' types then comparing yearly averages.

3.4 Whole body concentrations

The comparison of predicted (both initially and finally) and observed whole body concentrations are compared to observed values and are presented in Figure 4. Predicted to observed ratios (P/O) as well as indications if predicted values falls with confidence interval are shown in Tables 1 and 2 respectively. Initially predicted whole body ^{137}Cs concentrations

Table 3: Comparison of predicted and observed values for Leafy Vegetables

Cs137 Concentration in LEAFY VEG.: Region CB

HARVEST	X (Bq kg -1 f.w.) Cabbage Open Area	HARVEST	X (Bq kg -1 f.w.) Lettuce Green House	X (Bq kg -1 f.w.) Lettuce Open Area	HARVEST	X (Bq kg -1 f.w.) Spinach Open Area	HARVEST	X (Bq kg -1 f.w.) Yearly average for Total Leafy Vegetables Including Lettuce in a Green House	X (Bq kg -1 f.w.) Yearly average for Total Leafy Vegetables Including Lettuce in an Open Area	X (Bq kg -1 f.w.) Yearly average Observed values
31-Jul-86	4,33	01-Jun-86	45,39	446,17	30-May-86	494,66				
		15-Jul-86	4,81	5,42	01-Aug-86	8,09	1986	71,76	122,01	240,00
		30-Aug-86	4,78	5,32	20-Oct-86	7,26				
		15-Oct-86	4,55	4,79						
31-Jul-87	0,10	01-Jun-87	0,42	0,42	30-May-87	0,63				
		15-Jul-87	0,41	0,41	01-Aug-87	0,60	1987	0,44	0,44	0,50
		30-Aug-87	0,40	0,40	20-Oct-87	0,57				
		15-Oct-87	0,38	0,38						
31-Jul-88	0,08	01-Jun-88	0,35	0,35	30-May-88	0,61				
		15-Jul-88	0,34	0,34	01-Aug-88	0,49	1988	0,36	0,36	#N/A
		30-Aug-88	0,33	0,33	20-Oct-88	0,46				
		15-Oct-88	0,32	0,32						

overestimate observed values by factor about six in the II -nd and III-th QUARTER of 1986, by factor about 5 in 1987 and by factor about three in 1988. It reflects the general overestimation of main diet components e.g milk beef and pork. Our final whole body Cs-137 concentration is over-predicted by factor 1.5 + 2 for II-nd Quarter of 1986 and by factor 1.5 for 1987 despite of under-predictions of diet components. Because we took on account the diet restriction of about 60% until the mid of May so there is evidence that probably food processing and storage might have more effect on reducing the ^{137}Cs intake than it has been assumed, also very high daily consumption rate reported in the scenario description is matter of discussion.

4. Major sources of miss-prediction

Deposition

The mean value of 3.1 kBq was initially estimated for whole region CB as an average calculated from evaluated values for thirteen subregions CB. The dry deposition velocity in a range of ($2.2\ 10^{-4}$ + $2.2\ 10^{-3}$ ms^{-1}) depending on wind speed (1 + 15 ms^{-1}) respectively and wet deposition washout rate in e range ($3.3\ 10^{-6}$ + $8\ 10^{-5}$ [s^{-1}]) depending on a rain intensity range (0.1 +7.0 [mmh^{-1}]) were used . These values were taken from H.Bonka and H.G.Horn DEPOSITION VELOCITY AND WASHOUT RATIO COEFFICIENT OF RADIONUCLIDES BOUND TO AEROSOL PARTICLES AND ELEMENTAL RADIOIODINE; Radiation Protection Dosimetry Vol.21 No 1/3 pp. 43-49 (1987) for assumed log-normal aerosol distribution D_{ae} equal to (0.45 ± 0.75 μm).

The rain pattern data for each subregion was used also the wind speed data from station 518 was extended for whole region CB and the rain intensity was arbitrary set as equal to 1 mmh^{-1}.
The P/O value for initial prediction was 0.56 (assuming the last estimate of total deposition for CB equal to 5.57 kBq m^{-2}). The underestimation was caused by the fact that used values for dry deposition velocity give as result the deposition on vegetation surface (mainly grass). Therefore for final prediction of the total deposition to bare soil a correction was made related to grass maturity on 30 April. Assuming yield of the grass of 0.16 kg d.w m^{-2} and using the Chamberlain equation we obtained the correction factor (DEPOSITION TO BARE SOIL/DRY DEPOSITION ON VEGETATION) equal to 2.8 . This gave us the mean dry deposition to bare soil for whole CB equal to 3.75 $kBqm^{-2}$ and subsequently the mean total deposition for CB equal to 5,5 $kBqm^{-2}$. Therefore the P/O value was equal to 0.99 but there is still some doubt concerning correct prediction for particular subregions of region CB. For example when we consider only subregion AB as the region with the best evaluation data of air contamination and weather conditions (rain and wind data) there is overprediction of total deposition by factor of 1.4. Also for some subregions (KH; PB; KO; MB) the over prediction of total deposition is almost twice. Unfortunately there is no data concerning the rain intensity and wind speed for another twelve subregions of CB so it is very difficult to check the model performance from this part of the task. Nevertheless, the value of 5.5 $kBqm^{-2}$ as the best estimate for total deposition was used in evaluation of plants as well as milk, beef and pork contaminations in final prediction for whole region CB.

Milk & Beef:

There were probably two sources of overestimation the initial predictions.

One it was a formula error in the cows model that affected about five fold our predictions for milk although the dynamic response is good enough.

In the initial calculation the retention function for dairy cow was as follow:

$R(t)= 0.003*\exp(-^{\ln(2)}/_{2[d]})$ that gives equilibrium factor equal to <u>0,88%</u> [d/l] whereas the formula should be $R(t)=0.002*\{0.22*\exp(-^{\ln(2)}/_{2,2[d]}*t)+0.005*\exp(-^{\ln(2)}/_{35,2[d]}*t)\}$ that gives equilibrium factor equal to <u>0.2%</u> and this formula was used in the final calculation.

The second factor which caused the overestimation of ^{137}Cs concentration in milk was the misunderstanding of the cow's diet component namely ensilaged crops. In the initial prediction, this component was considered as a silage which consists of <u>alfalfa</u> , <u>clover</u> and <u>pasture vegetation.</u> These plants had elevated level of ^{137}Cs concentration of in May and June of 1986 (in order of 1.0 kBqkg^{-1} f.w). Because of high daily intake rate of the silage, the different composition of this component e.g. maize and pasture beets (with relatively low ^{137}Cs concentrations) will change milk and beef predictions remarkably. There is also some confusing information about dry matter contents comparing previous and final version of scenario CB. In the final version of scenario CB is reported that hay and ensilaged hay have 72% of dry matter content whereas in previous version of scenario CB, the seasonal intake rate for ensilaged hay indicates that this component is now considered as a silage with only 45% of dry matter content. Comparison of feeding regime for dairy and beef cow assumed in the initial predictions with the values item used in the final predictions is presented in the table below. All values are expressed in (kg day^{-1} fresh weight).

	DAIRY COW				BEEF COW			
	SPRING		WINTER		SPRING		WINTER	
PREDICTION	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL
ensilaged crops (defined as ensilage in firs version of scenario) in initial predictions it was considered as a silage)	not specified	2	not specified	25.0	not specified	7.0	not specified	15.0
ensilaged hay (defined as a silage in final version of scenario)	2.0	1.0	8	4	2.0	1	3.0	4
silage composition in wet weight: alfalfa 5%; clover 17%; maize 45%; beets 33%	5	1.0	25	4	7	1	16.0	4

Cereals

In the initial calculations a constant value of translocation rate for whole vegetation period equal to 0,025 [m^{-2}/m^{-2}d^{-1}] was used whereas in the final predictions the translocation rate varied according a specific normal distribution function . It does not remarkably affected the calculation as in the period of high deposition e.g from 29-April-86 to 1-May-86, this function yields similar values. Only the confidence interval become wider because of more sensitive model response on the assumed date of start growing and developing of the plants. In the initial prediction for 1987 and following years a plowing practice was not taken in to account that yielded too high ^{137}Cs concentration in soil. In the final predictions the plowing factor was introduced and 10 time dilution of radioisotope in soil by the first plowing after initial contamination was taken in to account. This improved the P/O values for harvest 1987. Previously assumed the soil-to-plant Bv ratio equal to 0.05 [kg soil d.w/kg plant f.w] both for winer wheat and spring barley caused the overestimation by factor two in finally predicted cereals results for harvest 1987, but this quantity is site specific variable with a wide range of uncertainty and we are not intended to fit model parameters to the observed values.

Pork:

Apart of over-prediction of ^{137}Cs concentration in whey, the poor dynamic response of pig model was caused by the fact that a simplification was made related to pig growing and feeding practice: the first cohort from 1-May to 1-November and the second cohort from 1-November to 1-May. It gives sharp variation in the initially predicted values at the time-point of changing feeding periods. We improved the pork model by introducing six cohorts of pigs fed in six periods each starting next two months, so we have got a better dynamic response of final predictions and also better P/O ratios. Although underprediction in finally calculated data by factor of about 0.6 in autumn 1986 and 1987 and by factor of about 0.4 in 1988 might be again caused by under-predictions in milk as well as under-predictions in barley in 1986.

4.1. Recommendations for changes to the model

Summary for changes made in the CLRP model when final prediction was performed.

i. User interpretation of CB scenario
  a) log-normal aerosol activity distribution D_{ae} equal to (0.45 ± 0.75 μm) for 29-30 April 1986.
  b) changed ensilaged crops composition and daily intake rate for dairy and beef cow.
  c) human diet restriction until 15-May-1986
ii. Changes made to the model
  a) time dependent plants' translocation factor
  b) introducing the plowing factor that reducing isotope concentration in soil
  c) corrected formula error in dairy and beef cow retention functions
  d) changing the pork model
iii. Improvements that could be made in the future

Designing a stochastic version of the model to be able to perform an uncertainty analysis.

4.2 Examples of how changes improve calculations

The results of the changes can be compared on Figures 1-4. Predicted to observed ratios (P/O) as well as indications if predicted values falls with confidence interval are shown in Tables 1 and 2 respectively.

5. Conclusions

The prediction made from CLRP were reasonable although initial results seams to be too conservative. The correct deposition calculations need additional detailed information about aerosol distribution activity and weather conditions and it is still crucial point of the model predictions. The next parameters of model sensitivity are growing and harvest date of the plants but these factors are more combined with proper interpretation of the scenario input data and they are less critical for well known region (for instance own country). Generally, in further model comparison, the voluntary interpretation of input data should be minimized by making scenario more simple- may be limited to the smaller region with the best evaluated input and observed values.

The clear, well evaluated observed data are absolutely necessary before any model comparison is performed. Despite of lack of some detailed information concerning measured data of particular components (for instant :pasture grass; alfalfa, particular species of leafy vegetables comparison between models on the base of scenario CB has given unique opportunity to check the model performance and gain additional knowledge about processes occurring in terrestrial ecosystem. Hovever sever corrections of the model base on CB data alone seems to be risky since these data may be characteristic for this particular region of Central Bohemia. We might believe that a model's performance will improve as many different scenarios it passes but the most profitable advantage of the VAMP Multi-pathway-task is the exchange of knowledge and experiences during the discussionis among the international participants as well as quick access to the latest results of scientific work performed by other VAMP groups.

III.9. LINDOZ

1. EVALUATION OF LINDOZ PERFORMANCE FOR CB SCENARIO

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2. General model description

2.1 Name of the model: LINDOZ
Developer: Dan Galeriu
Users: Authors

2.2 Unique features of model structure
In order to obtain realistic estimate, LINDOZ model is structured at process level with compartments and transfer rate oriented to describe transfer process and to include the influence of physics and chemical properties of pollutants or local characteristics. As an unique feature, the model include explicitly the initial solubility (related to speciation) of fallout particle and gases. Also it includes a preliminary plant growth model and the influence of meteorological factors.

2.3 Intended purpose of model in radiation assessment
LINDOZ model has been developed as a realistic assessment tool for radiological purposes to be applied in routine or accidental emissions. The model provides the concentration of pollutants in terrestrial ecosystem (soil, vegetation,animal tissues and animal products), concentration in whole body of humans due to inhalation and ingestion, external irradiation from cloud and soil. A specialized part for TRITIUM transfer in ecosystems is now under development and validation.

2.4 Intended accuracy of model prediction
As LINDOZ is developed for realistic assessment, the intended accuracy is near a factor 2-3, and depend on the quality and quantity of input data and local characteristics.

2.5 Method uses for deriving uncertainty estimates
The confidence interval is evaluated by judgment for all the parts. Uncertainty analysis was done in first phase using Monte-Carlo method. Finally a complete analysis for whole-body module was done using LHS technique. Sensitivity tests (oriented for dose variability) and validation runs (Romanian post Chernobyl data, Biomovs A4 and VAMP) had proven the possibility to obtain desired accuracy.

2.6 References describing detailed documentation model
For each module a description of initial version is available in romanian (internal reports) and essential information was given in: - BIOMOVS conference Stockholm 1990 : Upgrading LINDOZ model using BIOMOVS A4 scenario, D Galeriu et all

- LINDOZ model description VAMP working document 1991

3. Initial comparison of test data and model prediction

The initial results must be regarded in correlation with an underestimation of wet deposition due to an old and incorrect parameterization.

3.1 Total deposition

Initial prediction gives a predicted/observed ratio P/O=0.85 and the respective value is in the confidence interval of test data. While the data suppliers had estimated the total deposition from the lognormal soil data, a best estimate must include the contribution of dry retention on vegetation. This is quite difficult to do but from ECOSYS team contribution and our estimate we can assume a total deposition of 6.-6.4 kBq/m . The P/O decrease to aboui 0.73.

3.2 Major food items contributing to total diet

In the table nr.1 the P/O ratio is given. If the predicted value is included in the confidence interval find 'yes' in CI column.

TABLE nr.1

Initial P/O=predicted to observed; CI=confidence interval

Date	MILK		BEEF		PORK		WBC	
P/O CI	P/O	CI	P/O	CI	P/O	CI	P/O	CI
1986 May	1.3	no	0.4	-	-	-	1.2	yes
June	0.7	yes	0.6	yes	1.2	yes	1.8	no
July	1.0	yes	0.9	yes	1.6	yes	1.2	yes
Aug	1.0	yes	2.0	no	0.6	no	1.2	no
Sept	1.2	yes	2.0	no	0.45	yes	1.0	yes
1986 IV	1.7	yes	1.1	yes	0.85	yes	1.0	yes
1987 I	1.6	yes	1.6	yes	1.0	yes	1.2	no
II	1.3	yes	0.8	yes	0.9	yes	1.95	no
III	4.1	no	0.6	yes	1.1	yes	1.68	no
IV	5.0	yes	1.6	yes	2.0	no	1.15	no
1988 I	2.2	yes	1.6	yes	2.5	no	1.17	no
II	2.0	yes	0.8	yes	0.61	yes	1.1	yes
III	4.0	yes	0.2?	yes	0.4	yes	0.95	yes
IV	2.5	yes	0.2?	yes	1.0	yes	0.7	yes
1989 I	2.0	yes	0.9	yes	0.8	yes	0.65	yes

3.3 Other items of specific interest

3.3.1 Cereals

The prediction for winter wheat was 1.5 times greater than observation in 1986, outside CI. In the following years overpredictions of 4-5 were obtained. For spring barley some underprediction occurred: 0.55 (CI yes) in 1986 and 4 in 1987. Note that in the data analysis made by O.Hoffman in July 1991 the arithmetic mean for 1986 barley was lower and we are in good agreement with this estimate (P/O 1.2 in CI).

3.3.2 Leafy vegetables

The scenario end point was not clear; initially we are asked for monthly mean but finally the data was for annual mean. Also we are asked for unwashed vegetables, but observed data were mixed (washed and unwashed). The reported annual mean of 240 Bq/kgfw in 1986 is 4 times greater than our prediction and due to large uncertainty we are in CI. We observe that in Hoffman analysis the mean values for II-IV quarters are 93,120 and 3.4 Bq/kgfw in clear contradiction with the above annual mean and more close with our prediction.Also we note that many of data for leafy vegetables are from spinach, a vegetable with high initial contamination.

3.3.3 Fruits

Same as all modelers we are far of a good prediction for fruits. In 1986 we underpredict by 5 times and in the following years we are in reasonable agreement. Fruits are subject of intense foliar absorption and translocation, not included in our previous model.

3.3.4 Animal feed

One of weak point of CB scenario is the scarcity of information for pasture vegetation. The data for May and June are only from the Institute garden, and there are some doubts if they are representative for whole CB (CB mean) .If we consider this data we underpredict the May concentration by two fold and the June one by 3 fold, outside CI. But as we had underpredicted the wet interception this is fully explained. For hay we predict in 1986 an annual mean of 300 Bq/kg dw, corresponding to approx 160 Bq/kg for ensilaged hay while the observed value is 4 times higher. Same comment on wet deposition is valid.For silage we had supposed a mixture of green maize and beet leaf and due to agricultural practice the concentration is low. The P/O ratio is near 1 if we assume that data on ENSILAGED CROPS are representative. But if reported SILAGE data are considered we underpredict by 10 fold. As the representative value for silage is doubtful from observed data (see also the big difference between CB and B) it seems that a comparison between data and prediction is misleading

3.4 Whole body concentrations

3.4.1 Mean whole body concentration

The concentration in whole body is well predicted for more than half of time steps in the CI. Due to underprediction of wet interception (affecting animal products) we realize that human intake or metabolic model contain processes responsible for the overprediction of the observed data. The input scenario ignores any information related to food interdiction or limitation and we are obliged to make assumptions. We supposed only a 50 % limitation in milk and leafy vegetables for the first 14 days. It is possible that volultary limitation of contaminated food consumption was prolonged due to psychological stress. For mid 87 the overprediction seems to be related to overprediction of animal products in winter 86-87

3.4.2 Distribution of whole body concentrations

The whole body model was also run in stochastic version. We had used all our experience from Romanian data : distribution of milk, meat and grain activity at some reference points as well as distribution of diet items contribution and of human metabolic parameters. The mean values and variance of food items distribution was scaled in respect to CB predictions and the mean values of diet items was lowered by 15 %, as compared to input scenario . The resulted distribution of Whole body activity was statistically treated in an approximate way, as we were not clarified (in 1991) how to treat CI for lognormal distribution. The good prediction on whole body distribution is due to our experience with Romanian data (3400 measurements in IAP and some 5000 from other institutes) used for initial model calibration.

3.5 Inhalation dose. While it is not a direct measurable quantity, we compare our prediction with the best estimate done by the data supliers and also by H. Mueller (2.9 μSv with C.I. 0.74-6.2). Our initial estimate of 1.5 μSv is in good agreement as we included a filtration factor and inhalation rate adapted to various activities and ocupational group. Due to a mistake in the code, we subevaluated by a factor of 2. Considering now the best estimate of integrated air concentration (lower than our initial one) and the corect code result, an underestimation of 30 % is obtained, very satisfactory.

3.6 External dose from contaminated soil. Again we use the best estimate as before, of 230 μSv and C. I. of 68-660, comparing very favourable with our prediction of 190 μSv . We have included a detalied scheme for occupancy factors and shielding factors and we consider the effect of radionuclide migration in soil.

4. Explanation of major sources of misprediction

4.1 Major misprediction

a) The major source o misprediction was our old parameterization for wet deposition. It was deduced from wrong assumption and scarcely data we had in 1988. The parameterization suppose that for a very low rain intensity we must obtain the same interception as for dry deposition. We had adopted the wet interception from ECOSYS, which reasonably fits also the data from Oak Ridge for more intense rain. In CB condition the wet interception was increased by a factor 2.3. In the cereal and plant model, developed in 1989-1990, the wet retention was correctly estimate BUT we simply FORGOT to make the change in pasture model!.

b) Another source of misprediction was the initially assessment of the total deposition in CB using only the soil data. The lognormal distribution was analyzed, but we had used arithmetic mean from the row data. It follows that we slightly underestimate 4.8 kBq visa 5.5 KBq from lognormal distribution parameters. Later we also include the contribution of dry deposition on vegetation, in a similar manner as in ECOSYS. The new mean deposition is close to 6 kBq/m . For simplicity we use the same dry deposition for all vegetated soil (excepting forest).

4.2 Improvements

a) for dry deposition and interception

Improvements done for dry deposition and interception:The usual Chamberlain equation used for many vegetation types, is in contradiction with some new experimental data (RESSAC program in France) as well as with general theoretical considerations (See e.g. Sehmel,Bonka,Underwood). For the RESSAC data a satisfactory correlation with leaf area index was observed, prior to plant maturity. For cereals and fruit vegetables we must include explicitly the interception to this plant parts (time dependent). As leaf area index and interception are dependent on plant growth, we also introduced a preliminary plant growth model (for pasture, hay, cereals).

In assessing the mean deposition on vegetated surfaces we consider explicitly the roll of dry and wet interception. The distribution of plant deposition was obtained starting from the distribution of soil deposition. We assume that area with soil deposition less than 0.64 kBq/m were not affected by rain, and the main wet deposition was in 30 April. With a washout ratio of 5 10 and the leaf area index corresponding for pasture in 30 April we obtain an arithmetic mean plant initial deposition of 2.52 kBq/m , corresponding to 4.74 kBq/m total deposition. This correspond with 75% from the arithmetic mean of total deposition.

b)plant contamination at harvest

- introduction of a senescence loss for pasture and hay, when cows are not on pasture.
- introduction of a growth rate parameter obtained from experimental data (Festuca, Lolium) with a time dependence according to climate conditions in CB
- chosen the same growth rate for alfa-alfa and clover components of green fodder as for Festuca.
- revision of rate constants for migration and fixation in soil. The fixation rate is 10 times lower than the first value and the migration rates are mean values of Romanian data. All this changes affects the model prediction for the following years after fallout.
- a consistent treatment of the solubility of initial fallout. is now considered for pasture, hay (grass, alfalfa or clover) and vegetables. External plant surface and surface soil layer is divided in two compartments: one for receiving soluble form of contaminant; one for insoluble form . Foliar absorption is active only for the soluble form of pollutant while field loss affect both forms. The time dependence of plant contamination is followed and the net result is a gradual increase of soluble fraction in plant which influence bioavailability. As a major consequence it follows directly that grains are more digestible than hay or grass in the first year. Also the variation of transfer factor for milk and meat in the first year is a natural result and corresponds with observation in Europe.
- introduction direct interception for ear
- consideration of the mass of ear according to experimental data
- contribution of modified leaf and steam interception for cereals
- introduction of a "evapo-transpiration" loss rate and a vaxy cuticle loss rate for internal plant compartment (leaf and steam)
- introduction of a direct transfer rate (foliar absorption of ear and translocation) from external to internal compartment of ear. This improves the time dependence of grain concentration (related to fallout period) and also gives the correct ratio between grain and straw contamination. It is important when straw is consumed by cow, as in CB and mainly in Romania.

c)animal diet

- composition of cow and beef diet:

-green fodder in summer: fresh pasture vegetation, alfalfa, and clover

-ensilage in winter: 2/3 green maize, 1/3 beef leaf

-hay and ensilaged hay: 25% hay from grass, 40% clover, 35% alfalfa

-cereals: 1/2 winter wheat, 1/2 spring barley

- reduction of daily intake given in input scenario to 67%, in order to obtain mass and energy balance for a cow producing milk 10l/day in temperate climate.

d) Whole body deterministic and stohastic calculations.

We have improved our model prediction for CB in many aspects:

- human diet was considered for a 3000 Kcal/day, reduced at 75 % from the input scenario after a revision of human methabolism. The diet items were established for both fresh and stored foods. For milk 60 % is consumed fresh after 3-4 day delay, 23 % as cheese after 3 month and the rest as powdered milk (produced in summer and consumed in winter). For mweat 10 % is stored for one year and the rest is consumed after 1 month. 20 % from vegetables and 40 % from fruits are canned and consumed after 1 year. No food interdiction or limitation was used, as we have no clear information from the scenario. Food processing factors were considered after the last VAMP tecdoc.
- human methabolic parameters were introduced in the retention function starting with a revision of all experimental data. The uptake factor for the rapid loss compartment was established at 0.145 and the half time at 1.9 d while for the long retention comparment we use 93.6 d (in spite of ICRP model with 110 d). The long retention compartment contribute with more than 99 % to the body burden and our result are 25 % lower than using ICRP parameters.
- for the stohastic calculation we use now the corect approach with Latin Hipercube sampling and full lognormal analysis of result (inluding corect estimate of confidence interval). The initial distributions of model parameters for biological half time and diet was taken from recent reviw papers while the distributions for various food items concentration was derived from basic judgement and analysis of experimental data in Romania. By analysing the effect of wet retention (non linear with rain) , mixing in large industrial processing factory etc. we obtain the lognormal distribution with σ values lower than those from deposition on soil.

4.3 Examples of how changes improve calculation

a)pasture vegetation - the initial predictions were till 3 times smaller. The improved model over predict now with less than 50%.For the worth new predictions: May 86 P/O = 1.44 CI no June 86 P/O = 1.46 CI no

b)hay and ensilaged hay (dry matter equivalent)

harvest 1986 P/O=0.72 CI yes
harvest 1987 P/O=0.3 CI yes

c)spring barley

harvest 1986 P/O=0.55 CI yes
harvest 1987 P/O=2.99 CI no

For spring barley the arithmetic mean in 1986, obtained by O. Hoffman give P/O=0.7 ; the large number of'less than' can affect the evaluation.

d)winter wheat

harvest 86 P/O=1.72 CI no
harvest 87 P/O=2.4 CI yes

e)milk, beef and pork

The improved data are available in table nr. 2 and in figure nr.1 for "milk", figure nr.2 for "beef", figure nr.3 for "pork".

f)Whole body concentrations

The results of the deterministic model are given in Table 3 for the computed concentration of food items (pred I) and for the observed one (pred II). By analysing both predictions in respect with observed whole body concentrations some sistematic differences can be explained as seasonal diet effects or as a more prolonged storing time for some produces.

The results of the probabilistic calculation are given in the Table 4 as parameters of the lognormal distribution. The predicted to observed value of the σ parametre compare very favourably, when observed population sample is representative. The cumulative distribution is also very close of the observed one.

5. Conclusions

The CB scenario was a major test for our model but , much more important, we begun to understand the main aspect of the assessment task: the careful analysis of the input scenario data, the consistency chek of each information in the general context; the need of a basic understanding of processes and local parameters governing the transfer of radionuclides from atmosphere to man, the continous feed-back between output and imput. The free exchange of information with the data supliers and other modelers was a key point for improving our strategy for a realistic assessemnt.

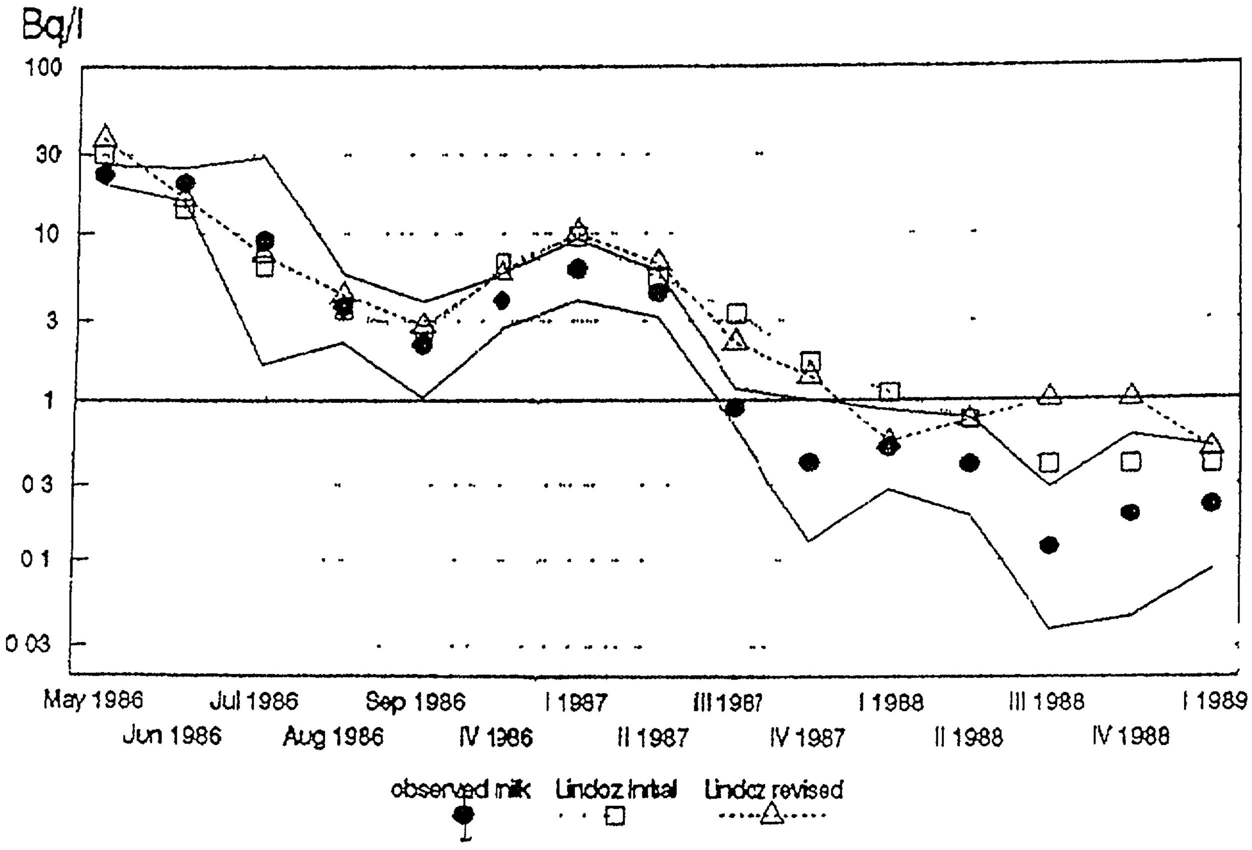

FIG. 1. Cs-137 concentration in milk.

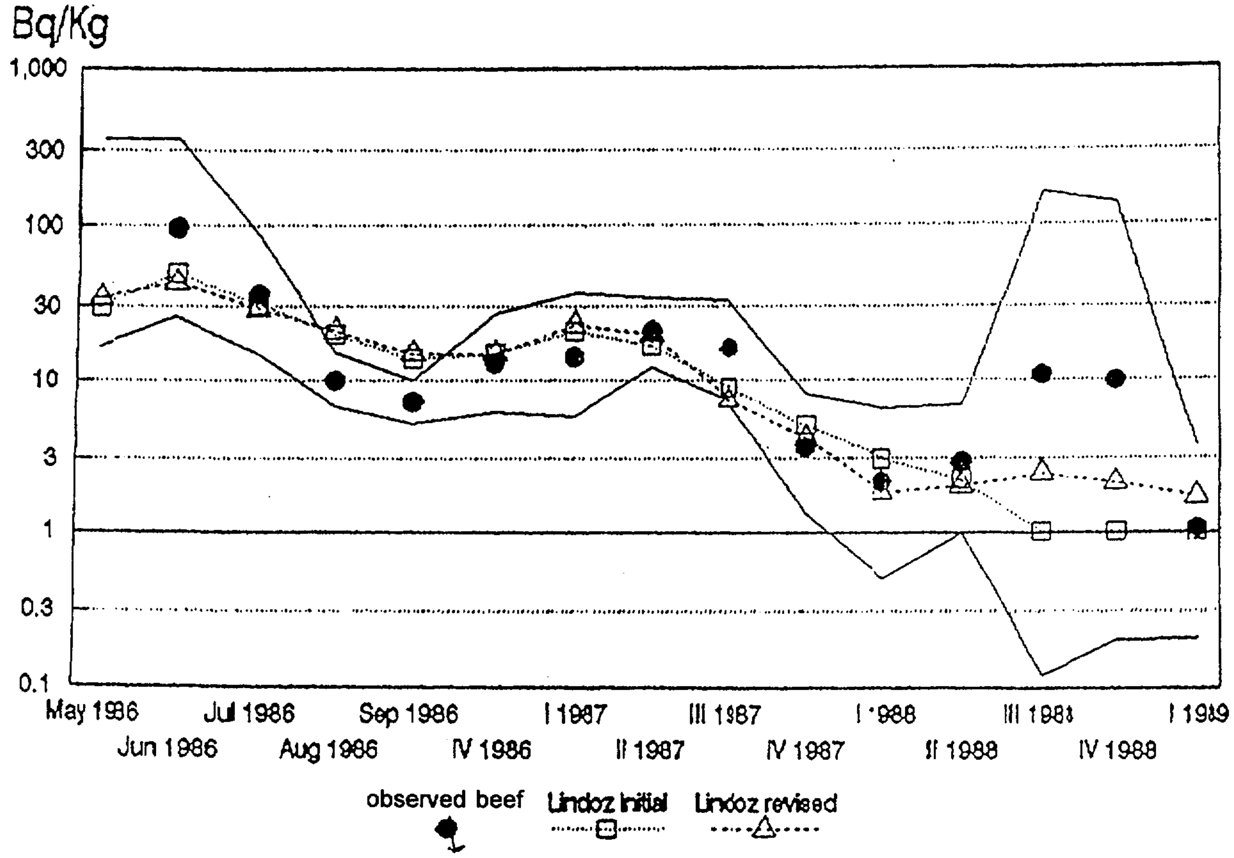

FIG. 2. Cs-137 concentration in beef.

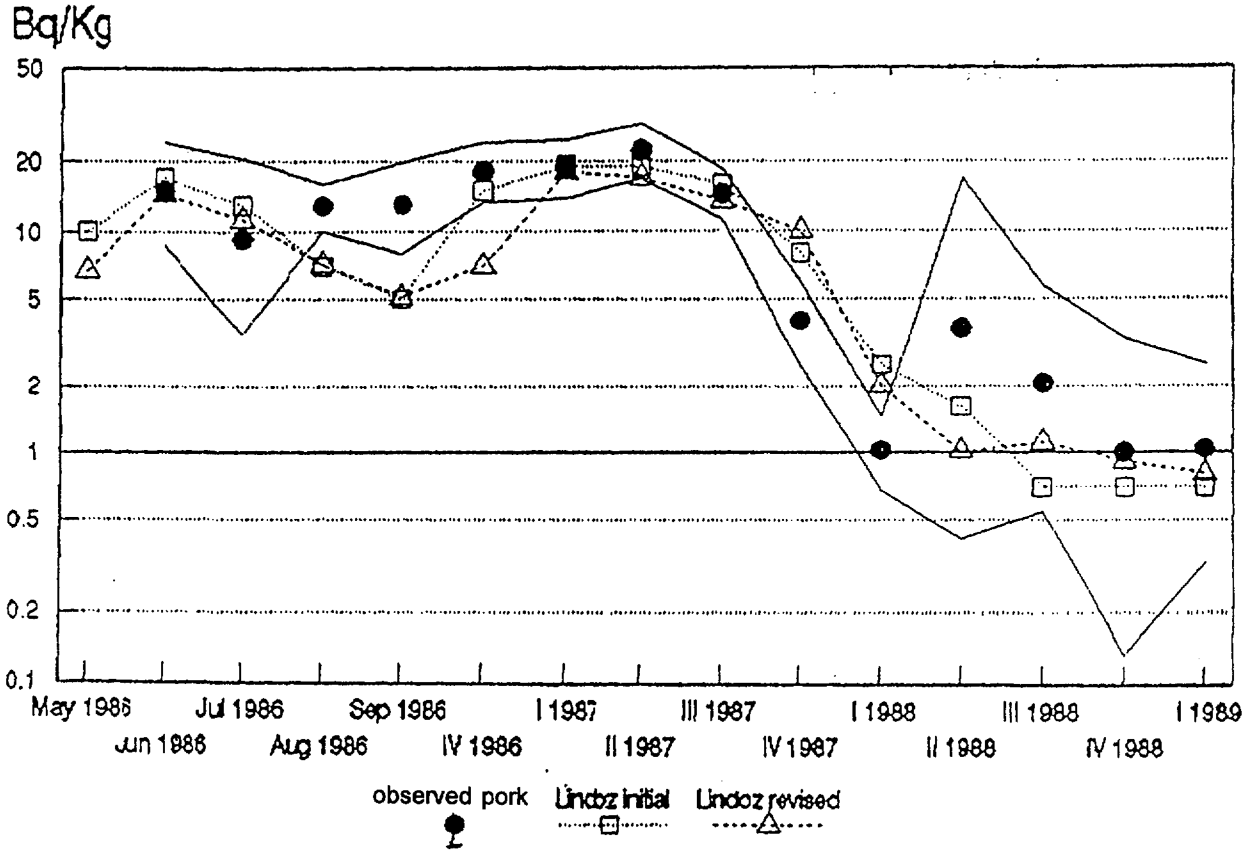

FIG. 3. Cs-137 concentration in pork.

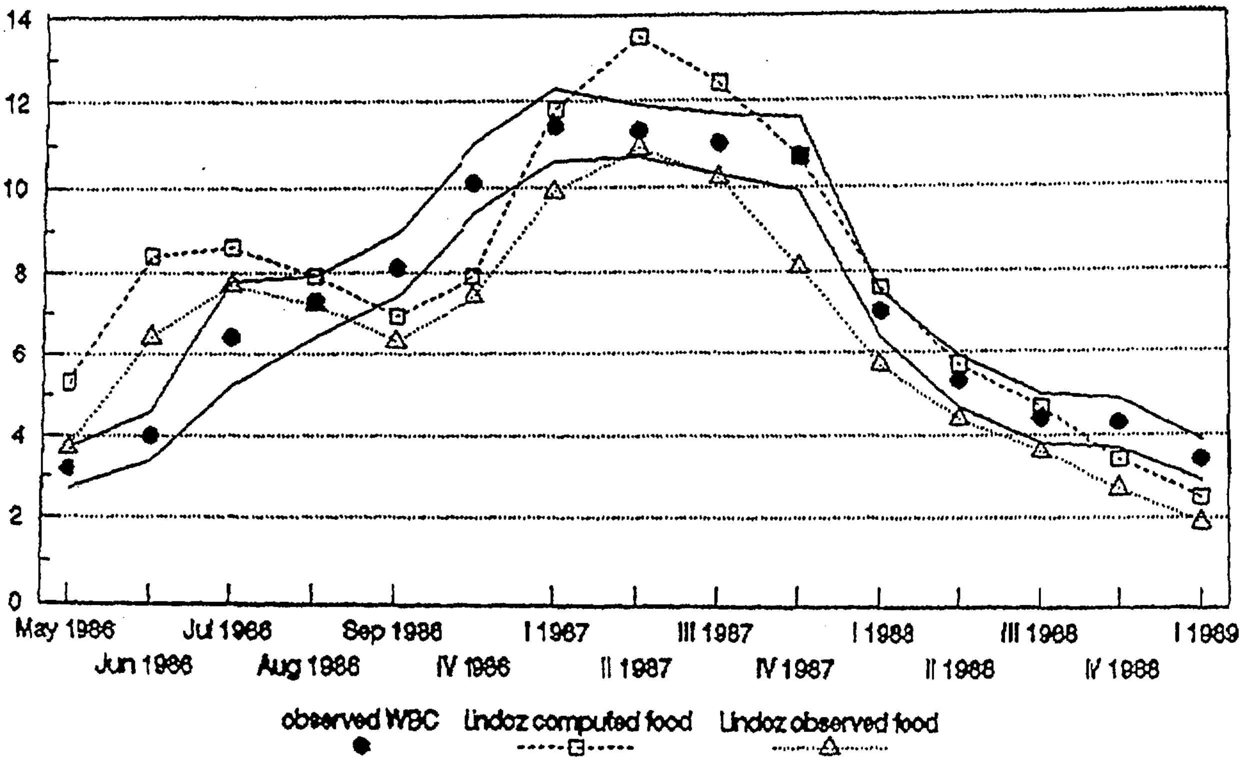

FIG. 4. CB whole body concentration.

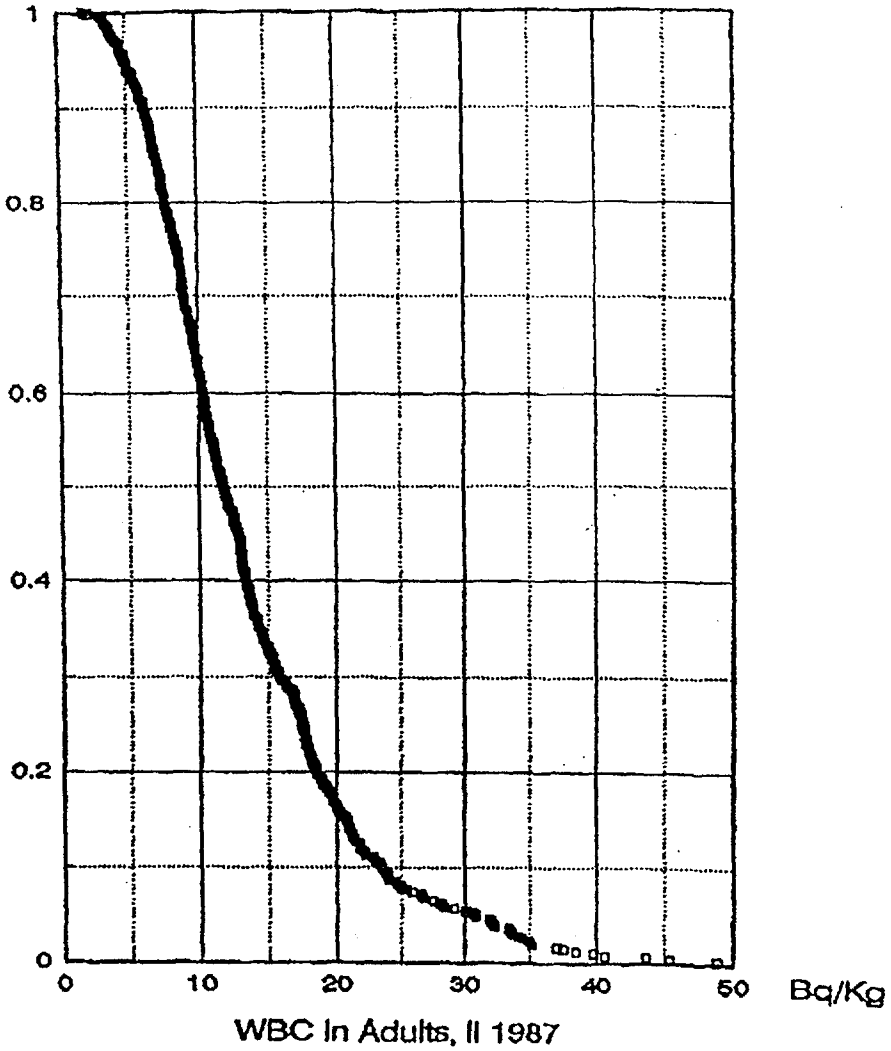

FIG. 5. Complementary cumulative distribution function.

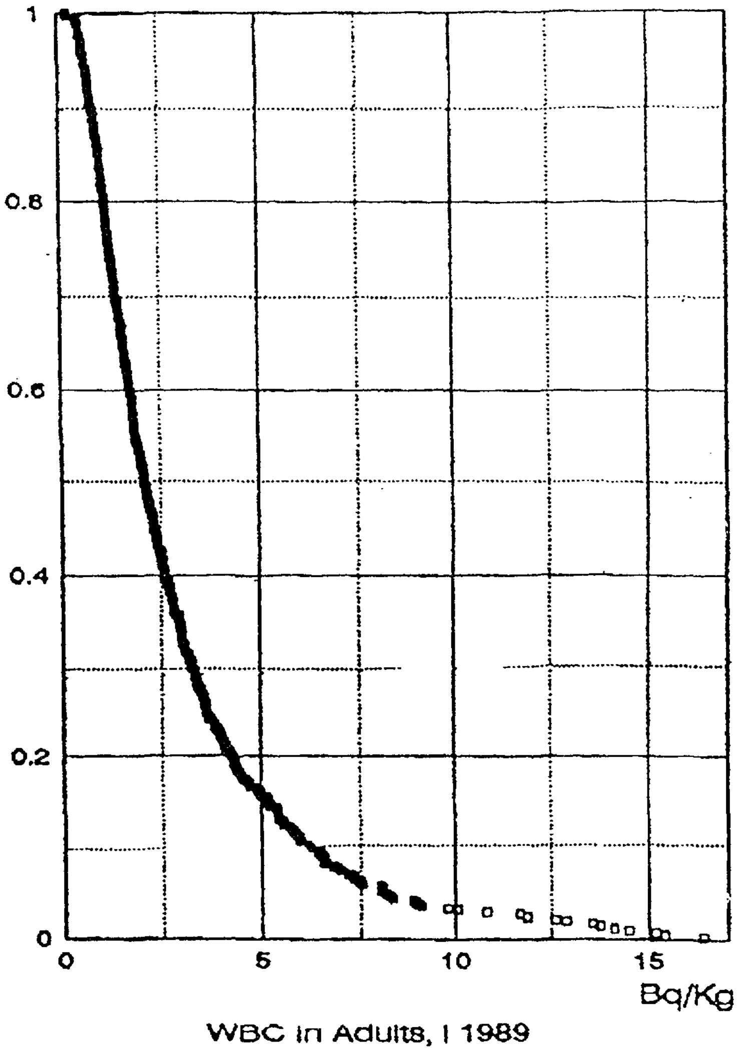

FIG. 6. Complementary cumulative distribution function.

TABLE nr II
Improved P/O

MILK	BEEF		PORK			
date	P/O	CI	P/O	CI	P/O	CI
1986 May	1.64	no	n.a.		n.a.	
June	0.8	yes	0.45	yes	0.98	yes
July	0.83	yes	0.8	yes	1.21	yes
Aug.	1.2	yes	2.1	no	0.55	no
Sept	1.3	yes	2.0	no	0.4	no
1986 IV	1.47	yes	1.1	yes	0.43	no
1987 I	1.63	no	1.6	yes	0.96	yes
II	1.5	no	1.0	yes	0.77	yes
III	2.44	no	0.46	yes	0.93	yes
IV	3.4	no	1.2	yes	2.5	no
1988 I	1.08	yes	0.85	yes	7.0	no
II	1.87	yes	0.72	yes	0.26	yes
III	8.0	no	0.22	yes	0.5	yes
IV	5.0	no	0.21	yes	0.9	yes
1989 I	3.0	no	1.6	yes	0.8	yes

TABLE nr III
Whole body concentration; deterministic calculations Bq/kg
pred I = computed food concentration
pred ii = observed food concentration

Date	pred I	pred II	obs - range
May 86	5.3 N	3.7 Y	3.2 (2.7-3.7)
June	8.4 N	6.4 N	4 (3.4-4.6)
Jul	8.6 N	7.7 Y	6.4 (5.1-8)
Aug	7.9 Y	7.2 Y	7.3 (6.6-8)
Sept	6.9 N	6.3 N	8.1 (7.3-9)
IV	7.9 N	7.4 N	10.1 (9.4-11)
I 87	11.8 Y	9.9 N	11.4 (10.6-12.3)
II	13.5 N	10.9 Y	11.3 (10.7-12.)
III	12.4 N	10.2 Y	11. (10.2-11.7)
IV	10.7 Y	8.1 N	10.7 (9.8-11.6)
I 88	7.6 N	5.7 N	7. (6.4-7.5)
II	5.7 Y	4.4 N	5.3 (4.7-5.8)
III	4.7 Y	3.6 N	4.3 (3.8-5)
IV	3.4 N	2.7 N	4.3 (3.7-4.9)
I 89	2.5 N	1.9 N	3.3 (2.9-3.9)

TABLE nr IV
Whole body concentration; stohastic model
geometric mean (m), geometric standard deviation(s)
arithemtic mean (E) and his C I; variance (D)

date	m	s	E(m,s)	CI	D	P/O s
May 86	1.5	0.55	5.22	4.80- 5.67	9.71	0.93 Y
June	1.94	0.58	8.21	7.71- 8.97	27.22	
Jul	1.99	0.54	8.45	7.78- 9.17	24.50	
Aug	1.90	0.55	7.70	7.08- 8.37	20.7	1.4 N
Sept	1.75	0.57	6.77	6.20- 7.38	17.3	1.8 N
IV	1.91	0.56	7.87	7.49- 8.27	22.9	1.24 N
I 87	2.34	0.52	11.8	11.27-12.34	43.1	
II	2.48	0.54	13.7	13.06-14.36	60.8	
III	2.38	0.58	12.8	12.16-13.47	66.4	
IV	2.22	0.63	11.2	10.58-11.85	61.3	
I 88	1.88	0.69	8.3	7.79- 8.84	42.3	1.2 N
II	1.58	0.73	6.4	5.98- 8.84	28.3	
III	1.39	0.73	5.3	4.95- 5.67	19.3	1.1 Y
IV	1.09	0.75	3.9	3.64 4.18	11.8	1.14 Y
I 89	0.79	0.76	2.9	2.70- 3.11	6.8	1.12 N

Cumulative distribution

	II ’87		I ’89	
fractile	X	CI	X	CI
2.5	33.64	32.07 - 35.29	9.83	9.10 - 10.6
32.	15.25	14.63 - 15.97	3.16	2.96 - 3.27
50.	11.92	11.42 - 12.43	2.21	2.08 - 2.34
68.	9.29	8.89 - 9.70	1.54	1.44 - 1.64
97.5	4.22	4.02 - 4.42	0.49	0.46 - 0.54

III.10. PRYMA

1. EVALUATION OF PRYMA MODEL'S MERFORMANCE FOR CB SCENARIO

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CIEMAT - Environmental Research Institute,
Madrid, Spain

2. GENERAL MODEL DESCRIPTION

2.1 Name of model, model developer, model user

PRYMA models for pathways AIR-FOOD, AIR-PASTURE, AIR-FEED (except pasture).
Authors: García-Olivares,A.J.; E.Carrasco; A.Suáñez; J.L.Font & D.Cancio.

Models for cereal, beef and milk are NRPB models.
Authors: Simmonds,J.R.; G.S.Linsley & J.A.Jones

"PORKY": Model for Pork was made for this exercise.
Authors: García-Olivares,A.J.; E. Carrasco, B.Robles & I.Simón.

The rest of the calculations were made for this exercise by E.Carrasco et al., IMA/CIEMAT Madrid, Spain.

2.2 Unique features of models structure

We calculate the concentrations everyday and for selected periods we estimate the average over the entire area.

These models use ordinary first-order differential equations for all the transfers except the root uptake where daily equilibrium is assumed. We used concentration factors for calculating the poultry and egg concentration.

The main parameters have been selected from bibliographic sources.

2.3 Intended purpose of the model in radiation assessment

They are deterministic, best-estimate compartment models.

2.4 Intended accuracy of the model predictions

Intended accuracy of predictions is to a factor of 2.

2.5 Method used for deriving uncertainty estimates

Uncertainty analysis can be applied to the model using the range of input parameters.

2.6 References describing detailed documentation of model

Reference for PRYMA MODEL first version: "PRYMA: Modelo de transferencia terrestre desarrollado para el programa internacional BIOMOVS" Cancio,D.; E.Carrasco, J.Ll.Font, A.J.García-Olivares & A.Suáñez. International Conference on Environmental Radioactivity in the Mediterranean Area. Barcelona, Spain, May 88.

"PRYMA-TO: A model of radionuclide transfer from air into foodstuff. Test with data from the Chernobyl accident". García-Olivares,A.J.; E.Carrasco & A.Suáñez. Editora del CIEMAT, Madrid 93 (to be published).

Models for cereal, beef and milk reference: "The influence of season of the year on the transfer of radionuclides to terrestrial foods following an accidental release to atmosphere" Simmonds. Chilton, NRPB-R121 1985.

"PORKY" model for pork is based on data from "Contamination of pork by Caesium radioisotopes" Viktor Kliment, Institute of Hygiene and Epidemiology-Centre of Radiation Hygiene. Czechoslovakia. J. Environmental Radioactivity 13 (1991).

3. INITIAL COMPARISON OF TEST DATA AND MODEL PREDICTIONS

3.1 Total deposition

The prediction for total deposition due to all CB is 7584 Bq m^{-2}, very close to the upper bound. The P/O ratio is 1.4 and the value of the prediction falls in the 95% confidence interval on the observations.

3.2 Major food items contributing to total diet

3.2.1 Milk

Figure 1 shows curves of predicted and observed concentrations in milk.

A total of 12 out of 15 of the predictions at the prescribed times correspond to a factor between 0.45 and 2.5 of the observations and 9 out of 15 predictions fall within the 95% confidence interval. In this last version of our calculations we used a different dynamic model to calculate milk and beef concentrations and this new model adjusts much better than the old one that we used before. These two models are very different NRPB models. The old model used compartments for the liver, meat, milk, lung and the G.I. tract. The new model (more recently published) has two compartments for soft tissues. One of them is for the diffusion from the blood to the rest of the body and the other for a slower concentrating mechanism. It has two compartments for the G.I. tract representing the stomach and the intestines. It also has a compartment for the lung and another compartment for circulating fluids.

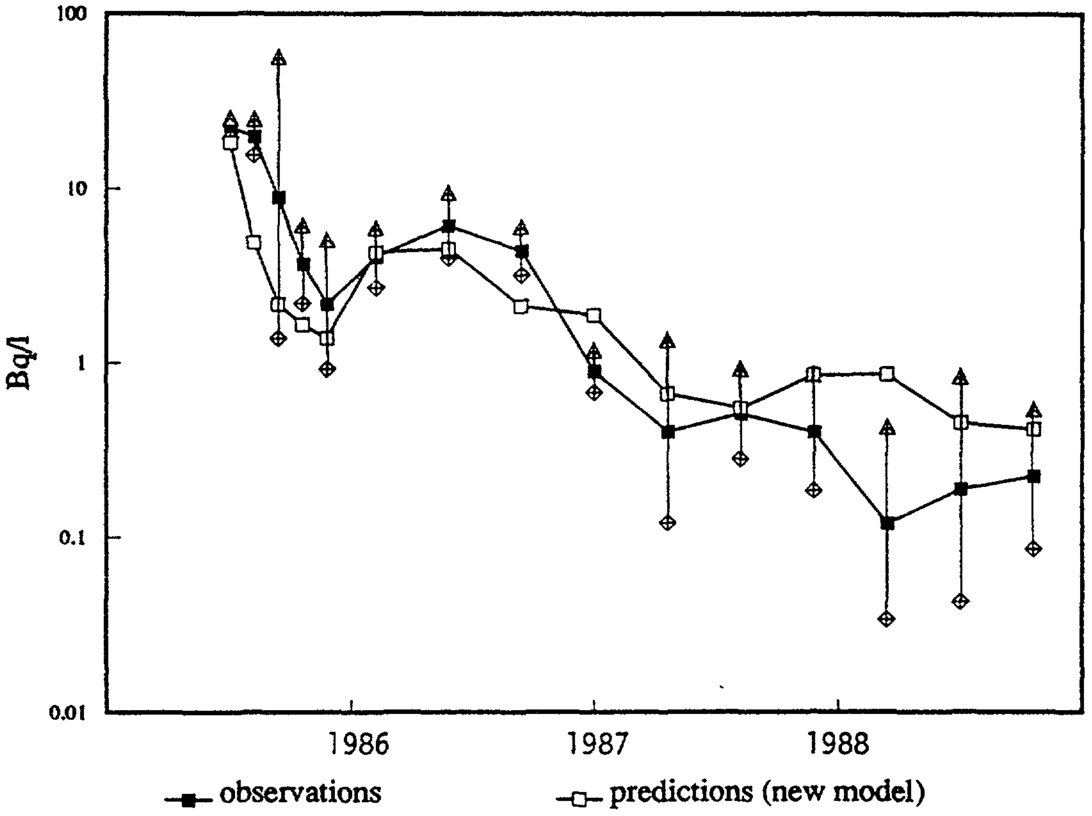

FIG. 1. Milk concentration (predicted and observed).

With this model the results have the same dynamics as the observations although the model underpredicts until the third quarter of 1987 and overpredicts (slightly) the rest of the time.

3.2.2 Beef

Figure 2 shows curves of predicted and observed concentrations in beef.

A total of 6 out of 14 of the predictions at the prescribed times correspond to a factor between 0.45 and 2.5 of the observations and 5 out of 14 predictions fall within the 95% confidence interval. We used the same model for milk and beef; the only difference is the milk-cow diet because the beef-cow eats different amounts of each product (silage, fresh pasture, roots, etc) and the total amount is smaller. We used 200 kg as the weight of soft tissues. This may be too small. The NRPB model uses 360 kg and with that number the results fit the observations much better (all the P/O ratios fall within a factor between 0.41 and 3.01, whereas 9 out of 14 fall within a factor 0.5-2.0, and 11 out of 14 predictions fall within the 95% confidence interval). Figure 3 shows the improvement in the fit using 360 kg of cow soft tissues weight.

The results for beef show overprediction except for the first value but the dynamics is more or less the same, although at the end the curve of the predictions does not fall so sharply as the curve of the observations. This means that the model correctly responds to the large differences in the input due to seasonal changes.

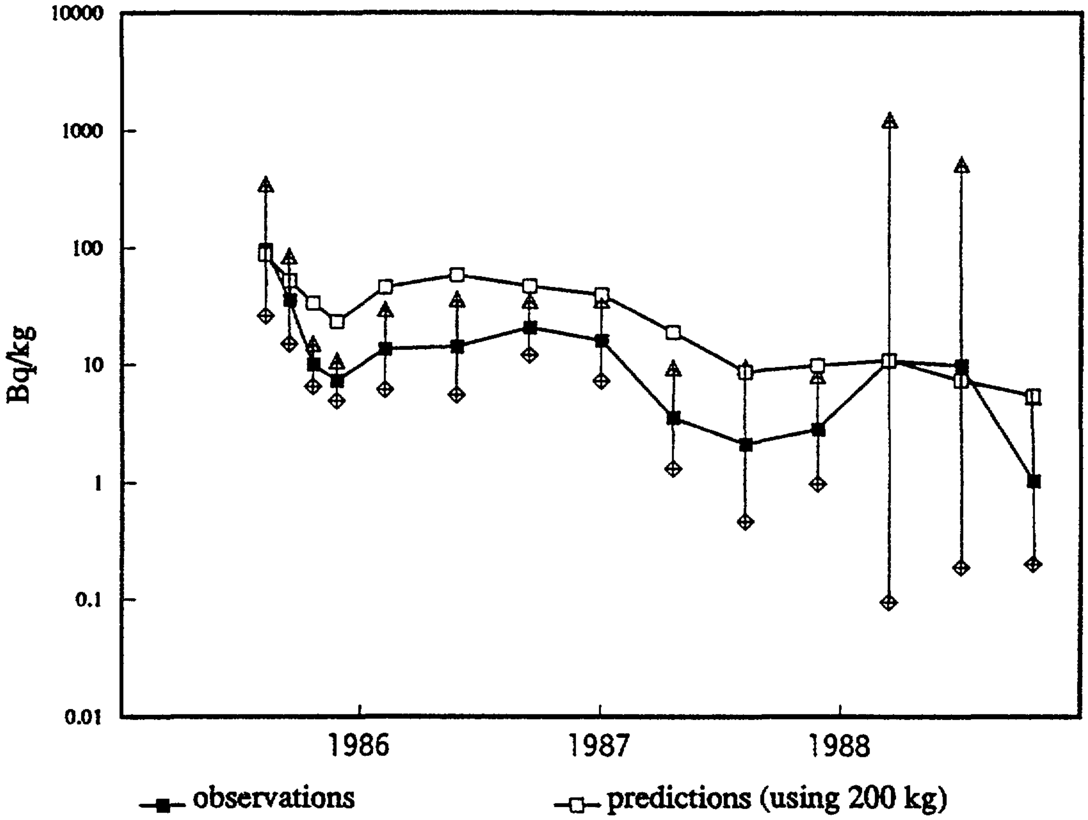

FIG. 2. Beef concentration (predicted and observed).

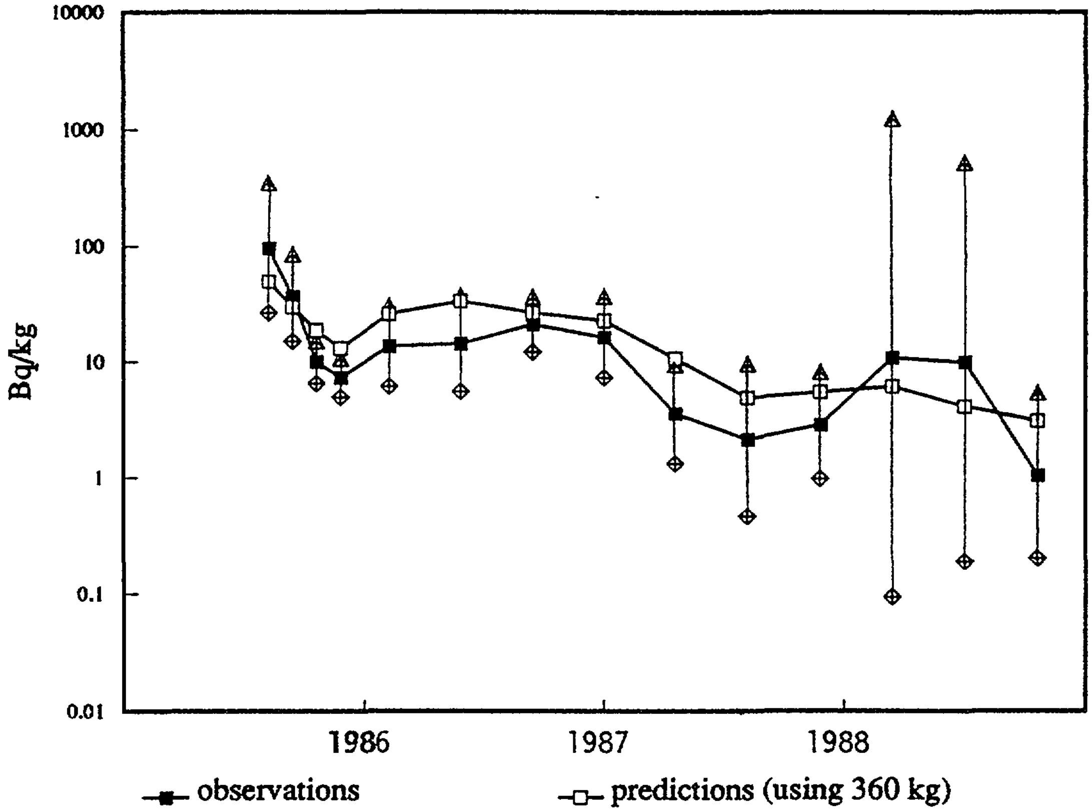

FIG. 3. Beef concentration (predicted and observed).

3.2.3 Pork

Figure 4 shows the curves of predicted and observed concentrations in pork.

A total of 7 out of 13 of the predictions at the prescribed times correspond to a factor between 0.45 and 2.5 of the observations but only 3 out of 13 predictions fall within the 95% confidence interval. We made a simple model for these calculations and it failed at the begining months. The results for the six first months are smaller than they should be. According to the model the accumulation in the pig meat is continuou and gradual for six months (life time of the pig before slaughtering) and we need to work more on it to adjust the first six months. Figure 5 shows the aspect of the curve when the pig is being fed on the observed values of cereal and milk. It fits much better and we may conclude that the model, except in the first six months, works quite acceptably.

3.3 Other items of specific interest

The list of P/O ratios is given here for the rest of the calculations with observations to compare with.

	P/O	Does the prediction fall within the 95% confidence interval of the observations?
Leafy vegetables		
Harvest 1986	1.47	yes
Fruit		
Harvest 1986	0.40	no
Harvest 1988	2.42	yes
Pasture		
May 1986	0.69	no
Cereal		
Winter wheat		
harvest 1986	0.62	yes
harvest 1987	0.97	yes
Spring barley		
harvest 1986	0.47	yes
harvest 1987	0.58	no
Silage		
harvest 1986	1.31	yes
harvest 1987	0.43	yes

3.4 Whole body concentrations

3.4.1 Mean whole body concentrations

Figure 6 shows the comparison of predicted and observed concentrations in whole body.

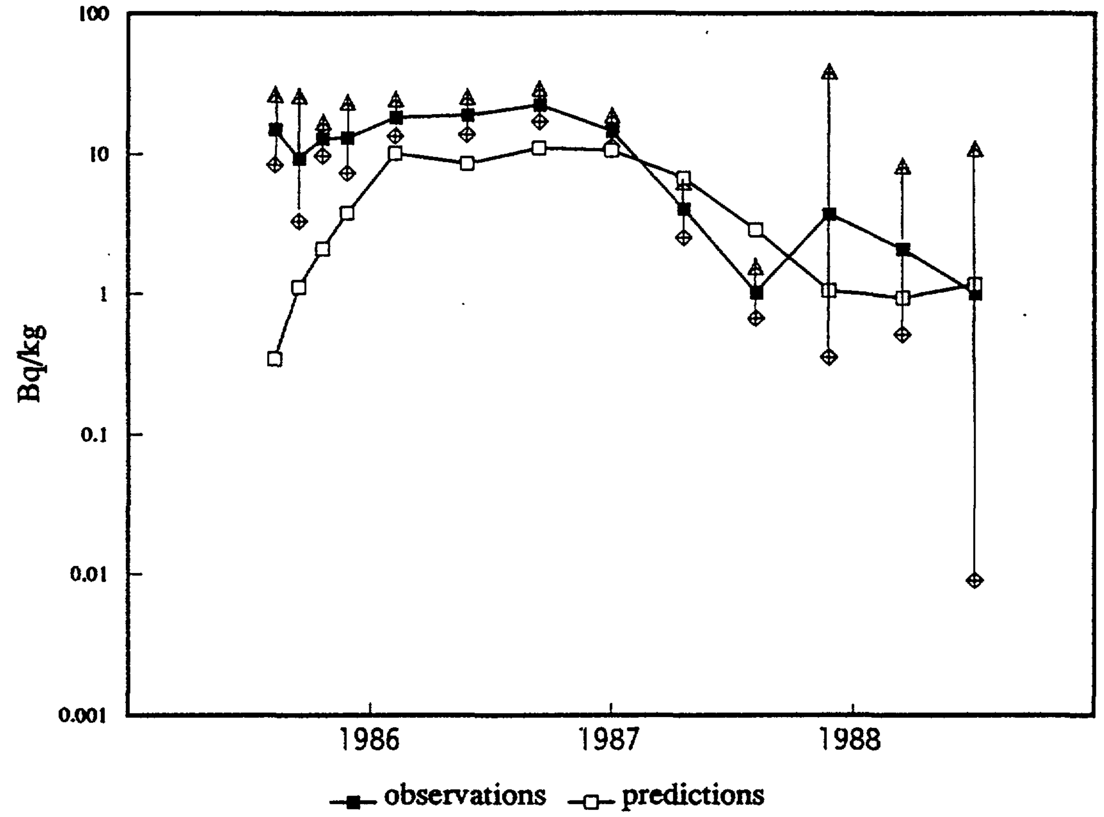

FIG. 4. concentration in pork (predicted and observed).

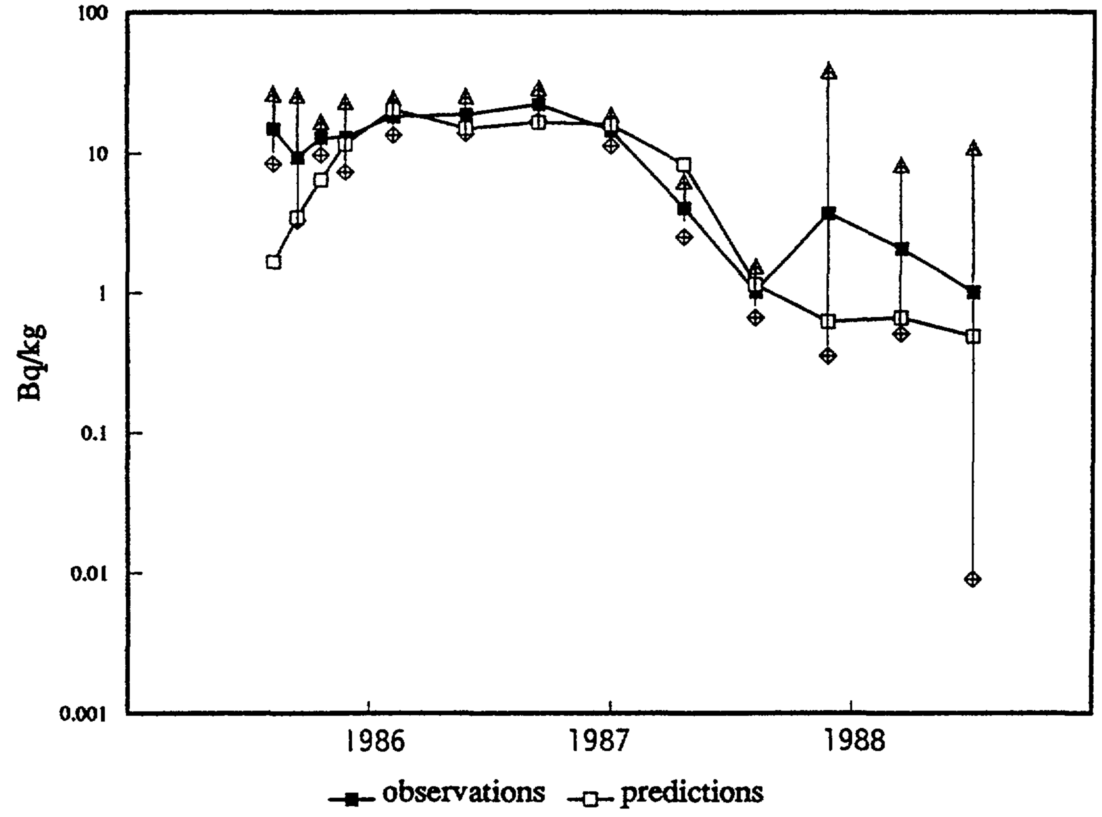

FIG. 5. Test of pork concentration (diet from measured values of cereal and milk).

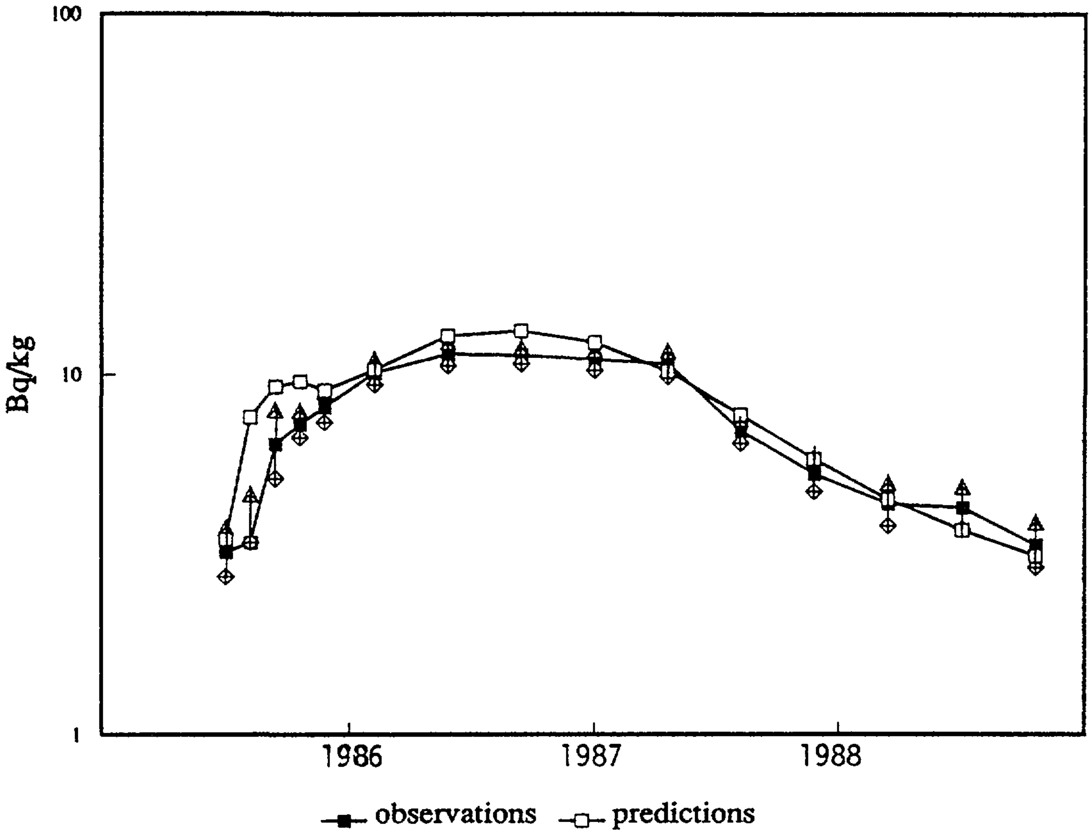

FIG. 6. Concentration in whole body (predicted and observed).

All the predictions at the prescribed times correspond to a factor between 0.45 and 2.5 of the observations but only 3 out of 15 predictions fall within the 95% confidence interval because the experimental bounds are really narrow in this case.

4. EXPLANATION OF MAJOR SOURCES OF MISPREDICTION

- With the data measured in only one station we made the calculations for the whole area. It is easy to see that this is a major source of misprediction. We continue with this error through our predictions because we use the concentration in air as the source term in our models.

- "Leafy vegetables" are all the vegetables with broad leaves and although the behaviour of them could be similar (speaking about root uptake or folia deposition) the life period of different species is different. The concentrations of contamination are not the same if the harvest happens in May-June or in October. For this reason we need to know if we are speaking about lettuce or kale, for example. We have in the input data harvesting and seeding periods and plant production and seeding area by species but in the observation data we have only a single value for leafy vegetables.

- Our model considers only one value of the retention factor and one for the yield density. The ratio between interception factor and yield density is constant during all the time that the vegetation is on the ground. It could be a source of error in the case of pasture because we are calculating everyday the contamination and we are using a Y value of harvest and R value when the grass is at its biggest. Maybe this is the reason for our underprediction in May 86.

- In general, our model is very sensitive to the yield density. Considering that these data are used very broadly, taking measurements for the entire area and only at the time of harvest, this could be another source of misprediction. In fact, in the first results that we sent, we incorrectly applied a conversion factor of units for yield and the results were incoherent.

- The information about the ensilage is still insufficient. Its composition is quite complicated and in some steps it is necessary to make assumptions. It implies another source of misprediction.

There are almost no input data for fruit but even if we had them there is no model for fruit trees as far as we know.

4.1 Recommendations for changes to the model

The model that we are using now for milk and beef works well but we have only one model for both pathways and it would be convenient to have two separate models for milk-cows and beef-cows. They are different in the amount of feed that they eat among other parameters and this is the only thing which is reflected in our calculations. Now we have incongruities such as the beef cow model only works with a loss due to milk production.

We need to work more on the pork model. We are assuming that every six months the animals are slaughtered but the first six months the model does not work well. The shapes of prediction and observation curves are not so similar.

4.2 Examples of how changes improve calculations

In our first calculations we used an average of all the data of rain, everyday, for the wet deposition and the results were very overpredicted. Now using the rain in the same station where the air contamination was measured the prediction is much better. The rain in the first days when the plume was over the site is critical and in the station where the air contamination was measured there was no rain these dates.

The diet of the cow needs more precision in the definition of each component and maybe the amount of feed is too large. In our case we can say that putting more effort into reflecting all the input data exactly in the way that they are defined, the predictions improve greatly. We made some attempts to recreate the diet of the cow more detailed every time and the values and the dynamics of the milk and beef predictions got closer and closer to the observations.

We used an ingestion of soil by the cow when they are fed the fresh pasture on the field. In our first calculations it was 4% of the total amount of the cow diet. Now we change this parameter to 500 g of soil everyday. The first assumption sounded fairly reasonable but it implied almost 2 kg of soil consumed by the milk-cow everyday; it seemed like a lot of soil. The new assumption seems to work better.

In the first predictions that we made we did not consider losses due to food processing. Considering these losses the model for whole body predicts much better than before. It is also necessary to consider that the most important pathway to get the whole body concentration is milk and the results for milk are similar to the observations. Leafy vegetables and beef have a high concentration in the first months but they lose a lot of contamination through food processing and their importance becomes lower.

5. CONCLUSIONS

Our model is an assessment model with a lot of simplifications and default parameters. We have here a detailed scenario - it is not the normal situation - and it was necessary to adjust the model and try to use the input data as much as possible. In this situation we can say that the results of the model are reasonably good.

On the other hand we learned a lot in this exercise and after the meetings we were able to make some changes to improve our model. Of course there are more improvements that we need to make in order to get better predictions of the real events occurring in nature. For example:

- inclusion of time-dependent transfer factors.
- consideration of loss for growth dilution
- consideration of translocation into the plant
- R and Y changing depending on the growth state of the vegetation
- two different models for milk-cow and beef-cow.

We need to improve our knowledge about agricultural practices and to get a more flexible model capable of adjusting to different situations, and we need to add as soon as possible the uncertainty analysis capability to the model.

III.11. ECOSYS-CH

1. EVALUATION OF MODEL PERFORMANCE FOR SCENARIO CB

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2. General Model Description

2.1 Model name

ECOSYS-87, a product of the Gesellschaft für Umweltforschung (GSF) in Neuherberg, Germany.

2.2 Unique features of model structure

Default data bases exist within ECOSYS that contain information on agricultural practices, plant and animal metabolic data, and human ecological information for conditions specific to Bavaria. I altered many of these files to more closely represent the conditions presented in the CB scenario. The actual ECOSYS code, however, was not changed for the CB exercise.

ECOSYS has the reputation of being a good predictor of the dynamics of radionuclide concentrations in grains. This is partially due to the use of time-dependent leaf area indices that determine the initial plant contamination, and the time-dependent translocation factors that govern the transfer of contamination from leaves to the edible portions of plants. ECOSYS also accounts for the reduction of radionuclide concentrations in pasture due to plant growth by using the yield at the time of deposition and a monthly dependent loss rate, representing growth dilution.

Another interesting aspect of ECOSYS is the way in which retention of wet deposition onto plants is modeled. Two interception constants (k1 and k2) are defined for each plant and radionuclide of interest. These constants, in addition to the leaf area index at the time of deposition and the rainfall amount, define the portion of activity in the rainwater that is retained by the plants.

ECOSYS does not estimate whole body concentrations in humans; the closest parameter is an integrated dietary intake. Whole body predictions were therefore predicted by using the latter as input to an auxiliary model that I constructed.

2.3 Intended purpose of the model

The model is used for accident consequence analyses.

2.4 Intended accuracy of the model predictions

Best estimate.

2.5 Method used for deriving uncertainty estimates

A major disadvantage of ECOSYS-87 is its inability to construct confidence limits on its predictions. Nor is it currently possible to operate ECOSYS in a batch mode, because interim menu-driven choices are required from the user. This makes it difficult to couple an external Monte Carlo simulator to the program and thus use an auxiliary uncertainty analysis model. ECOSYS is too complex to do error calculations by hand, particularly since the covariance between parameters is not known. This leaves "scientific guess" as the method of estimating the confidence associated with predictions. I am suspicious of such subjective procedures and have chosen not to venture a "guess", primarily because it requires a thorough knowledge of the model's performance under a wide range of conditions. Because this was the first time I had rigorously used ECOSYS I was not familiar with its predictive abilities and, therefore, did not feel qualified to attach confidence limits to the predictions.

Although I cannot offer a quantitative analysis, three areas probably dominated the uncertainty. The first is in my estimation of the initial deposition, the second is my assumption concerning the composition of silage, and the third is the contamination of fruit. The uncertainties with deposition are large because my deposition predictions are based on integrated air concentrations (Bq-h/m^3) estimated from a single air sampling station. This sample size of one was then deemed to be representative of the entire CB area; unfortunately, no additional air concentration data were provided in the scenario description. In contrast, soil concentration (Bq/m^2) data were given for 152 locations throughout the country. I examined the soil data and found the soil concentration in the area of the sole air sampler to be around the mean for the entire country. This calculation was partial reassurance that the air concentration data might represent a mean for the country. A preferable approach was used by some other modelers. They started with the soil concentration data as their input, or if their models required air concentration data as initial starting values (as does ECOSYS), then they back calculated from soil to air for a more representative estimate of the mean deposition. The point is -- using data from a single station and then generalizing for the entire country introduced a substantial uncertainty into the final predictions.

The second area of obvious uncertainty arises from the composition of silage. This was an area that caused confusion among most of the modelers. The scenario description of silage was confusing. Silage is particularly critical because it represents a surge of activity for cattle during the first winter months and thus affects the dynamic concentration of radionuclides in beef, milk, and thereby, activity intake by humans.

The third area of uncertainty is the contamination of fruit and its contribution to human dose. My initial predictions for CB indicated that the dominant dose contributing pathway was ingestion, specifically the ingestion of contaminated fruit. From the Biomovs-1 exercise it was learned that uncertainties in the dominant pathway will likewise have the greatest influence on the uncertainty associated with the total dose. The dominance of fruit to overall dose caused a number of mental alarms to sound, as normally milk, beef, or perhaps leafy vegetables dominate. I have never heard of a situation where the primary dose contributing food was fruit. As this was the first time I had used ECOSYS I was faced with three options: (1) I had made user input errors that were causing fruit to incorrectly dominate (probable); (2) there was a problem with the fruit model within ECOSYS, either a conceptual or mathematical error (possible); or (3) neither #1 nor #2 had occurred and the accident scenario and population I was modeling were unique and fruit truly dominated their ingestion dose (unlikely). Upon rechecking the input data and finding no mistakes, I decided to submit the predictions as is, with fruit dominating. Because I was submitting predictions contrary to past experience and it was my first time using the model, I would place a substantial amount of uncertainty on my predictions. Users that are well acquainted with their model's performance would be better able to determine if such an unusual prediction was a function of user input error, poor model performance, or the specific scenario being modeled. I have since learned that there are problems with the fruit model within ECOSYS as it considerably over predicts activity concentrations. This is discussed in detail within section 4.

2.6 References describing detailed documentation of model

Pröhl G. 1990. Modellierung der radionuklidausbreitung in Nahrungsketten nach Deposition von Strontium-90, Cäsium-137 und Jod-131 auf landwirtschaftlich genutzte Flächen. GSF repot 29/90.

Müller, H. and G. Pröhl. 1993. A dynamic model for the assessment of the radiological consequences of nuclear accidents. Health Physics 64:232-252.

3. Initial Comparison of Test Data and Model Predictions

3.1 Total deposition

My estimate of area-averaged, total deposition was 8830 Bq/m^2, which placed me above the upper 95% confidence limit (7590 Bq/m^2) for the mean observed value of 5533 Bq/m^2. The predicted to observe ratio (P/O) was 1.6.

3.2 Major food items contributing to total diet

Predictions of Cs concentrations in milk, beef, and pork are compared to observed values in Figures 1, 2, and 3, respectively. In each figure the initial prediction is graphed as a solid line (Prediction 1) and the observed values are graphed as unconnected points with attached 95% confidence limits. The graphs reveal an over prediction in all cases, largely because of the over prediction of

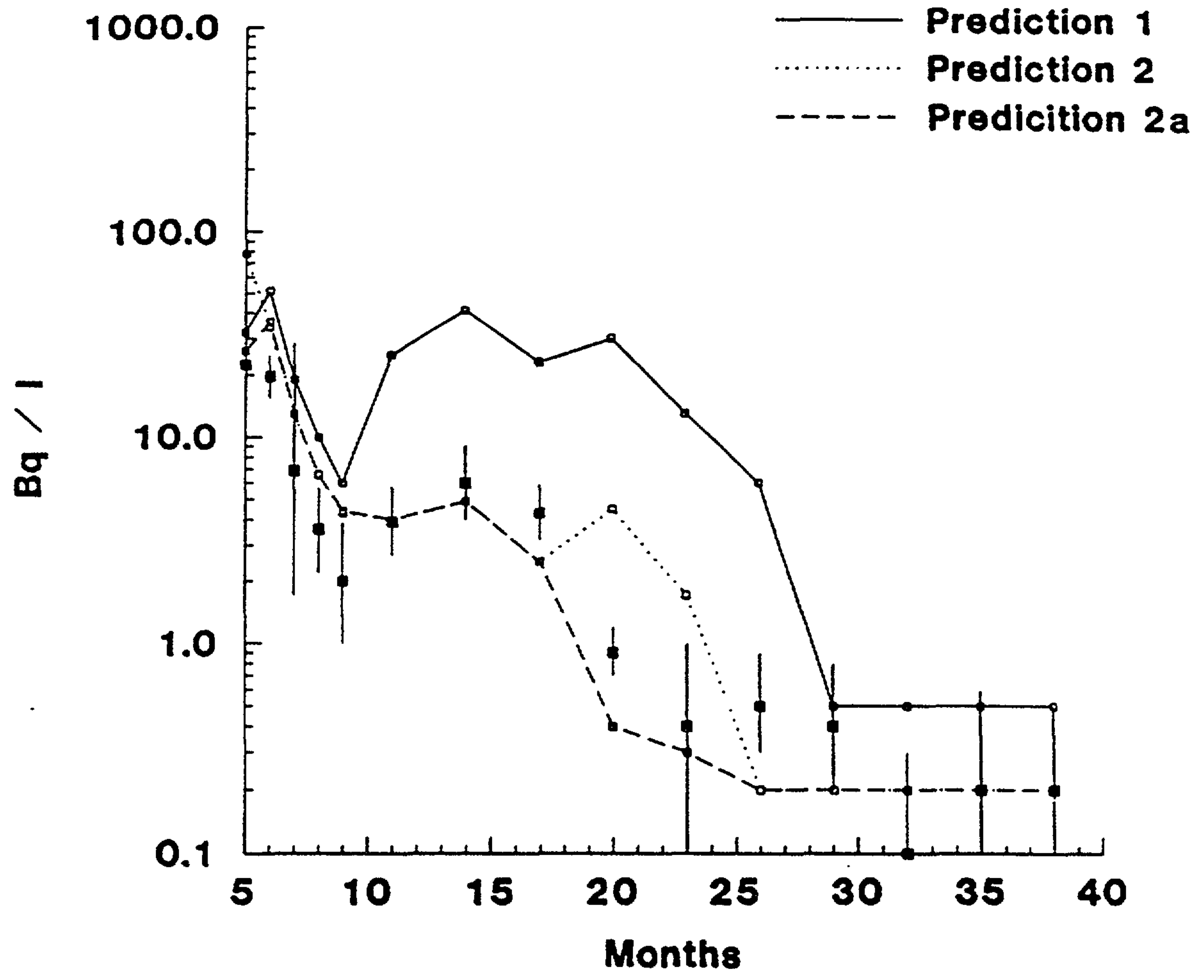

FIGURE 1. Predicted Cs concentrations in milk. The first prediction is represented by a solid line and the second prediction by the dotted line. Prediction 2a was made after correcting a typographical error in cattle feeding regimes (see text, Section 3.0). Observed data are shown as black squares with attached 95% confidence limits.

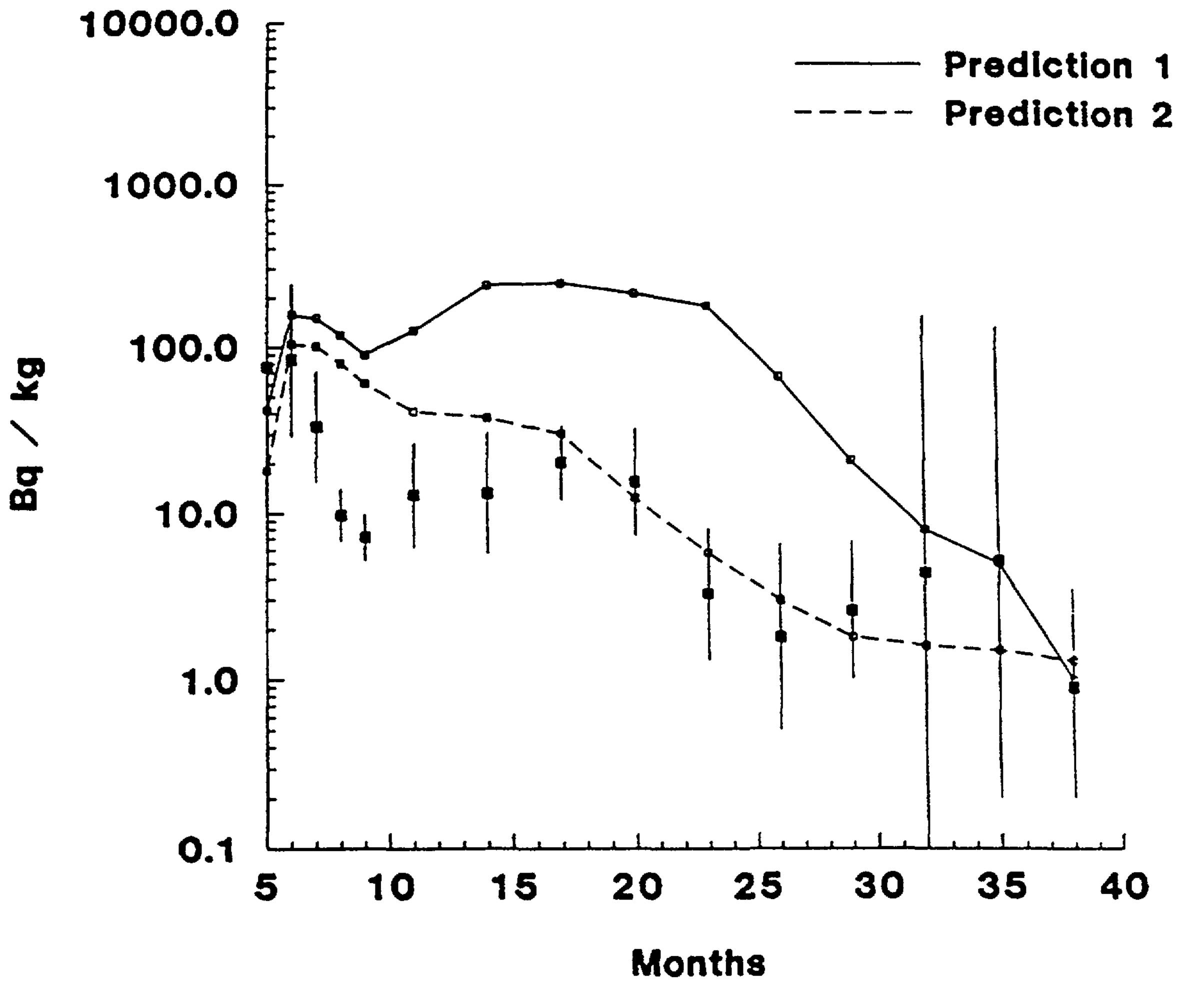

FIGURE 2. Predicted Cs concentrations in beef. The first prediction is represented by a solid line and the second prediction by a dotted line. Observed data are shown as black squares with attached 95% confidence limits.

the initial deposition, although other factors are also responsible and are discussed below. Predicted to observed ratios (P/O) for milk, beef and pork are shown in Table 1.

In addition to the over prediction, the P/O ratios demonstrate a problem in correctly predicting the time-dependent dynamics of Cs concentration. Notice the sudden rise in milk P/O ratios after the 2nd quarter of 1987, and after the 3rd quarter of 1987 in the beef P/O ratios. The explanation for the sudden rise is given in section 4 .0.

An additional index to a model's predictive abilities can be obtained by examining the geometric means (GM) and geometric standard deviations (GSD) of the time-dependent predictions. GM and GSD values of the P/O ratios are presented in Table 2. Values of GM close to 1.0 indicate an unbiased prediction; all of my values are above 1.0 demonstrating the over prediction. The ability of the model to predict the dynamic behavior of Cs within the environment is indicated by the GSD; the closer the value to 1.0, the better the model's simulation of the observed dynamics. The GM and GSD for beef are particularly high for the first prediction.

3.3 Other items of specific interest:

In the initial model prediction fruit dominated the ingestion dose, contributing more that milk, leafy vegetables or beef (Table 3). The dominance of

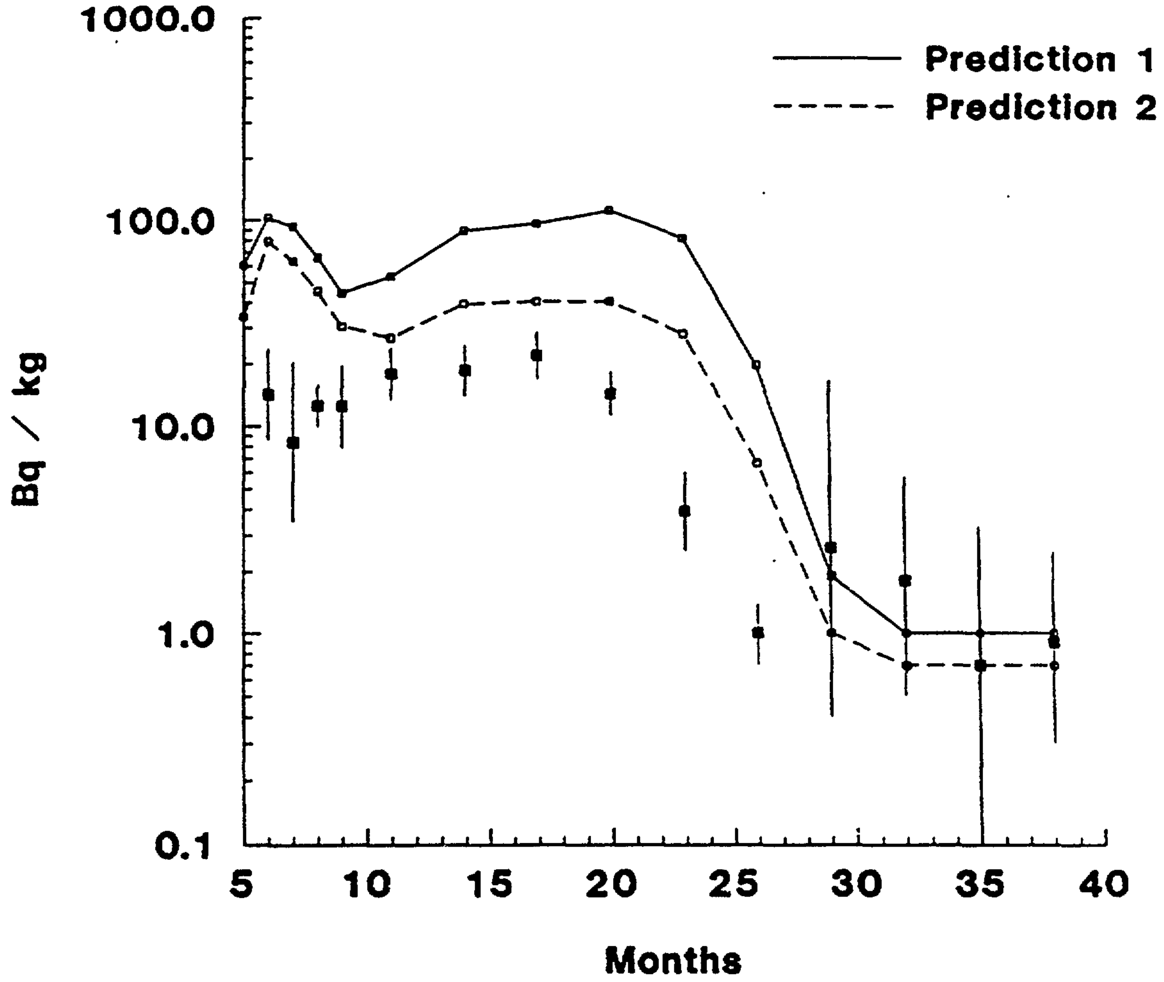

FIGURE 3. Predicted Cs concentrations in pork. The first prediction is represented by a solid line and the second prediction by the dotted line. Observed data are shown as black squares with attached 95% confidence limits.

fruit is contrary to what might be expected. The P/O ratio for fruit contamination was 6.5. Further analysis of the fruit prediction is presented in section 4.0. P/O ratios for other environmental components are presented in Table 4.

3.4 Whole body concentrations

ECOSYS does not calculate whole body concentrations, so an auxiliary model was used. Figure 4.0 shows the observed data, and the first and second predictions for Cs whole body concentrations in adult humans. The P/O ratios, and GM and GSD respectively are in Tables 1 and 2. Distributions of whole body concentrations were not made because ECOSYS is deterministic and multiply predictions were not performed.

4. Explanation of Major Sources of Misprediction

Numerous factors contributed to discrepancies between observed and predicted values. They fall into three broad categories: (1) user inexperience and mistakes, (2) model deficiencies, and (3) inadequate scenario description.

User inexperience with the model and not understanding its capabilities was evident in the way I modeled silage. I assumed that the maximum number of

TABLE 1. The Predicted to Observed Ratios (P/O) for the Concentration of Cs in Milk, Beef, Pork, and Human Whole Body Are Given for Both the First and Second Analyses.

Category		P/O 1st Prediction	P/O 2nd Prediction
MILK	(May 86)	1.4	1.2
	(July 86)	2.8	2.0
	(Sept. 86)	3.0	2.2
	(IV - 86) *	6.4	1.0
	(I - 87)	6.8	0.8
	(II - 87)	5.3	0.6
	(III - 87)	33.3	0.4
	(IV - 87)	32.5	0.7
	(I - 88)	12.0	0.4
	(II - 88)	1.3	0.5
BEEF	(May 86)	0.5	0.2
	(July 86)	4.5	3.0
	(Sept. 86)	12.5	8.4
	(IV - 86)	9.7	3.2
	(I - 87)	18.0	2.9
	(II - 87)	12.0	1.5
	(III - 87)	13.7	0.8
	(IV - 87)	53.9	1.8
	(I - 88)	36.7	1.7
	(II - 88)	8.1	0.7
PORK	(May 86)	-	-
	(July 86)	11.1	7.6
	(Sept. 86)	3.5	2.4
	(IV - 86)	3.0	1.5
	(I - 87)	4.8	2.1
	(II - 87)	4.4	1.8
	(III - 87)	7.8	2.8
	(IV - 87)	21.0	7.1
	(I - 88)	19.6	6.6
	(II - 88)	0.7	0.4
WHOLE BODY CONCENTRATION **			
	(May 86)	6.1	2.0
	(July 86)	9.2	3.0
	(Sept. 86)	12.4	2.4
	(IV - 86)	11.3	2.1
	(I - 87)	13.1	2.0
	(II - 87)	12.7	2.1
	(III - 87)	7.8	2.5
	(IV - 87)	4.7	2.2
	(I - 88)	2.5	1.9
	(II - 88)	1.9	1.6

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* Roman numeral notation represents the quarters of the year, P/O values are based on means for that quarter.

** ECOSYS does not calculate WBC, predictions were obtained using ECOSYS's estimate of integrated human dietary intake and an auxiliary model.

TABLE 2. Geometric Mean (GM) and Geometric Standard Deviations (GSD) of the Predicted to Observed Ratios of Cs Concentrations in Milk, Beef, Pork, and Human Whole Body. Values Are Given for Both Predictions.

Component	1st Prediction			2nd Prediction		
	GM		GSD	GM		GSD
Milk	4.9	±	2.7	1.0	±	1.8
Beef	6.7	±	3.7	1.5	±	3.0
Pork	4.5	±	3.0	2.2	±	2.7
WBC **	5.4	±	2.5	2.0	±	1.3

** ECOSYS does not calculate WBC, predictions were obtained using ECOSYS's estimate of integrated human dietary intake and an auxiliary model.

TABLE 3. Ranking of the Major Food Items Contributing to Adult Dose from Ingestion During the First Year after the Accident and for a Life Time Exposure. Data Are Presented for Both Model Runs. Values in Parentheses Are Dose in mSv.

Time	1st Prediction	2nd Prediction
1st year	Fruit (0.14)	Milk (0.02)
	Milk (0.05)	Leafy Veg. (0.02)
	Leafy Veg. (0.04)	Fruit (0.02)
Lifetime (50 y)	Fruit (0.18)	Wheat (0.03)
	Beef (0.08)	Milk (0.03)
	Milk (0.08)	Fruit (0.03)

dietary food items was four. This limited the realism of the cattle feeding regimes I was using, when actually I could have increased the number of feed items in ECOSYS's default data base beyond four. Thus not fully understanding the model's capabilities decreased my ability to properly model the situation. Tabe 4 shows P/O ratios for various environmental components, including silage

I also erred by misjudging the planting seasons. I shifted the default planting and harvest dates given in ECOSYS ahead by 20 days. This resulted in a greater leaf area index (LAI) at the time of deposition and thus greater contamination. From the standpoint of plant emergence the Chernobyl accident occurred at a sensitive time of the year. Changing the planting season by a few days could change whether or not plants were exposed to foliar deposition. In the first analysis P/O ratios for spring barley, winter wheat and pasture were 2.0, 4.6 and 2.3, respectively, but after changing the planting seasons for the second run the respective P/O values were reduced to 0.2, 2.0 and 1.5 (Table 4).

Much of the error in incorrectly predicting the dynamic behavior of Cs in milk and beef was due to a typographical error, which caused the 2nd summer to last from 1 May to 23 July, rather than the intended period of 1 May to 31 October. All subsequent seasons were also off by 100 days. The influence of the error can be seen in the dynamics of Cs in milk, Figure 1. The difference between Prediction 2 and Prediction 2a (at month 17) is due solely to correcting the seasons; no other change was made. The improved predictions are evident in Figure 1's 2a Prediction, in the stabilizing of the P/O ratios after the 2nd quarter of 1987 (for the 2nd predictions, Table 1), and in the 33% reduction in the GSD, from 2.7 to 1.8 (Table 2). The influence of the typographical error can also be seen in the Cs dynamics in beef, Figure 2. The corrected 2nd prediction starts a

TABLE 4. The Predicted to Observed Ratios (P/O) for Cs Concentration in Various Environmental Components Are Given for Both Analyses.

Category		P/O 1st Prediction	P/O 2nd Prediction
SILAGE	(1986) +	3.2	1.4
	(1987)	0.1	0.0
SPRING BARLEY			
	(1986)	2.0	0.2
WINTER WHEAT			
	(1986)	4.6	2.0
FRUIT	(1986)	6.5	1.7
PASTURE	(May 86) ++	2.3	1.5
	(June 86)	1.1	0.5
LEAFY VEGETABLES *			
	(1986)	9.5	1.3

\+ For the 1st prediction a single "silage plant" was modeled with characteristics approximating the individual species which comprised silage. For the 2nd prediction corn and oats were modeled individually and combined for silage.

++ No observed data exist for pasture, P/O ratios are based on Cs measurements from a lawn.

* The 1st prediction assumed that the harvests started 1 May, 2nd prediction assumed harvest started on 15 June. P/O ratios are inflated for the 1st prediction because plants are heavily contaminated in May, excluding the May value reduces the P/O ratio for the first prediction to 0.9.

decline at month 17, while the 1st prediction does not start to decline appreciably until month 23.

The high P/O ratio for silage was caused, in part, to an inadequate scenario description. The actual composition of silage was only alluded to in the scenario description, and few consistencies existed among the modelers as to its composition. In the second model run I changed the silage composition and the P/O ratio dropped from 3.2 to 1.4. Had the actual silage mixture been obvious in the scenario description a better prediction would have been possible and uncertainty reduced. My predictions for Cs in milk, beef and human whole body were inflated because silage is an important component in the winter diet of animals. This is obvious in the enclosed figures where a steep increase in Cs concentrations is observed during the first winter.

The final factor contributing to discrepancies between predictions and observations is inadequacy of the model. This was evident by the dominance of fruit to ingestion dose (Table 3). In preparing for the second model run I found that I had mistakenly typed the consumption rate for fruit as 153 g/d rather than 123 g/d. Correcting this error, however, had little impact on the ingestion dose and fruit still dominated. In searching for other possible reasons for the over prediction of fruit contamination I found that ECOSYS uses a default Cs deposition velocity (Vg) for fruit of 5.0 mm/s, greater than all other species modeled (most are at 2.0 mm/s). I reduced Vg to 2.0, but fruit still dominated the ingestion dose. I then systematically reduced the soil to plant TF from 0.02 to 0.01, the fruit consumption rate to 100 g/d, and finally the harvest intervals, before the dominance in fruit disappeared. To determine the relative importance of these parameters in the fruit model I calculated a sensitivity index (SI) as 1 - $(Cmin)_i$ / $(Cmax)_i$, where $(Cmin)_i$ was the dose from fruit at the end of the 1st year, calculated when parameter *i* was set to its minimum value, and $(Cmax)_i$ was the dose from fruit when the same parameter *i* was set to its maximum value. The

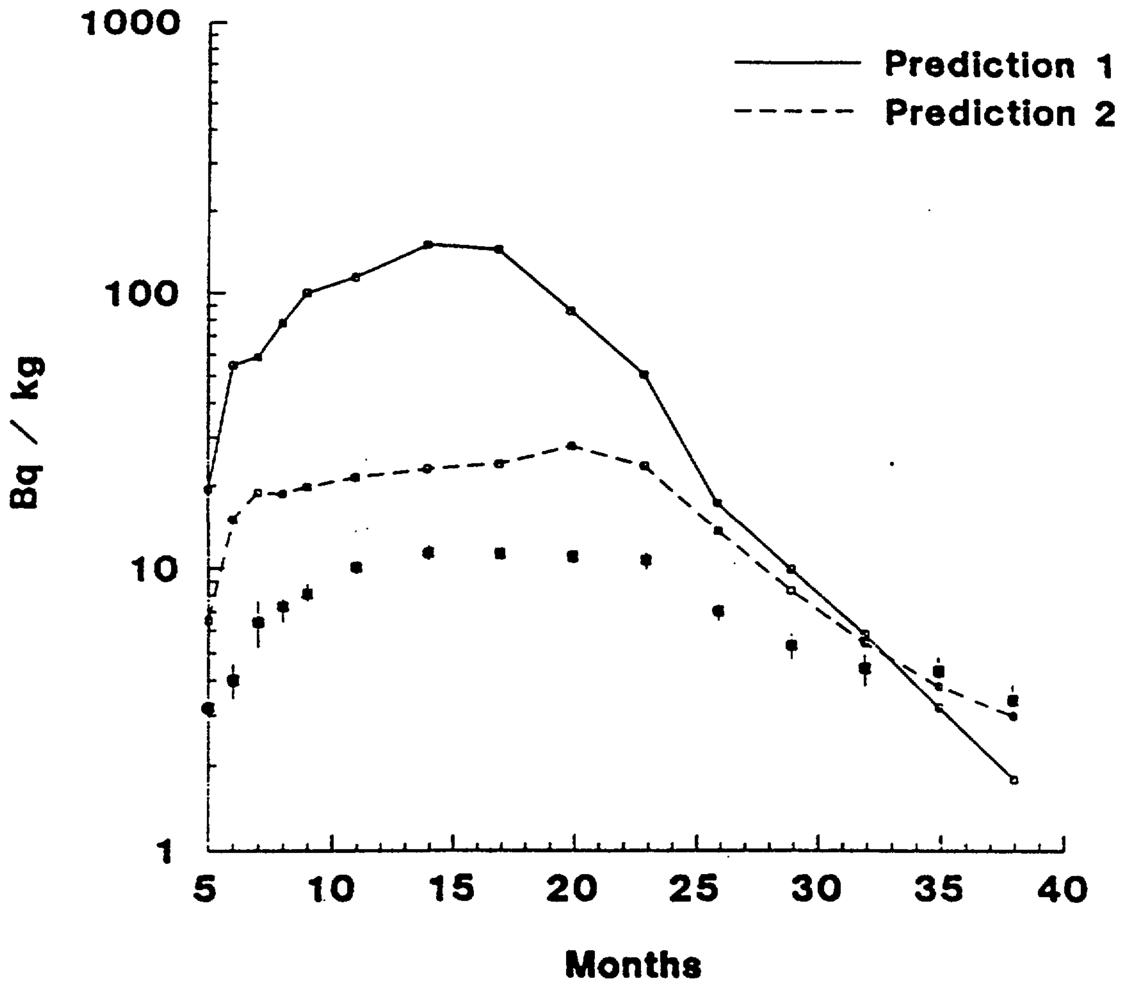

FIGURE 4. Predicted human whole body Cs concentrations. The first prediction is represented by a solid line and the second prediction by the dotted line. Observed data are shown as black squares with attached 95% confidence limits.

parameters, range of values used, and SI are shown in Table 5. Values for the SI can range from 0.0 to 1.0. A large SI implies that changes to that parameter have a large impact on the model end point (in this case the dose from ingesting fruit). In this analysis the translocation factor, which determines the transfer of Cs from the leaves to the fruit, was the most sensitive parameter. I was surprised, however, at how sensitive the harvest interval is in ECOSYS. Merely lengthening the harvest interval by 30 days reduces the ingestion dose from fruit by one third. Obviously, the harvest season and interval affects the amount of time the translocation factor from leaf to edible fruit can operate. More work is required to specifically determine the problems with predicting contamination of fruit.

4.1 Recommendation for changes to the model

Changes were made according to the categories below and a second model prediction performed:

A) User influence or interpretation of the scenario:
- 30% reduction in deposition, to 6090 Bq/m^2
- reduction in leaf area indices by setting the season back 20 days
- changed silage composition and method of incorporating it into the cattle diet
- corrected typographical error dealing with the seasonality of the cattle diets

TABLE 5. Sensitivity Index (SI) of Parameters Affecting the Contamination of Fruit and its Contribution to Dose from Ingestion.

Parameter	Change	SI
Translocation Factor	0.1 to 0.02	0.80
Ingestion Rate	150 to 50 g/d	0.66
Start of harvest	1 Sept. to 1 Aug.	0.49
Deposition Velocity	5 to 2 mm/s	0.47
Length of harvest	30 d longer	0.33
TF (soil to plant)	.02 to .01	0.00

- reduced human dietary intake

B) Changes made to the model:

- reduced numerous parameters in the fruit model to lower its contribution to dose

4.2 Examples of how changes improve calculations

The results of the changes can be seen in Figures 1-4 where the second predictions are graphed as dotted lines, along with the observed data and the first predictions. For the 2nd analysis the P/O ratios decreased substantially (Table 1), and the dynamics of the predictions improved in all cases. The Cs activity intake in cattle was sufficiently lowered in the 2nd prediction to significantly alter the dynamics of Cs in both beef and milk during the first winter. The decrease intake was due to a cumulative effect of a 30% decrease in deposition and a reduced activity of the winter diet. These changes resulted in the milk GSD improving substantially (Table 2); it decreased from 2.7 to 1.8, indicating an improved ability of the model to predict the observed dynamics. But the decrease in GSD was not as good for beef of pork, indicating that improvements in predicting the Cs dynamics in these components were still needed.

5. Conclusions

All predictions made with ECOSYS-87 were conservative. Most problems were user generated, and predictions improved as these were eliminated. The dominance of fruit to ingestion dose, however, seems to be a problem with the model and requires further study. Changes made to the translocation factor, deposition velocity and harvest date in the fruit model particularly effect dose from ingestion.

Modeling exercises of this size require team efforts. Risks of not detecting input errors increases substantially when working alone. Input data should be confirmed by a person other than the model user.

A clear, well defined scenario description is crucial, particularly if one wants to minimize user interpretation of input data. Even as well documented as the CB scenario was, the magnitude of the user's interpretation of the scenario was enormous. Not a single modeler used the input data as they were presented; everyone made alterations.

A great deal of effort was spent analyzing the observed data for spatial and temporal representativeness. Much of this work was done after the predictions had been submitted. Efficiency could have been improved if this work had occurred prior to the model predictions. For example, the modelers were initially asked to make predictions for which no observed data existed (alfalfa and pasture grass).

The CB scenario represented a unique situation based on the Chernobyl accident. A model's predictive performance will change, howerver, as each scenario changes. Models need to be tested over a spectrum of conditions prior to deeming them worthy tools in accident consequence analyses.

The extensive debate and discussion among the international participants was a learning experience, and the efficiency of knowledge gained was substantially increased in this forum.

III.12. GENII

1. COMPARISON OF MODEL PREDICTIONS WITH OBSERVATIONS

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2. GENERAL MODEL DESCRIPTION

The GENII model is a simplified, steady state, multiplicative chain model that was applied in its "prospective" sense. GENII is usually only used in this way to get an upper bound on potential doses resulting from hypothetical acute releases (e.g. safety analysis reports). It is intended to get conservative answers. It is interesting that this "compliance" type model gave results that were only about a factor of three larger than most of the far more complex models that were tested with the VAMP CB scenario.

3. INITIAL COMPARISON OF TEST DATA AND MODEL PREDICTIONS

The total deposition and integrated air concentrations used in this GENII application were derived from those used for the HEDR model application. The value for total deposition was only about 6% lower than the actual consensus deposition, so that should not significantly affect the GENII predictions.

The integral formulation of the GENII model does not allow the month-by-month evaluation of predicted concentrations. However, it does give annual averages which may be compared. The GENII model, since it is intended to be used in a prospective sense, gives answers corresponding to the four seasons (winter, spring, summer, and fall). Both the spring and summer values were submitted in the VAMP comparison, to see which would more closely approximate the CB time period. Analysis shows that the "summer" numbers are the most representative. The values do not particularly represent true seasons as much as sets of different starting assumptions.

For leafy vegetables, the integrated concentration predicted for 1986 is somewhat lower than the observed values at harvest. However, it is well within the range of variability, and because it represents the entire year's intake, is not felt to be a bad indicator. Later years seem to be a notable underprediction. This is most likely the result of using a soil-to-plant concentration ratio not appropriate to the CB area.

Concentrations of Cs-137 in cereals are somewhat overestimated in the GENII summer formulation, by about a factor of three. Later years are underestimated, for reasons similar to those for leafy vegetables.

Concentrations predicted for fruit are remarkably close to the observations the first year (32 versus 26 bq/kg). This may just be fortuitous, since the general approach is similar to that used in the HEDR model with much less success. Later years tend to show an underprediction, similar to other types of vegetation.

Predictions for milk are slightly high the first year (about a factor of 5). This is most likely due to the series of feeding assumptions built into the GENII integral model. The cows are assumed to consume a large fraction fresh pasture, and even the stored feed has only a short weathering time prior to harvest, so that both are assumed to have relatively high foliar contamination. (This is illustrated with the silage concentrations - the predictions are a bit below the observations for the year 1986, but since so little of it is assumed to be eaten, it does not drive down the animal product concentrations). This same set of assumptions is used also for beef cattle, which show a nearly order-of-magnitude overestimate above the observations. For both animal products, the feeding regime detail available from the CB scenario description was not used. Both milk and beef show underestimations in following years, related to the underestimations in vegetation discussed above.

Although not transmitted with the current set of observations, a note was made that the GENII doses from external exposure were relatively high. The GENII model assumes essentially full-time exposure to a simple slab source geometry, with no reductions beyond soil self-shielding. Application of residence times and building shielding factors would reduce the predictions to within the ranges of the other codes involved in the comparisons.

Overall, the developers of GENII are pleased with the results of the VAMP test. For a general-purpose prediction tool, the code performed well. Investigations will be made in the area of soil-to-plant transfer factors, to see if the current set can continue to be defended, but no major overhaul of the code is foreseen.

III.13. HEDR

1. COMPARISON OF MODEL PREDICTIONS WITH OBSERVATIONS

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2. GENERAL MODEL DESCRIPTION

The HEDR model was developed to allow calculation of doses to people over a large area, resulting from releases of radionuclides over a long period of time. The HEDR model is structured to allow concurrent calculation for many geographic areas, allowing for transfer of food products between areas. In its initial application, the HEDR model was used for short-lived iodine-131.

3. INITIAL COMPARISON OF TEST DATA AND MODEL PREDICTIONS

In a superficial sense, the CB scenario greatly resembled the design intent of the HEDR model. The scenario involved calculation of time-dependent parameters for several geographic areas. However, the initial contamination mechanism was acute, rather than chronic. Additionally, there was little information regarding inter-area food transfers - one of the main HEDR model components. A number of modifications and approximations had to be made to fit the HEDR model to the CB scenario.

One conceptual mistake was made in using the chronic HEDR model for the essentially acute Chernobyl deposition. The model was designed to run in tandem with an atmospheric transport/deposition model. The time step for the HEDR model is one month. Input is expected on total monthly time-integrated air concentration and month-end ground deposition. The VAMP air and soil data were integrated and put in as average values over the month of May, 1986. Since the largest part of the deposition occurred early in the month, this resulted in a significant overestimation of the foliar retention and also integrated retention for the month of May. This can be illustrated in a simplified manner by comparing the quantity remaining at month-end assuming an instantaneous deposition on the first day with the quantity remaining assuming continuous, chronic deposition. This ratio is:

$$\frac{\frac{I_0}{31}\left(\frac{1 - e^{-\lambda_w 31}}{\lambda_w}\right)}{I_0\, e^{-\lambda_w 31}} \qquad (1)$$

where I_0 is the total initial deposition, $I_0/31$ is the daily deposition rate averaged over 31 days, 31 is the number of days in the month, and λ_w is the weathering rate constant, days^{-1}. For a weathering rate constant of 0.050 (a half-time of 14 days), this ratio has a value of 2.5, indicating that the results depending on foliar deposition for months following the first month are a factor of about 2.5 too high. In addition, the time-integrated amount on the ground during the month of May was also overestimated, as the integrals of the quantities in Equation 1, as

$$\frac{\int_0^{31} \frac{I_0}{31}\left(\frac{1 - e^{-\lambda_w t}}{\lambda_w}\right) dt}{\int_0^{31} I_0\, e^{-\lambda_w t} dt} \qquad (2)$$

For a weathering half-time of 14 days, this ratio has a value of about 19.4, indicating that the values depending on the integrated foliar concentration are nearly a factor of twenty too high for the first month.

The initial predictions made with the HEDR model can be reduced by the amounts shown above. When this is done , the predicted mean quantities for leafy vegetables and pasture grasses agree within about factors of two of the actual observations. The following years tend to show an underestimation of about the same order, so it is likely that the soil-to-plant concentration ratio used is a bit low. Also, the relatively simple HEDR formulation (since it was derived for short-lived radionuclides) does not include any resuspension or splashup terms - these may also be needed.

Some loss of correlation between the predicted and observed concentrations of Cs-137 in animal products was anticipated.

When the initial months' vegetation overprediction is accounted for, the predictions for milk agree within factors of two with the observations for May through July, 1986, and again later in 1987 and 1988. In this respect, the results were better than anticipated. However, there is a significant underprediction starting in August 1986 through about November. Analysis shows this to be an artifact of the model resulting from the adaptations made to fit the VAMP CB scenario. The model was designed to handle several different feeding regimes for cattle, including some with essentially no fresh pasture and some with a large fraction. These feeding regimes were designed for a "6-season" year (winter, early spring, spring, summer, early fall, fall, and winter). Using the VAMP data, only a "two-season" year was constructed (summer and winter). For the VAMP CB summer season, a large fraction of the cows' consumption was fresh pasture grass. An oversight in the conversion allowed the grass compartment to be used for both grazing and grass-hay harvest. Following the hay harvest, our simulated cows were left grazing on "barren" fields! (The hay harvest resulted in removal of the foliar portion of the contamination). Until the shift to the winter feeding regime (August through October), we had an underestimate of the intake of contamination, which is reflected in the low estimates of milk contamination.

The HEDR predictions for beef (corrected for the first few months) also tend to be lower than the observations. The difference in August - October 1986 is for the same reason as the low milk values. Differences later are due in part to a simplification of the HEDR model - beef cows were assumed to eat only fresh pasture (a consequence of its application to the Hanford area in the early 1940s). Enhancement to use a more realistic feeding regime would help this.

An interesting note may be added here. The first time the HEDR model was run for the CB scenario, the animal product predictions were very much higher than those finally reported. Analysis showed that this was a result of a newly-added animal soil-ingestion model. This model was added for short-lived iodine-131, and consisted in part of a very thin soil layer compartment. Because iodine-131 has only an 8-day half-life, no removal mechanisms were assigned to this soil layer. This proved a major overestimation for long-lived cesium-137; after the first year the soil ingestion pathway became the major route of contamination of animal products. A slight revision was made to the pathway for the VAMP work.

The only major unresolved problem with the comparison of the observations with the predictions is the fruit model. Tree fruits seem to have been uniformly underestimated throughout the period. This may be a combination of underestimation of both soil-to-plant uptake and foliar-to-fruit translocation, or other factors.

Although not transmitted with the current set of observations, a note was made that the HEDR doses from external exposure were among the highest presented. The HEDR model assumes essentially full-time exposure to a simple plane geometry. This also is a consequence of the initial application of the model to iodine-131, which would not have time to migrate or mix with soil. The external pathway is not particularly significant for iodine, while it is quite important for cesium.

The HEDR model is currently undergoing essentially compete revision. The time step is being converted from months to days, much of the internal logic is changing to rate equations rather than simple linear equations, and additional compartments are being added. When it is operational, this model will also be run against the CB scenario, to ensure that at least the more obvious of the difficulties noted above have been addressed.

A final note on the CB scenario results. The HEDR model was applied to all of the CB regions. The reported results are the means over the entire area. In the call for results (VAMP Multiple Pathways Assessment Newsletter, December 1990), the quantities requested were the arithmetic mean and 95% confidence interval for each parameter. We calculated time-dependent CCDFs for concentration in numerous products and for dose in each of the CB subregions. In assembling the summary tables, we provided the means of these values and the 95% confidence intervals <u>about these means</u>. (This confidence interval is a measure of the uncertainty we have in the mean value.) We also generated the 0.025 and 0.975 fractiles of the overall distributions. (The fractiles, covering 95% of the ranges, are a description of the overall distribution.) For the forms, we provided both types of distributions. Our uncertainty about the means is quite small; the variability of each of the distributions generally exceeds some orders of magnitude. It is apparent from the observations that the quantity desired was the range over all observations. Thus, the wider of the ranges (Type #1 of the initial predictions) should be used.

Appendix IV

DOCUMENTATION OF INITIAL AND REVISED MODEL PREDICTIONS FOR SCENARIO CB

(*Note: The inital predictions by the participants are given in Tables IV.2 to IV.17 with a summary in Table IV.1. The revised predictions follow in Tables IV.19 to IV.34 with a summary in Table IV.18. The observed values given in Tables IV.2 to IV.12 and IV.19 to IV.30 of this appendix are slightly different from those in Tables I.24 to I.60 of Appendix I, which have been recalculated using a modified technique. For the intercomparison and analysis of results in the main text, the values given in this appendix have been used.*)

TABLE IV.1. SUMMARY OF INITIAL MODEL PREDICTIONS FOR SCENARIO CB

Name CODE	Obs. data	Sohier DOSDIM	Peterson CHERPAC	Hu HUMOD	Horyna SCHRAADLO-T	Kliment ENCONAN	Müller ECOSYS	Kanyar TERNIRBU	Krajewski CLRP	Galeriu LINDOZ	Carrasco PRYMA	Hinton ECOSYS	Tarrant SPADE2	Napier GENII	Napier HEDR
Total deposition	+↕		+	+	+↕	+	+↕	+↕	+↕	+↕	+	+	+	+	+↕
Leafy vegetables	+↕	+	+	+	+↕	+	+↕	+↕	+↕	+↕	+↕	+	+	+	+↕
Cereals: - winter wheat	+↕	+	+	+	+↕	+	+↕	+↕	+↕	+↕	+↕	+	+	+	+↕
Fruits: - apples/pears	+↕		+			+	+↕	+↕	+↕	+↕	+↕	+		+	+↕
Milk	+↕	+	+	+	+↕	+	+↕	+↕	+↕	+↕	+↕	+	+	+	+↕
Beef	+↕	+	+	+	+↕	+	+↕	+↕	+↕	+↕	+↕	+	+	+	+↕
Pork	+↕	+	+	+	+↕	+	+↕	+↕	+↕	+↕	+↕	+			
Pasture vegetation	+↕		+	+	+↕	+	+↕	+↕	+↕	+↕	+↕	+			+↕
Animal feed:															
- silage	+↕			+		+	+↕	+↕	+↕	+↕	+↕	+		+	+↕
- spring barley	+↕		+	+		+	+↕	+↕	+↕	+↕	+↕	+		+	+↕
Human intake	+↕		+	+		+	+↕	+↕	+↕	+↕	+↕	+			
Whole body	+↕	+	+	+	+↕	+	+↕	+↕	+↕	+↕	+↕	+			
WBC distribution					+			+		+↕	+				
External dose	+↕*	+↕	+	+	+↕	+	+↕	+↕	+↕	+↕	+	+		+	+↕
Inhalation dose	+↕*	+↕	+	+	+↕	+	+↕	+↕	+↕	+↕	+	+		+	+↕
Ingestion dose	+↕*	+↕	+	+	+	+	+↕	+↕	+↕	+↕	+	+		+	+↕
Total dose		+	+	+	+↕	+	+↕	+↕	+↕	+↕	+	+		+	+↕

+	only arithmetic mean
+↕	both arithmetic mean and 95% confidence interval
*	estimated values

TABLE IV.2. INITIAL PREDICTIONS FOR SCENARIO CB
TOTAL [WET AND DRY] DEPOSITION (Bq/m-2)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
total deposition	5570	4050	7660	8000			5900	500	38000	7200	2000	15000	9700	7046	12290				4340			4700		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII *			Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	'mean	lower	upper	mean	mean	up	mean	low	up	mean	low	up
total deposition	3100	2000	4200	4800	4000	6000	27000			5200	1500	13000	(sprg) 5200	(summ) 5200		8830			4500		

* GENII assumptions of "spring" and "summer", using integral over 1 year intervals. Derived initial condition.

TABLE IV.3. INITIAL PREDICTIONS FOR SCENARIO CB
CONCENTRATIONS IN LEAFY VEGETABLES (Bq/kg f.w.)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lo	up	mean	lo	up	mean	lo	up
monthly avg.:																								
May 1986							340.0	30.0	1000.0	2800.0	1000.0	6000.0	700.0	588.6	832.4	27.1			392.0			16.0		
Jun 1986				5.5			90.0	12.0	240.0	130.0	30.0	400.0	140.0	91.0	213.7	27.9			115.0			6.7		
Jul 1986				6.7						0.3	0.1	2.0	0.7	0.5	1.1	13.7			38.5			5.5		
Aug 1986				6.9			15.0	2.0	30.0	0.3	0.1	2.0	1.2	0.8	1.9	7.1			20.6			3.5		
Sep 1986	240.0	63.4	909.0	6.9			7.0	2.0	20.0	0.3	0.1	2.0	1.8	1.2	2.6	18.5			15.2			3.5		
quarterly avg.																								
II 1987				4.8			0.9	0.1	4.0	0.3	0.1	2.0	1.2	0.8	1.9	15.2			9.7			2.5		
III 1987				0.5			0.9	0.1	4.0	0.3	0.1	2.0	1.2	0.8	1.9	0.4			12.5			2.5		
II 1988				0.4			0.9	0.1	4.0	0.3	0.1	2.0	1.1	0.7	1.7	0.4			9.4			1.5		
III 1988				0.4			0.9	0.1	4.0	0.3	0.1	2.0	1.1	0.7	1.7	0.4			12.1			1.5		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII *		Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	lo	up	mean	lo	up
monthly avg.:													(sprg)	(summ)						
May 1986	41.0	26.0	55.0	250.0	100.0	500.0	47.5	42.2	49.6	6500.0	1900.0	18000.0	0.045		2155.00			309.0		
Jun 1986	15.0	9.2	20.0	30.0	15.0	60.0	49.4	48.9	49.7	740.0	180.0	2100.0			212.00					
Jul 1986	7.5	4.1	11.0	10.0	5.0	20.0	48.0	47.3	48.7	160.0	35.0	500.0		63.0	0.52			1214.0		
Aug 1986	6.6	3.5	9.7	10.0	5.0	20.0	46.3	45.6	47.0	40.0	10.0	38.0			0.51			1347.0		
Sep 1986	5.5	2.7	8.4	10.0	5.0	20.0	44.7	44.0	45.4	12.0	3.1	37.0			0.51			1333.0		
quarterly avg.																				
II 1987	3.8	1.6	6.1	0.8	0.4	2.0	33.5	32.0	35.2	0.72	0.31	1.40	0.047		0.48					
III 1987	3.6	1.5	5.7	0.8	0.4	2.0	30.1	28.7	31.6	0.28	0.12	0.71		0.047	0.46					
II 1988	2.9	1.2	4.7	0.6	0.3	1.5	22.0	21.0	23.0	0.26	0.11	0.60	0.046		0.43					
III 1988	2.7	1.1	4.3	0.6	0.3	1.5	19.8	18.9	20.7	0.28	0.12	0.71		0.046	0.42					

* GENII assumptions of "spring" and "summer", using integral over 1 year intervals

TABLE IV.4. INITIAL PREDICTIONS FOR SCENARIO CB
CONCENTRATIONS IN CEREALS (Bq/kg f.w.)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
Winter Wheat	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
harvest 1986	13.30	10.50	16.90	11.00			13.00	2.00	35.00	37.00	10.00	100.00	140.00	82.64	199.73	0.265			25.90			12.00		
harvest 1987	0.128	0.048	0.340	0.51			0.90	0.30	3.00	0.40	0.10	2.00	0.72	0.46	1.01	0.259			12.60			0.31		
harvest 1988				0.50			0.80	0.20	2.00	0.30	0.10	2.00	0.60	0.56	0.82	0.252			12.20			0.23		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII		Hinton/ECOSYS			Tarrant/SPADE2		
Winter Wheat	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
													(sprg)	(summ)						
harvest 1986	16.00	12.00	19.00	20.00	10.00	40.00	38.00	36.00	42.00	1.40	0.278	4.80	0.04	44.00	60.00			1300.00		
harvest 1987	3.60	1.50	5.70	0.70	0.30	2.00	28.00	23.00	34.00	0.12	0.007	0.50	0.04	0.04	0.51			22.00		
harvest 1988	2.80	1.10	4.40	0.50	0.20	1.50	19.00	15.00	22.00	0.11	0.006	0.48	0.04	0.04	0.46			20.00		

* GENII assumptions of "spring" and "summer", using integral over 1 year intervals

TABLE IV.5. INITIAL PREDICTIONS FOR SCENARIO CB
CONCENTRATIONS IN FRUIT (Bq/kg f.w.)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
Apples/Pears	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
harvest 1986	26.20	20.70	33.00	24.00						140.00	20.00	200.00	0.062	0.041	0.096							28.00		
harvest 1987				12.00						0.40	0.10	2.00	0.060	0.039	0.093							2.50		
harvest 1988	1.99	0.41	9.58	7.70						0.30	0.10	2.00	0.059	0.037	0.091							1.60		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII		Hinton/ECOSYS			Tarrant/SPADE2		
Apples/Pears	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
													(sprg)	(summ)						
harvest 1986	4.70	3.80	5.60	5.00	2.00	20.00	70.00	65.00	75.00	1.80	1.2000	6.80	0.082	32.000	169.00					
harvest 1987	1.20	0.50	2.00	3.00	1.00	10.00	48.00	43.00	53.00	0.12	0.0064	0.53	0.081	0.081	0.50					
harvest 1988	1.10	0.50	1.80	2.00	1.00	5.00	31.00	28.00	35.00	0.12	0.0068	0.52	0.080	0.080	0.41					

TABLE IV.6. INITIAL PREDICTIONS FOR SCENARIO CB
CONCENTRATIONS IN MILK (Bq/L)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
monthly avg.:																								
May 1986	22.50	19.70	25.60	140.00			49.00	4.00	220.00	87.00	20.00	200.00	45.00	30.34	59.76				47.10			51.00		
Jun 1986	19.90	15.70	25.20	85.00			31.00	4.00	140.00	48.00	10.00	100.00	41.00	25.46	56.70	30.50			13.50			22.00		
Jul 1986	8.90	1.38	57.30	21.00						18.00	5.00	50.00	24.00	16.05	29.26	69.50			4.27			8.40		
Aug 1986	3.67	2.18	6.16	5.80			4.00	0.50	13.00	9.20	2.00	20.00	25.00	15.18	35.36	75.00			2.09			5.20		
Sep 1986	2.16	0.92	5.07	2.60			3.00	0.30	12.00	8.50	2.00	20.00	29.00	18.87	39.01	77.80			1.44			5.20		
quarterly avg.:																								
IV 1986	4.00	2.69	5.96	3.70			16.00	2.00	65.00	29.00	5.00	100.00	45.00	30.09	59.76	178.00			14.00			11.00		
I 1987	6.13	3.95	9.50	4.80			17.00	2.00	62.00	40.00	10.00	150.00	46.00	29.33	62.82	111.00			14.80			14.00		
II 1987	4.38	3.18	6.04	2.50			6.00	0.90	28.00	21.00	5.00	50.00	21.00	13.32	28.17	23.70			5.23			6.60		
III 1987	0.90	0.68	1.19	1.00			4.00	0.70	12.00	6.50	1.00	15.00	2.70	1.71	3.69	20.80			5.84			1.10		
IV 1987	0.41	0.12	1.36	0.90						0.60	0.10	2.00	1.80	1.06	2.53	3.36			2.77			0.55		
I 1988	0.51	0.28	0.93	0.83			0.40	0.20	1.40	0.50	0.10	2.00	1.50	0.96	2.04	1.04			2.77			0.59		
II 1988	0.40	0.19	0.87	0.66						0.50	0.10	2.00	1.10	0.70	1.48	0.52			2.58			0.29		
III 1988	0.12	0.034	0.43	0.54			0.30	0.10	1.30	0.50	0.10	2.00	0.37	0.12	0.60	0.32			3.16			0.09		
IV 1988	0.19	0.043	0.84	0.54						0.50	0.10	2.00	0.10	0.03	0.17	0.46			2.68			0.06		
I 1989	0.22	0.086	0.58	0.54			0.30	0.10	1.00	0.40	0.10	2.00	0.03	0.01	0.08	0.58			2.68			0.06		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII *		Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
monthly avg.:													(sprg)	(summ)						
May 1986	180.00	160.00	200.00	30.00	15.00	60.00	3.97	2.85	9.62	210.00	21.00	810.00	34.00		32.00			119.00		
Jun 1986	200.00	170.00	220.00	14.00	7.00	30.00	3.48	3.46	3.49	79.00	8.80	310.00			51.00			277.00		
Jul 1986	39.00	34.00	44.00	6.40	4.00	12.00	3.43	3.40	3.45	17.00	1.50	71.00		43.00	20.00			161.00		
Aug 1986	23.00	19.00	27.00	3.50	2.00	7.00	3.37	3.34	3.39	0.46	0.06	1.90			10.00			97.00		
Sep 1986	14.00	11.00	18.00	2.50	1.50	5.00	3.32	3.31	3.34	0.51	0.07	2.10			6.00			67.00		
quarterly avg.:																				
IV 1986	86.00	78.00	95.00	6.60	4.00	12.00	3.45	3.36	3.49	6.00	0.79	23.00			25.00			44.00		
I 1987	73.00	67.00	79.00	9.50	5.00	20.00	3.47	3.47	3.48	1.60	0.46	4.40			41.00			33.00		
II 1987	14.00	12.00	17.00	5.50	3.00	10.00	3.51	3.47	3.63	0.89	0.24	2.70	0.031		24.00			33.00		
III 1987	13.00	9.30	17.00	3.30	2.00	6.00	3.65	3.29	3.84	0.44	0.11	1.20		0.031	30.00			33.00		
IV 1987	15.00	11.00	19.00	1.70	1.00	4.00	2.69	2.50	3.14	0.44	0.068	1.40			13.00			22.00		
I 1988	8.40	6.40	10.00	1.10	0.50	2.00	2.56	2.49	2.74	0.53	0.074	1.70			6.00			22.00		
II 1988	7.20	4.40	10.00	0.75	0.40	1.50	2.99	2.81	3.08	0.36	0.055	1.10	0.030		0.40			22.00		
III 1988	6.70	3.50	9.80	0.40	0.20	1.00	2.88	2.49	3.04	0.25	0.037	0.90		0.030	0.50			22.00		
IV 1988	6.50	3.40	9.60	0.40	0.20	1.00	1.96	1.78	2.36	0.42	0.052	1.50			0.60			11.00		
I 1989	7.00	3.70	10.00	0.40	0.20	1.00	1.77	1.77	1.78	0.54	0.066	1.80								

* GENII assumptions of "spring" and "summer", using integral over 1 year intervals

TABLE IV.7. INITIAL PREDICTIONS FOR SCENARIO CB
CONCENTRATIONS IN BEEF (Bq/kg)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
monthly avg.:																								
May 1986				210.00			11.00	2.00	50.00	100.00	10.00	300.00	110.00	82.62	138.94				28.20			140.00		
Jun 1986	95.70	26.20	350.00	320.00			35.00	2.00	160.00	190.00	20.00	500.00	160.00	107.00	213.79	9.49			81.00			58.00		
Jul 1986	35.90	15.00	85.50	170.00						160.00	20.00	500.00	110.00	71.83	147.95	56.40			25.60			23.00		
Aug 1986	10.00	6.55	15.30	76.00			15.00	2.00	64.00	110.00	10.00	300.00	120.00	72.51	166.99	98.70			12.50			21.00		
Sep 1986	7.34	4.98	10.80	33.00			10.00	1.00	42.00	86.00	10.00	300.00	96.00	62.28	128.69	131.00			8.66			21.00		
quarterly avg.:																								
IV 1986	13.60	6.17	30.00	14.00			18.00	2.00	77.00	130.00	10.00	300.00	150.00	100.31	200.62	209.00			48.10			34.00		
I 1987	14.30	5.53	37.00	16.00			26.00	2.00	130.00	200.00	20.00	500.00	160.00	103.49	218.85	270.00			48.10			40.00		
II 1987	20.80	12.20	35.70	11.00			13.00	2.00	58.00	190.00	10.00	300.00	95.00	60.86	127.68	159.00			25.40			24.00		
III 1987	16.30	7.29	36.40	3.90			10.00	1.00	43.00	110.00	10.00	200.00	15.00	9.58	20.37	98.50			26.90			6.30		
IV 1987	3.56	1.32	9.57	3.20						47.00	5.00	100.00	5.40	3.18	7.40	58.20			7.88			1.80		
I 1988	2.12	0.465	9.63	2.70			0.80	0.20	2.00	14.00	2.00	30.00	4.90	3.37	6.48	30.30			7.88			1.70		
II 1988	2.83	0.977	8.22	2.40						7.00	1.00	20.00	4.00	2.73	5.26	16.00			7.46			1.10		
III 1988	1.79	0.679	4.73	1.80			0.50	0.10	2.00	4.10	0.50	10.00	1.30	0.55	2.10	8.59			8.86			0.39		
IV 1988	1.53	0.424	5.53	1.80						3.10	0.50	10.00	0.43	0.20	0.90	4.82			7.61			0.21		
I 1989	1.04	0.20	5.42	1.80			0.50	0.10	2.00	2.70	0.50	10.00	0.15	0.05	0.20	3.00			7.61			0.20		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII *		Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
monthly avg.:													(sprg)	(summ)						
May 1986	270.00	240.00	300.00	30.00	10.00	50.00	1.67	0.93	2.20	1900.00	210.00	7200.00	200.00		42.00			451.00		
Jun 1986	620.00	550.00	690.00	49.00	25.00	100.00	2.75	2.34	3.14	430.00	43.00	1700.00			159.00			1567.00		
Jul 1986	360.00	320.00	410.00	31.00	15.00	70.00	3.58	3.24	3.89	94.00	8.60	410.00		200.00	150.00			1258.00		
Aug 1986	210.00	180.00	230.00	20.00	10.00	40.00	4.24	3.98	4.48	2.20	0.24	7.50			118.00			967.00		
Sep 1986	130.00	110.00	140.00	14.00	16.00	30.00	4.74	4.54	4.94	1.20	0.14	1.10			90.00			667.00		
quarterly avg.:																				
IV 1986	140.00	120.00	160.00	15.00	6.00	30.00	5.99	5.07	6.93	32.00	3.80	140.00			126.00			109.00		
I 1987	260.00	230.00	290.00	21.00	10.00	50.00	7.73	7.12	8.30	1.90	0.55	5.00			239.00			219.00		
II 1987	180.00	160.00	200.00	17.00	9.00	40.00	9.01	8.44	9.53	0.88	0.20	2.50	0.17		245.00			109.00		
III 1987	77.00	66.00	87.00	9.00	5.00	20.00	9.89	9.63	10.00	0.63	0.09	1.90		0.17	213.00			219.00		
IV 1987	34.00	25.00	43.00	5.00	2.00	10.00	9.35	8.75	9.89	0.71	0.14	2.20			178.00			109.00		
I 1988	16.00	9.80	23.00	3.00	2.00	10.00	8.25	7.97	8.63	0.73	0.13	2.20			66.00			109.00		
II 1988	16.00	8.90	24.00	2.20	1.00	5.00	8.01	7.95	8.10	0.68	0.11	2.20	0.16		21.00			109.00		
III 1988	18.00	9.30	28.00	1.00	0.50	2.00	8.12	8.02	8.16	0.63	0.11	2.20		0.16	8.00			109.00		
IV 1988	15.00	8.70	21.00	1.00	0.50	2.00	7.45	6.93	7.94	0.65	0.10	2.00			5.00			109.00		
I 1989	11.00	7.60	15.00	1.00	0.50	2.00	6.46	6.15	6.82	0.66	0.11	2.00						109.00		

* GENII assumptions of "spring" and "summer", using integral over 1 year intervals

TABLE IV.8. INITIAL PREDICTIONS FOR SCENARIO CB
CONCENTRATIONS IN PORK (Bq/kg)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
monthly avg.:																								
May 1986				100.00			8.00	1.00	37.00	15.00	3.00	50.00	26.00	20.27	32.57							26.00		
Jun 1986	14.80	8.36	26.30	150.00			25.00	4.00	140.00	47.00	10.00	100.00	22.00	15.19	28.62	19.00						27.00		
Jul 1986	9.20	3.27	25.90	130.00						41.00	10.00	100.00	14.00	8.71	19.05	43.50						20.00		
Aug 1986	12.80	9.68	16.80	120.00			21.00	3.00	90.00	28.00	5.00	50.00	11.00	5.71	16.45	47.00						15.00		
Sep 1986	13.00	7.27	23.20	97.00			18.00	3.00	80.00	20.00	5.00	50.00	18.00	8.95	26.38	48.80						13.00		
quarterly avg.:																								
IV 1986	18.10	13.30	24.60	52.00			20.00	2.00	80.00	33.00	5.00	150.00	30.00	15.79	44.09	111.00			2.94			15.00		
I 1987	18.70	13.70	25.40	33.00			20.00	2.00	90.00	55.00	10.00	200.00	39.00	19.82	58.69	69.70			2.94			25.00		
II 1987	22.10	16.80	29.10	34.00			14.00	2.00	60.00	53.00	10.00	200.00	38.00	18.42	56.06	15.00			2.94			22.00		
III 1987	14.40	11.20	18.70	29.00			10.00	2.00	45.00	32.00	10.00	200.00	31.00	16.35	45.98	13.20			2.94			13.00		
IV 1987	3.97	2.50	6.30	19.00						11.00	2.00	50.00	7.50	3.24	11.18	2.27			0.98			6.80		
I 1988	1.01	0.661	1.54	5.90			4.00	0.80	12.00	2.00	0.50	10.00	1.30	0.60	2.01	0.82			0.98			1.50		
II 1988	3.67	0.351	38.40	3.20						1.10	0.20	5.00	1.10	0.53	1.65	0.49			0.98			0.87		
III 1988	1.33	0.696	2.54	2.80			3.00	0.80	11.00	1.00	0.20	5.00	0.99	0.49	1.45	0.36			0.98			0.53		
IV 1988	0.67	0.322	1.41	2.60						1.00	0.20	5.00	0.21	0.12	0.39	0.45			0.96			0.40		
I 1989	1.02	0.307	3.41	2.50			3.00	0.70	9.00	0.90	0.20	5.00	0.13	0.07	0.25	0.53			0.96			0.30		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII		Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
monthly avg.:													(sprg)	(summ)						
May 1986	8.70	7.00	10.00	10.00	5.00	25.00									61.00					
Jun 1986	82.00	69.00	96.00	17.00	10.00	35.00									103.00					
Jul 1986	68.00	57.00	79.00	13.00	4.00	20.00									93.00					
Aug 1986	43.00	36.00	50.00	7.00	4.00	20.00									66.00					
Sep 1986	28.00	24.00	33.00	5.00	2.00	15.00	12.80	3.25	19.90						44.00					
quarterly avg.:																				
IV 1986	13.00	9.60	15.00	15.00	8.00	35.00	26.70	22.20	28.40						53.00					
I 1987	4.30	3.20	5.40	19.00	10.00	45.00	28.40	28.30	28.40						89.00					
II 1987	14.00	11.00	18.00	19.00	10.00	45.00	28.20	28.10	28.30						96.00					
III 1987	35.00	33.00	37.00	16.00	6.00	25.00	26.90	22.80	28.10						111.00					
IV 1987	17.00	16.00	19.00	8.00	3.00	20.00	20.50	20.00	21.80						82.00					
I 1988	2.20	2.00	2.40	2.50	1.00	7.00	19.90	19.90	20.00						20.00					
II 1988	3.90	3.20	4.50	1.60	0.50	4.00	19.80	19.70	19.80						2.00					
III 1988	9.50	7.90	11.00	0.70	0.30	3.00	18.80	15.40	19.70						1.00					
IV 1988	6.10	5.10	7.20	0.70	0.30	3.00	13.50	13.10	14.60						1.00					
I 1989	2.00	1.60	2.30	0.70	0.30	3.00	13.02	12.99	13.07											

* GENII assumptions of "spring" and "summer", using integral over 1 year intervals

TABLE IV.9. *INITIAL PREDICTIONS FOR SCENARIO CB*
CONCENTRATIONS IN PASTURE VEGETATION (Bq/kg f.w.)

	observed *			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lo	up	mean	lo	up	mean	lo	up
May 1986	1685.0	546.0	858.0	1000.0			850.0	100.0	3000.0	1400.0	500.0	3000.0	1800.00	1405.96	2211.31				272.0			760.00		
Jul 1986	1291.0	205.0	414.0	65.0			220.0	30.0	800.0	100.0	25.0	3000.0	320.00	216.46	424.40				30.4			62.00		
May 1987				2.5			0.9	0.2	4.3	2.4	0.5	10.0	1.10	0.64	1.52				12.0			6.00		
Jul 1987				2.4			0.9	0.2	4.3	2.3	0.5	10.0	0.24	0.13	0.34				12.5			2.80		
May 1988				1.5			0.9	0.2	4.3	2.1	0.5	10.0	0.02	0.01	0.03				11.5			0.36		
Jul 1988				1.5			0.9	0.2	4.3	2.1	0.5	10.0	0.02	0.01	0.03				12.1			0.36		

* Jul 86 value is from Jun 86

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII		Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	lo	up	mean	lo	up
May 1986	1550.0	480.0	610.0	350.0	150.0	700.0	61.5	57.4	69.6	5200.00	1500.00	14000.00			1572.0					
Jul 1986	37.0	32.0	41.0	15.0	5.0	35.0	55.7	55.4	56.1	260.00	51.00	240.00			113.0					
May 1987	4.8	1.9	7.5	7.0	3.0	20.0	47.9	47.6	48.3	0.61	0.24	1.30			2.9					
Jul 1987	4.6	1.2	7.4	2.5	1.5	10.0	46.5	46.2	46.8	0.26	0.09	0.68			2.9					
May 1988	4.4	1.8	7.0	1.5	0.5	5.0	40.2	40.0	40.5	0.28	0.10	0.71			2.6					
Jul 1988	4.3	1.8	6.9	1.0	0.5	5.0	39.1	38.9	39.3	0.36	0.13	0.84			2.6					

TABLE IV.10. INITIAL PREDICTIONS FOR SCENARIO CB
CONCENTRATIONS IN ANIMAL FEED (Bq/kg f.w.)

SILAGE	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
harvest 1986	51.80	12.80	209.00							350.00	100.00	1000.00	51.00	20.38	92.42				69.40			0.62		
harvest 1987	11.00	0.455	266.00							5.20	1.00	20.00	0.37	0.22	0.58				34.20			0.20		
harvest 1988										4.50	1.00	20.00	0.26	0.17	0.37				32.40			0.20		

SILAGE	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII		Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
													(sprg)	(summ)						
harvest 1986	32.00	26.00	34.00	3.00	1.50	10.00	31.00	29.00	33.00	11.00	2.700	32.00	0.045	63.000	38.20					
harvest 1987	0.70	0.20	1.00	2.00	1.00	5.00	21.00	19.00	23.00	0.32	0.098	0.84	0.047	0.047	4.00					
harvest 1988	0.60	0.20	0.80	1.50	0.50	5.00	13.50	12.00	15.00	0.23	0.063	0.73	0.046	0.046	4.80					

SPRING BARLEY	observed			Peterson/CHERPAC			Horyna/SCHRAADLO			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
harvest 1986	19.40	7.20	52.10	7.70						23.00	5.00	50.00	37.00	22.76	50.66				49.50			6.50		
harvest 1987	0.21	0.17	0.27	0.50						0.40	0.10	2.00	0.69	0.45	0.90				12.60			0.30		
harvest 1988				0.49						0.30	0.10	2.00	0.63	0.41	0.82				12.30			0.30		

SPRING BARLEY	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII		Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
													(sprg)	(summ)						
harvest 1986	18.00	15.00	21.00	10.00	5.00	20.00	39.00	36.00	42.00	6.50	0.850	25.00	0.04	49.00	36.00					
harvest 1987	4.00	1.00	6.00	1.00	0.50	2.50	25.00	23.00	27.00	0.12	0.007	0.51	0.04	0.04	0.51					
harvest 1988	3.00	1.00	4.00	0.70	0.20	2.00	17.00	15.00	18.00	0.12	0.011	0.53	0.04	0.04	0.46					

TABLE IV.11. INITIAL PREDICTIONS FOR SCENARIO CB
HUMAN INTAKE (Bq/d)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
monthly avg.:																								
May 1986				110.00						70.00	20.00	150.00	93.00	83.00	103.01				66.80			26.00		
Jun 1986				94.00						49.00	10.00	100.00	46.00	36.88	54.85				25.40			27.00		
Jul 1986				42.00						44.00	10.00	100.00	45.00	32.99	56.27				12.60			16.00		
Aug 1986				30.00						35.00	5.00	70.00	30.00	21.07	38.57				9.52			11.00		
Sep 1986				23.00						30.00	5.00	70.00	28.00	19.13	36.52				7.32			11.00		
quarterly avg.:																								
IV 1986				19.00						48.00	10.00	100.00	58.00	42.03	73.55				42.20			16.00		
I 1987				19.00						60.00	10.00	100.00	68.00	45.81	74.88				42.20			21.00		
II 1987	5.88	3.47	9.98	16.00						51.00	10.00	100.00	33.00	26.63	39.24				33.90			16.00		
III 1987	(*)			10.00						22.00	5.00	50.00	14.00	13.18	14.70				30.20			7.70		
IV 1987				6.30						4.10	1.00	10.00	3.50	3.08	4.12				21.60			3.90		
I 1988				3.70						1.70	0.50	5.00	1.90	1.46	2.32				21.60			1.90		
II 1988				3.10						1.10	0.20	5.00	1.20	1.01	1.48				20.50			1.40		
III 1988				2.50						0.90	0.20	5.00	0.27	0.22	0.35				21.50			0.91		
IV 1988				2.30						0.80	0.20	5.00	0.22	0.17	0.29				21.10			0.85		
I 1989				2.30						0.70	0.20	5.00	0.20	0.15	0.25				21.10			0.83		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII		Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
monthly avg.:													(sprg)	(summ)						
May 1986	62.00	55.00	69.00	16.00	8.00	32.00	5.70		10.10						101.00					
Jun 1986	93.00	82.00	100.00	11.00	5.00	20.00	6.40	6.38	6.40						50.00					
Jul 1986	57.00	50.00	64.00	8.00	4.00	16.00	12.80	12.40	13.00						74.00					
Aug 1986	34.00	29.00	39.00	5.00	2.00	10.00	13.90	13.70	14.00						89.00					
Sep 1986	21.00	18.00	25.00	4.20	2.00	9.00	30.60	30.20	30.90						53.00					
quarterly avg.:																				
IV 1986	38.00	32.00	44.00	8.50	4.00	18.00	30.70	33.70	36.80						72.00					
I 1987	56.00	48.00	65.00	11.50	6.00	22.00	31.30	24.70	34.30						96.00					
II 1987	27.00	23.00	31.00	10.00	5.00	20.00	25.90	24.60	27.20						96.00					
III 1987	19.00	15.00	22.00	9.00	5.00	20.00	30.10	26.00	32.20						51.00					
IV 1987	8.50	5.20	12.00	5.00	2.00	10.00	25.90	24.80	28.20						28.00					
I 1988	4.60	2.50	6.80	2.50	1.00	5.00	22.60	18.20	24.80						4.00					
II 1988	5.40	2.70	8.00	2.00	1.00	5.00	19.70	18.30	20.20						2.00					
III 1988	6.10	3.20	9.10	1.40	0.70	3.00	21.30	17.50	22.40						1.00					
IV 1988	4.20	2.60	5.90	1.10	0.50	2.00	16.60	16.00	17.40						1.00					
I 1989	3.30	2.20	4.50	0.80	0.40	2.00	14.50	11.60	15.90											

(*) value for 7.6. - 14.7.1987

TABLE IV.12. INITIAL PREDICTIONS FOR SCENARIO CB
CONCENTRATIONS IN WHOLE BODY (Bq/kg)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
monthly avg.:																								
May 1986	3.21	2.74	3.76	37.00			5.50	2.20	14.00	8.50	2.00	15.00	16.00	14.04	18.06				14.10			7.00		
Jun 1986	3.99	3.42	4.65	73.00			11.00	3.10	40.00	25.00	5.00	50.00	21.00	16.75	25.27	4.94			16.80			12.00		
Jul 1986	6.39	5.12	7.97	83.00						31.00	7.00	70.00	23.00	17.38	28.60	33.20			16.40			14.00		
Aug 1986	7.27	6.65	7.95	79.00			12.00	2.90	45.00	35.00	5.00	70.00	24.00	16.97	31.02	62.70			15.50			15.00		
Sep 1986	8.11	7.36	8.94	73.00			12.80	2.70	48.00	36.00	5.00	70.00	22.00	15.27	28.84	87.50			11.80			15.00		
quarterly avg.:																								
IV 1986	10.10	9.36	11.00	59.00			14.00	2.70	50.00	42.00	10.00	100.00	27.00	18.69	35.53	138.00			30.40			17.00		
I 1987	11.40	10.60	12.30	46.00			21.00	2.90	78.00	57.00	10.00	100.00	35.00	24.28	45.50	215.00			40.70			22.00		
II 1987	11.30	10.70	11.90	39.00			18.00	2.70	70.00	65.00	10.00	100.00	35.00	22.80	46.60	162.00			41.60			24.00		
III 1987	11.00	10.30	11.70	31.00			15.00	2.90	57.00	54.00	10.00	100.00	26.00	15.86	35.85	113.00			40.20			19.00		
IV 1987	10.70	9.86	11.60	22.00						34.00	5.00	70.00	20.00	10.29	28.72	75.10			34.60			14.00		
I 1988	6.96	6.43	7.53	15.00			5.00	1.00	21.00	18.00	5.00	50.00	8.30	3.86	12.52	45.60			31.50			9.10		
II 1988	5.27	4.73	5.87	10.00						11.00	2.00	50.00	6.00	2.84	8.66	27.40			29.00			6.10		
III 1988	4.37	3.81	5.01	7.60			2.40	0.50	10.00	6.00	1.00	30.00	2.20	1.06	3.17	16.50			28.30			4.10		
IV 1988	4.27	3.73	4.88	5.90						3.50	0.50	5.00	1.20	0.52	1.68	10.00			27.60			2.80		
I 1989	3.36	2.91	3.89	5.00			1.40	0.40	4.20	2.20	0.50	5.00	0.81	0.33	1.18	6.43			27.60			2.10		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII		Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
monthly avg.:													(sprg)	(summ)						
May 1986	6.40	5.30	7.60	4.03	2.00	7.86	1.09		2.10						19.00					
Jun 1986	31.00	27.00	35.00	6.44	3.14	12.86	3.16	2.30	3.98						55.00					
Jul 1986	41.00	36.00	47.00	8.07	4.00	15.71	6.12	4.30	7.87						59.00					
Aug 1986	43.00	37.00	48.00	8.57	4.29	17.14	9.91	8.24	11.47						78.00					
Sep 1986	41.00	36.00	46.00	8.14	4.14	16.43	16.22	12.33	19.91						100.00					
quarterly avg.:																				
IV 1986	42.00	37.00	47.00	9.71	4.86	20.00	32.64	21.68	41.66						114.00					
I 1987	53.00	47.00	60.00	13.43	7.14	25.71	48.40	43.22	51.19						150.00					
II 1987	50.00	44.00	56.00	21.43	8.57	28.57	51.15	50.85	51.80						144.00					
III 1987	40.00	35.00	46.00	18.57	7.86	28.57	54.34	52.30	55.84						86.00					
IV 1987	29.00	24.00	34.00	12.43	6.43	27.14	55.57	54.55	56.18						50.00					
I 1988	20.00	16.00	24.00	8.43	4.29	17.14	53.07	50.77	54.32						17.00					
II 1988	14.00	11.00	18.00	6.00	2.86	11.43	47.72	46.04	50.02						10.00					
III 1988	11.00	7.50	15.00	4.29	2.14	8.57	45.63	44.81	46.03						6.00					
IV 1988	9.20	5.80	13.00	3.00	1.43	5.71	42.21	40.05	44.49						3.00					
I 1989	8.20	5.20	11.00	2.21	1.14	4.29	38.08	36.73	39.63											

TABLE IV.13. INITIAL PREDICTIONS FOR SCENARIO CB
DISTRIBUTION OF WHOLE BODY CONTENT

fractile (%) *	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
II 1987																								
97.5							190.0						9000.0											
68							610.0						3100.0											
50							820.0						2400.0											
32							1200.0						1600.0											
2.5							4900.0						560.0											
I 1989																								
97.5							30.0						490.0											
68							60.0						34.0											
50							82.0						16.0											
32							110.0						9.2											
2.5							300.0						4.2											

fractile (%) *	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII		Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
II 1987													(sprg)	(summ)						
97.5				70.0	50.0	200.0	51.9													
68				390.0	200.0	800.0	51.2													
50				1050.0	500.0	2000.0	51.0													
32				1150.0	500.0	2000.0	50.9													
2.5				4600.0	3000.0	10000.0	50.8													
I 1989																				
97.5				40.0	30.0	100.0	39.7													
68				90.0	50.0	200.0	38.8													
50				155.0	70.0	300.0	38.0													
32				200.0	100.0	400.0	37.5													
2.5				710.0	300.0	1500.0	36.7													

* fractile of a CCDF or (1-p), where p is a fractile of CDF.
CCDF = Complementary Cumulative Distribution Function
CDF = Cumulative Distribution Function

TABLE IV.14. INITIAL PREDICTIONS FOR SCENARIO CB
EXTERNAL DOSE

	estimated			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
cloud exposure (nSv)	14.0	9.2	22.0	3400.0			54.0	9.0	100.0	24.0	5.0	200.0	10.0	9.0	12.0	28.9	27.7	42.9	46.5			2800		
ground exposure (mSv)																								
29-Apr-86 - 30-Apr-87				0.024			0.033	0.007	0.120	0.014	0.005	0.030	0.026	0.022	0.029				0.037			0.018		
29-Apr-86 - 30-Apr-88				0.036			0.052	0.016	0.200	0.024	0.007	0.050	0.045	0.041	0.052				0.073			0.034		
29-Apr-86 - 30-Apr-89	34.0	20.0	52.0	0.041			0.080	0.030	0.300	0.035	0.010	0.070	0.059	0.052	0.066	0.027	0.011	0.038	0.097			0.046		
29-Apr-86 - lifetime										0.230	0.070	0.500	0.250	0.180	0.360				0.238			0.188		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII *		Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
													(sprg	(summ)						
cloud exposure (nSv)	70.0	35.0	110.0	40.0	30.0	70.0	63.4			66.0	14.0	180.0	160.0	160.0	25.0					
ground exposure (mSv)																				
29-Apr-86 - 30-Apr-87	0.022	0.014	0.030	0.011	0.006	0.020	0.00012			0.067	0.030	0.120	0.019	0.019	0.021					
29-Apr-86 - 30-Apr-88	0.034	0.022	0.046	0.018	0.009	0.038	0.00021			0.130	0.076	0.200	0.038	0.038	0.037					
29-Apr-86 - 30-Apr-89	0.044	0.029	0.059	0.025	0.014	0.050	0.00023			0.200	0.130	0.280	0.056	0.056	0.049					
29-Apr-86 - lifetime	0.250	0.160	0.330	0.190	0.100	0.400							0.570	0.570	0.350					

* GENII assumptions of "spring" and "summer", using integral over 1 year intervals

TABLE IV.15. INITIAL PREDICTIONS FOR SCENARIO CB
INHALATION DOSE (nSv)

	estimated			Peterson/CHERPAC			Horyna/SCHRAADLO			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
inhalation from cloud	2900	1800	4600	20000			4100	800	8000	8000	2000	20000	1100	900	1400	5140	5140	5140	5620			5100		
inhalation of resuspension																								
29-Apr-86 - 30-Apr-87							1.2			6.7	1.0	20.0	3.3	2.5	4.2				0.56			45.0		
29-Apr-86 - 30-Apr-88							1.8			8.5	1.0	20.0	3.4	2.5	4.2				1.10			47.0		
29-Apr-86 - 30-Apr-89							2.2			9.6	1.0	20.0	3.4	2.5	4.2				1.46			48.0		
29-Apr-86 - lifetime										25.0	5.0	500.0	3.6	2.5	4.2	41.1	16.1	57.6	35.90			75.0		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII *		Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
													(sprg	(summ)						
inhalation from cloud	6100	3300	9000	1500	1000	3000	10100			7300	680	30000	14000	14000	8000					
inhalation of resuspension																				
29-Apr-86 - 30-Apr-87				3.0	1.0	10.0	3.3								8.3					
29-Apr-86 - 30-Apr-88				4.2	2.0	20.0	6.8													
29-Apr-86 - 30-Apr-89				5.0	2.5	25.0	7.0													
29-Apr-86 - lifetime				6.0	3.0	30.0														

* GENII assumptions of "spring" and "summer", using integral over 1 year intervals

TABLE IV.16. INITIAL PREDICTIONS FOR SCENARIO CB
INGESTION DOSE (mSv)

	estimated values	Peterson/CHERPAC	Horyna/SCHRAADLO-T	Mueller/ECOSYS	Kanyar/TERNIRBU	Sohier/DOSDIM	Hu/HUMOD	Kliment/ENCONAN
29-Apr-86 - 30-Apr-87								
total:		0.160		0.260	0.260		0.165	0.085
lower conf. interval				0.070	0.240			
upper conf. interval				0.500	0.280			
food type 1:		0.069 milk	0.038 milk	0.063 milk	0.130 milk		0.047 milk	0.035 milk
food type 2:		0.035 pork	0.028 l.veg	0.053 fruit	0.043 beef		0.033 wheat	0.020 meat
food type 3:		0.019 beef	0.020 cereals	0.042 beef	0.038 baker's ware		0.018 beef	0.015 fruit
29-Apr-86 - 30-Apr-88								
total:		0.230		0.340	0.320		0.297	0.120
lower conf. interval				0.100	0.301			
upper conf. interval				0.700	0.336			
food type 1:		0.085 milk	0.041 milk	0.070 milk	0.145 milk		0.071 wheat	0.040 milk
food type 2:		0.055 pork	0.036 cereals	0.064 fruit	0.079 baker's ware		0.061 milk	0.031 meat
food type 3:		0.023 beef	0.030 l.veg	0.063 beef	0.049 beef		0.058 beef	0.019 fruit
29-Apr-86 - 30-Apr-89								
total:	0.062	0.250	0.150	0.340	0.325		0.369	0.130
lower conf. interval	0.058			0.100	0.304			
upper conf. interval	0.070			0.700	0.340			
food type 1:		0.088 milk	0.043 milk	0.070 milk	0.146 milk		0.089 wheat	0.049 milk
food type 2:		0.058 pork	0.043 cereals	0.064 fruit	0.080 baker's ware		0.085 beef	0.033 meat
food type 3:		0.028 fruit	0.031 l.veg.	0.064 beef	0.050 beef		0.067 milk	0.021 fruit
29-Apr-86 - lifetime								
total:				0.370	0.330	0.549	0.369	0.230
lower conf. interval				0.100	0.308	0.215		
upper conf. interval				0.700	0.344	0.768		
food type 1:				0.078 milk	0.146 milk		0.089 wheat	
food type 2:				0.071 beef	0.081 baker's ware		0.085 beef	
food type 3:				0.066 fruit	0.051 beef		0.067 milk	

TABLE IV.16. INITIAL PREDICTIONS FOR SCENARIO CB
INGESTION DOSE (mSv)
(continued)

	Krajewski/CLRP	Galeriu/LINDOZ	Carrasco/PRYMA	Napier/HEDR	Napier/GENII * (sprg)	Napier/GENII * (summ)	Hinton/ECOSYS	Tarrant/SPADE2
29-Apr-86 - 30-Apr-87								
total:	0.090	0.022	0.106	0.320	0.270	0.480	0.420	
lower conf. interval	0.067	0.010		0.076				
upper conf. interval	0.110	0.050		1.000				
food type 1:	0.061 milk	0.008 milk	0.047 cereals	0.210 meat	0.150 meat	0.200 meat	0.140 fruit	
food type 2:	0.023 meat	0.005 meat	0.018 potatoes	0.063 milk	0.086 milk	0.160 fr&veg	0.050 milk	
food type 3:	0.006 cereals	0.005 grain	0.010 milk	0.045 plant	0.011 fr&veg	0.110 milk	0.040 veg.	
29-Apr-86 - 30-Apr-88								
total:	0.160	0.052	0.218	0.330	0.310	0.540	0.610	
lower conf. interval	0.120	0.025		0.081				
upper conf. interval	0.200	0.100		1.000				
food type 1:	0.100 milk	0.015 milk	0.107 cereals	0.220 meat			0.170 fruit	
food type 2:	0.043 meat	0.014 grain	0.031 potatoes	0.064 milk			0.080 beef	
food type 3:	0.015 cereals	0.013 meat	0.020 milk	0.046 plant			0.070 milk	
29-Apr-86 - 30-Apr-89								
total:	0.190	0.060	0.299	0.330	0.310	0.540	0.610	
lower conf. interval	0.140	0.030		0.085				
upper conf. interval	0.230	0.130		1.000				
food type 1:	0.110 milk	0.017 milk	0.148 cereals	0.220 meat			0.180 fruit	
food type 2:	0.051 meat	0.016 grain	0.041 potatoes	0.065 milk			0.080 beef	
food type 3:	0.020 cereals	0.016 meat	0.027 milk	0.047 plant			0.070 milk	
29-Apr-86 - lifetime								
total:	0.200				0.320	0.560	0.640	
lower conf. interval	0.150							
upper conf. interval	0.250							
food type 1:	0.120 milk				0.180 meat	0.220 meat	0.180 fruit	
food type 2:	0.054 meat				0.099 milk	0.190 fr&veg	0.080 beef	
food type 3:	0.021 cereals				0.021 fr&veg	0.120 milk	0.080 milk	

* GENII assumptions of "spring" and "summer", using integral over 1 year intervals

TABLE IV.17. INITIAL PREDICTIONS FOR SCENARIO CB
TOTAL DOSE (mSv)

	Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
29-Apr-86 -30-Apr-87																					
total:	0.200						0.280	0.070	0.500	0.290	0.240	0.400				0.208			0.090		
pathway 1:	0.160 ing						0.260 ing	0.070	0.500	0.260 ing						0.165 ing			0.085 ing		
pathway 2:	0.024 ext			0.033 ext	0.007,	0.120	0.014 ext	0.005	0.030	0.026 ext						0.037 ext			0.004 inh		
pathway 3:	0.019 inh			0.004 inh	0.001	0.008	0.008 inh	0.002	0.020	0.001 inh						0.006 inh					
29-Apr-86 -30-Apr-88																					
total:	0.290						0.370	0.100	0.700	0.360	0.300	0.470				0.376			0.130		
pathway 1:	0.230 ing						0.340 ing	0.100	0.700	0.319 ing						0.297 ing			0.125 ing		
pathway 2:	0.036 ext			0.052 ext	0.016	0.200	0.024 ext	0.007	0.050	0.045 ext						0.073 ext			0.005 inh		
pathway 3:	0.021 inh						0.008 inh	0.002	0.020							0.006 inh					
29-Apr-86 -30-Apr-89																					
total:	0.310			0.234			0.380	0.100	0.700	0.380						0.471			0.140		
pathway 1:	0.250 ing			0.150 ing			0.340 ing	0.100	0.700	0.325 ing						0.369 ing			0.134 ing		
pathway 2:	0.041 ext			0.080 ext	0.030	0.300	0.035 ext	0.010	0.070	0.059 ext						0.097 ext			0.006 inh		
pathway 3:	0.021 inh			0.004 inh			0.008 inh	0.002	0.020							0.006 inh					
29-Apr-86 - lifetime																					
total:							0.610	0.200	1.000	0.580			0.581			0.613			0.240		
pathway 1:							0.370 ing	0.100	0.700	0.330 ing			0.549 ing	0.215	0.768	0.369 ing					
pathway 2:							0.230 ext	0.070	0.500	0.250 ext			0.027 ext	0.011	0.038	0.238 ext					
pathway 3:							0.008 inh	0.002	0.020				0.005 inh	0.005	0.005	0.006 inh					

ext	external
ing	ingestion
inh	inhalation

TABLE IV.17. INITIAL PREDICTIONS FOR SCENARIO CB
TOTAL DOSE (mSv)
(continued)

	Krajewski/CLRP				Galeriu/LINDOZ				Carrasco/PRYMA				Napier/HEDR				Napier/GENII *			Hinton/ECOSYS				Tarrant/SPADE2		
	mean		lower	upper	mean		lower	upper	mean		lower	upper	mean		lower	upper	mean		mean	mean		low	up	mean	low	up
29-Apr-86 -30-Apr-87																	(spring)		(summer)							
total:	0.120		0.084	0.150	0.045		0.022	0.100	0.116				0.400		0.140	1.100	0.300		0.510	0.450						
pathway 1:	0.090	ing	0.067	0.110	0.029	ing			0.106	ing			0.320	ing	0.076	1.000	0.270	ing	0.480	0.420	ing					
pathway 2:	0.022	ext	0.014	0.030	0.014	ext			0.010	inh			0.067	ext	0.030	0.120	0.019	ext	0.019	0.020	ext					
pathway 3:	0.006	inh	0.003	0.009	0.002	inh			0.0002	ext			0.007	inh	0.001	0.030	0.014	inh	0.014	0.008	inh					
29-Apr-86 -30-Apr-88																										
total:	0.200		0.150	0.260	0.072		0.036	0.150	0.228				0.470		0.210	1.200	0.350		0.580	0.660						
pathway 1:	0.160	ing	0.120	0.200	0.053	ing			0.218	ing			0.330	ing	0.081	1.000				0.610	ing					
pathway 2:	0.034	ext	0.022	0.046	0.018	ext			0.010	inh			0.130	ext	0.076	0.200				0.040	ext					
pathway 3:	0.006	inh	0.003	0.009	0.001	inh			0.0003	ext			0.007	inh	0.001	0.030				0.008	inh					
29-Apr-86 -30-Apr-89																										
total:	0.240		0.170	0.300	0.087		0.045	0.200	0.310				0.540		0.270	1.260	0.370		0.600	0.670						
pathway 1:	0.190	ing	0.140	0.230	0.060	ing			0.299	ing			0.330	ing	0.085	1.000				0.610	ing					
pathway 2:	0.044	ext	0.029	0.059	0.025	ext			0.011	inh			0.200	ext	0.130	0.280				0.050	ext					
pathway 3:	0.006	inh	0.003	0.009	0.001	inh			0.0003	ext			0.007	inh	0.001	0.030				0.008	inh					
29-Apr-86 - lifetime																										
total:	0.460		0.310	0.590													0.890		1.100	1.000						
pathway 1:	0.250	ext	0.160	0.330													0.320	ing	0.560	0.640	ing					
pathway 2:	0.200	ing	0.150	0.250													0.570	ext	0.570	0.350	ext					
pathway 3:	0.006	inh	0.003	0.009													0.014	inh	0.014	0.008	inh					

* GENII assumptions of "spring" and "summer", using integral over 1 year intervals

ext	external
ing	ingestion
inh	inhalation

TABLE IV.18. SUMMARY OF REVISED MODEL PREDICTIONS FOR SCENARIO CB

Name▸	Obs.	Sohier	Peterson	Hu	Horyna	Kliment	Müller	Kanyar	Krajewski	Galeriu	Carrasco	Hinton	Tarrant	Napier	Napier
CODE▸	data	DOSDIM	CHERPAC	HUMOD	SCHRAADLO-T	ENCONAN	ECOSYS	TERNIRBU	CLRP	LINDOZ	PRYMA	ECOSYS	SPADE2	GENII	HEDR
Total deposition	+↕	+	+↕	+	+↕	+	+	+↕	+	+↕	+	+			
Leafy vegetables	+↕	+	+↕	+	+↕	+	+	+↕	+	+	+	+			
Cereals:															
- winter wheat	+↕	+	+↕	+	+↕	+	+	+↕	+	+↕	+	+			
Fruits:															
- apples/pears	+↕		+↕	+		+	+		+	+↕	+	+			
Milk	+↕	+	+↕	+	+↕	+	+	+↕	+	+↕	+	+			
Beef	+↕	+	+↕	+	+↕	+	+	+↕	+	+↕	+	+			
Pork	+↕	+	+↕	+	+↕	+	+	+↕	+	+↕	+	+			
Pasture vegetation	+↕	+	+↕	+	+↕	+	+	+↕	+	+↕	+	+			
Animal feed:															
- silage	+↕	+		+		+	+		+		+	+			
- spring barley	+↕	+	+↕	+		+	+	+↕	+	+↕	+	+			
Human intake	+↕	+	+↕	+		+	+	+↕	+		+	+			
Whole body	+↕	+	+↕	+	+↕	+	+	+↕	+	+↕	+	+			
WBC distribution			+							+↕					
External dose	+↕*	+	+↕	+		+	+		+	+↕		+			
Inhalation dose	+↕*	+	+↕	+		+	+		+	+	+	+			
Ingestion dose	+↕*	+	+↕	+		+	+		+		+	+			
Total dose		+	+	+		+	+		+		+	+			

+	only arithmetic mean
+↕	both arithmetic mean and 95% confidence interval
*	estimated values

TABLE IV.19. REVISED PREDICTIONS FOR SCENARIO CB
TOTAL [WET AND DRY] DEPOSITION (Bq m-2)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
total deposition	5570	4050	7660	6500	1100	35000	5900	4700	7100	5600			5900	4700	6800	7400			5123			4700		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII			Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
total deposition	5482			6100	5000	7000	7584									6090					

TABLE IV.20. REVISED PREDICTIONS FOR SCENARIO CB
CONCENTRATIONS IN LEAFY VEGETABLES (Bq/kg f.w.)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
monthly avg.:																								
May 1986							340.0	250.0	420.0	2000.0			290.0	120.0	380.0	1344.0			986.0			16.0		
Jun 1986				7.0	1.4	100.0	90.0	70.0	110.0	86.0			58.0	25.0	84.0	768.0			123.0			6.7		
Jul 1986				9.5	1.9	130.0				0.3			1.2	0.6	1.9	395.0			15.9			5.5		
Aug 1986				10.0	2.0	130.0	15.0	12.0	18.0	0.3			1.1	0.6	1.8	192.0			2.5			3.5		
Sep 1986	240.0	63.4	909.0	10.0	2.0	130.0	7.0	5.0	9.0	0.3			1.1	0.6	1.8	94.0			0.9			3.5		
quarterly avg.																								
II 1987				7.00	1.60	84.00	0.90	0.70	1.10	0.20			0.82	0.38	1.50	1.03			0.60			2.50		
III 1987				0.65	0.12	9.20	0.90	0.70	1.10	0.20			0.82	0.37	1.50	0.52			0.60			2.50		
II 1988				0.65	0.11	7.70	0.90	0.70	1.10	0.20			0.76	0.32	1.40	0.51			0.39			1.50		
III 1988				0.64	0.12	9.00	0.90	0.70	1.10	0.20			0.71	0.30	1.40	0.51			0.39			1.50		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII		Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
monthly avg.:													(sprg	(summ)						
May 1986	804.0			290.0			352.5								683.0					
Jun 1986	199.1			52.0			352.5								289.0					
Jul 1986	55.7			18.0											0.8					
Aug 1986	31.6														0.8					
Sep 1986				10.0											0.8					
quarterly avg.																				
II 1987	0.89			1.20			5.32								0.30					
III 1987	1.44			1.20											0.30					
II 1988	0.69			1.00			3.51								0.30					
III 1988	1.13			0.90											0.30					

TABLE IV.21. REVISED PREDICTIONS FOR SCENARIO CB
CONCENTRATIONS IN CEREALS (Bq/kg f.w.)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
Winter Wheat	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
harvest 1986	13.30	10.50	16.90	24.00	1.40	290.00	13.00	10.00	35.00	24.00			21.00	7.80	34.00	0.371			9.20			12.00		
harvest 1987	0.128	0.048	0.340	0.86	0.06	8.60	0.90	0.70	1.10	0.30			0.91	0.47	1.60	0.363			0.12			0.31		
harvest 1988				0.84	0.05	8.40	0.80	0.60	1.00	0.30			0.87	0.42	1.60	0.354			0.12			0.23		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII		Hinton/ECOSYS			Tarrant/SPADE2		
Winter Wheat	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
													(sprg)	(summ)						
harvest 1986	9.12			22.80	11.00	44.00	8.30								26.40					
harvest 1987	0.30			0.32	0.10	1.00	0.12								0.40					
harvest 1988	0.23			0.26	0.10	1.00	0.12								0.30					

TABLE IV.22. REVISED PREDICTIONS FOR SCENARIO CB
CONCENTRATIONS IN FRUIT (Bq/kg f.w.)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
Apples/Pears	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
harvest 1986	26.20	20.70	33.00	45.00	7.90	525.00				16.00									15.30			28.00		
harvest 1987				22.00	3.70	250.00				0.30									2.76			2.50		
harvest 1988	1.99	0.41	9.58	14.00	2.40	160.00				0.30									1.02			1.60		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII		Hinton/ECOSYS			Tarrant/SPADE2		
Apples/Pears	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
													(sprg)	(summ)						
harvest 1986	2.03			5.00	2.00	20.00	10.60								45.00					
harvest 1987	0.01			3.00	1.00	10.00	6.90								0.20					
harvest 1988	0.01			2.00	1.00	5.00	4.60								0.10					

TABLE IV.23. REVISED PREDICTIONS FOR SCENARIO CB
CONCENTRATIONS IN MILK (Bq/l)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
monthly avg.:																								
May 1986	22.50	19.70	25.60	370.00	62.00	3000.00	49.00	37.00	61.00	18.00			23.00	14.00	32.00	50.40			63.00			51.00		
Jun 1986	19.90	15.70	25.20	210.00	18.00	1800.00	31.00	23.00	39.00	19.00			13.00	7.30	19.00	33.20			57.00			22.00		
Jul 1986	8.90	1.38	57.30	50.00	2.90	660.00				10.00			6.20	3.20	9.40	15.30			21.00			8.40		
Aug 1986	3.67	2.18	6.16	12.00	0.80	140.00	4.00	3.30	4.70	5.80			5.20	3.00	7.50	7.96			9.20			5.20		
Sep 1986	2.16	0.92	5.07	4.40	0.24	38.00	3.00	2.30	3.80	4.50			5.30	2.80	7.90	5.31			5.80			5.20		
quarterly avg.:																								
IV 1986	4.00	2.69	5.96	7.10	0.49	69.00	16.00	13.00	20.00	9.70			8.40	4.80	13.00	12.60			8.78			11.00		
I 1987	6.13	3.95	9.50	9.90	0.73	97.00	17.00	13.00	21.00	13.00			7.40	4.40	11.00	18.70			8.78			14.00		
II 1987	4.38	3.18	6.04	2.00	0.19	23.00	6.00	4.40	7.60	6.60			3.00	1.70	4.30	10.10			5.00			6.60		
III 1987	0.90	0.68	1.19	1.50	0.22	23.00	4.00	3.20	5.80	2.00			1.50	0.72	2.30	2.09			2.30			1.10		
IV 1987	0.41	0.12	1.36	1.20	0.17	18.00	1.00	0.70	1.30	0.30			1.40	0.70	2.30	0.54			0.41			0.55		
I 1988	0.51	0.28	0.93	1.10	0.14	17.00	0.40	0.30	0.50	0.30			1.40	0.65	2.10	0.42			0.41			0.59		
II 1988	0.40	0.19	0.87	0.73	0.10	12.00	0.40	0.30	0.50	0.20			1.30	0.62	2.10	0.33			0.34			0.29		
III 1988	0.12	0.034	0.43	0.70	0.10	12.00	0.30	0.20	0.40	0.20			0.48	0.22	0.75	0.28			0.30			0.09		
IV 1988	0.19	0.043	0.84	0.70	0.10	12.00	0.30	0.20	0.40	0.20			0.44	0.14	0.75	0.33			0.28			0.06		
I 1989	0.22	0.086	0.58	0.70	0.10	12.00	0.30	0.20	0.40	0.20			0.42	0.13	0.72	0.37			0.28			0.06		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII			Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
monthly avg.:																					
May 1986	29.59			37.00	17.00	70.00	18.57									26.10					
Jun 1986	10.35			16.00	8.00	32.00	4.85									36.50					
Jul 1986	3.87			7.40	3.60	15.00	2.16									13.60					
Aug 1986	2.10			4.40	2.20	9.00	1.64									6.90					
Sep 1986	1.53			2.80	1.40	6.00	1.38									4.40					
quarterly avg.:																					
IV 1986	3.33			5.90	3.00	12.00	4.26									4.00					
I 1987	4.76			10.00	5.00	20.00	4.46									4.90					
II 1987	2.41			6.60	3.00	13.00	2.10									2.50					
III 1987	0.63			2.20	1.10	3.30	1.86									0.40					
IV 1987	0.37			1.30	0.60	3.00	0.67									0.30					
I 1988	0.15			0.60	0.30	1.20	0.55									0.20					
II 1988	0.18			0.70	0.30	1.40	0.85									0.20					
III 1988	0.36			0.90	0.50	1.80	0.86									0.30					
IV 1988	0.32			0.90	0.50	1.80	0.46									0.20					
I 1989	0.13			0.70	0.30	1.40	0.42									0.20					

TABLE IV.24. REVISED PREDICTIONS FOR SCENARIO CB
CONCENTRATIONS IN BEEF (Bq/kg)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
monthly avg.:																								
May 1986				570.00	68.00	6900.00	11.00	8.00	14.00	17.00			40.00	19.00	58.00	13.20			158.00			140.00		
Jun 1986	95.70	26.20	350.00	810.00	82.00	10000.00	35.00	27.00	43.00	51.00			42.00	25.00	58.00	28.90			137.00			58.00		
Jul 1986	35.90	15.00	85.50	440.00	35.00	5700.00				55.00			16.00	8.10	24.00	33.90			48.90			23.00		
Aug 1986	10.00	6.55	15.30	190.00	14.00	2600.00	15.00	12.00	18.00	45.00			13.00	7.20	21.00	31.60			23.40			21.00		
Sep 1986	7.34	4.98	10.80	76.00	4.70	1000.00	10.00	8.00	12.00	36.00			11.00	5.70	19.00	29.40			11.50			21.00		
quarterly avg.:																								
IV 1986	13.60	6.17	30.00	30.00	1.80	450.00	18.00	13.00	23.00	41.00			19.00	11.00	30.00	30.30			34.90			34.00		
I 1987	14.30	5.53	37.00	32.00	1.60	520.00	26.00	19.00	33.00	59.00			17.00	9.70	26.00	41.00			34.90			40.00		
II 1987	20.80	12.20	35.70	13.00	0.95	220.00	13.00	10.00	16.00	54.00			8.30	4.30	13.00	42.30			23.90			24.00		
III 1987	16.30	7.29	36.40	5.40	0.77	80.00	10.00	8.00	12.00	29.00			4.30	1.60	7.10	28.80			18.40			6.30		
IV 1987	3.56	1.32	9.57	4.50	0.63	69.00	3.20	2.60	3.80	12.00			3.30	1.50	5.30	15.60			1.73			1.80		
I 1988	2.12	0.465	9.63	3.60	0.34	63.00	0.80	0.70	0.90	4.10			3.10	1.40	5.10	8.60			1.73			1.70		
II 1988	2.83	0.977	8.22	2.70	0.27	50.00	0.70	0.60	0.80	2.30			3.10	1.40	4.90	5.05			1.50			1.10		
III 1988	1.79	0.679	4.73	2.30	0.23	43.00	0.50	0.40	0.60	1.50			1.20	0.50	2.00	3.15			1.40			0.39		
IV 1988	1.53	0.424	5.53	2.30	0.24	44.00	0.50	0.40	0.60	1.30			1.00	0.30	1.80	2.19			1.30			0.21		
I 1989	1.04	0.20	5.42	2.30	0.24	44.00	0.50	0.40	0.60	1.20			0.90	0.31	1.60	1.78			1.30			0.20		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII			Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
monthly avg.:																					
May 1986	18.24			31.00	15.00	60.00	100.17									18.20					
Jun 1986	30.10			43.00	22.00	90.00	87.51									104.80					
Jul 1986	27.82			29.00	14.00	60.00	52.53									101.60					
Aug 1986	22.28			21.00	10.00	44.00	33.73									80.20					
Sep 1986	17.69			14.80	7.00	30.00	23.48									60.80					
quarterly avg.:																					
IV 1986	18.19			15.00	7.00	30.00	46.03									41.00					
I 1987	26.06			22.00	11.00	44.00	58.85									37.80					
II 1987	22.94			21.00	11.00	43.00	47.28									30.20					
III 1987	7.56			7.60	4.00	15.00	40.21									12.40					
IV 1987	2.64			4.30	2.00	9.00	19.22									5.80					
I 1988	1.20			1.80	1.00	4.00	8.77									3.00					
II 1988	0.87			2.00	1.00	4.00	9.93									1.80					
III 1988	0.86			2.30	1.00	5.00	11.01									1.60					
IV 1988	1.07			2.10	1.00	5.00	7.38									1.50					
I 1989	0.80			1.70	0.70	4.00	5.51									1.30					

TABLE IV.25. REVISED PREDICTIONS FOR SCENARIO CB
CONCENTRATIONS IN PORK (Bq/kg)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
monthly avg.:																								
May 1986				54.00	9.00	440.00	8.00	6.00	10.00	2.90			5.00	1.70	11.00	31.50			15.70			26.00		
Jun 1986	14.80	8.36	26.30	75.00	11.00	600.00	25.00	19.00	31.00	12.00			12.00	7.20	17.00	20.70			28.40			27.00		
Jul 1986	9.20	3.27	25.90	69.00	9.40	590.00				14.00						9.55			10.50			20.00		
Aug 1986	12.80	9.68	16.80	58.00	7.40	540.00	21.00	17.00	25.00	11.00						4.97			10.60			15.00		
Sep 1986	13.00	7.27	23.20	49.00	6.00	470.00	18.00	14.00	22.00	9.10						3.33			8.90			13.00		
quarterly avg.:																								
IV 1986	18.10	13.30	24.60	24.00	2.70	220.00	20.00	15.00	25.00	21.00						8.13			10.60			15.00		
I 1987	18.70	13.70	25.40	13.00	1.50	130.00	20.00	15.00	25.00	31.00						12.00			10.60			25.00		
II 1987	22.10	16.80	29.10	13.00	1.40	130.00	14.00	10.00	18.00	31.00						6.58			9.50			22.00		
III 1987	14.40	11.20	18.70	11.00	1.20	110.00	10.00	7.00	13.00	23.00						1.55			8.50			13.00		
IV 1987	3.97	2.50	6.30	7.10	0.70	71.00	5.00	3.00	7.00	8.50						0.57			0.50			6.80		
I 1988	1.01	0.661	1.54	2.00	0.28	24.00	4.00	3.20	4.80	1.40						0.50			0.50			1.50		
II 1988	3.67	0.351	38.40	0.88	0.14	11.00	3.00	2.40	3.60	0.60						0.44			0.47			0.87		
III 1988	1.33	0.696	2.54	0.77	0.13	11.00	3.00	2.40	3.60	0.60						0.41			0.47			0.53		
IV 1988	0.67	0.322	1.41	0.75	0.13	11.00	3.00	2.40	3.60	0.50						0.44			0.44			0.40		
I 1989	1.02	0.307	3.41	0.74	0.13	10.00	3.00	2.40	3.60	0.50						0.46			0.44			0.30		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII			Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
monthly avg.:																					
May 1986	8.30			8.00	4.00	16.00										33.90					
Jun 1986	13.14			14.00	7.00	28.00	0.35									79.00					
Jul 1986	9.91			11.00	5.00	22.00	1.11									63.60					
Aug 1986	7.51			7.00	3.00	15.00	2.08									45.30					
Sep 1986	8.72			5.20	2.50	10.00	3.74									30.40					
quarterly avg.:																					
IV 1986	10.31			13.00	6.00	25.00	10.05									26.70					
I 1987	11.41			18.00	9.00	36.00	8.46									39.10					
II 1987	10.96			17.00	8.00	35.00	10.99									40.10					
III 1987	6.98			13.40	6.00	26.00	10.54									40.20					
IV 1987	1.40			10.00	5.00	20.00	6.71									27.80					
I 1988	0.45			2.00	3.00	15.00	2.83									6.60					
II 1988	0.40			1.00	0.50	2.00	1.04									1.00					
III 1988	0.50			1.10	0.50	2.00	0.92									0.70					
IV 1988	0.58			0.90	0.40	2.00	1.16									0.70					
I 1989	0.35			0.80	0.40	2.00										0.70					

TABLE IV.26. REVISED PREDICTIONS FOR SCENARIO CB
CONCENTRATIONS IN PASTURE VEGETATION (Bq/kg f.w.)

	observed *			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
May 1986	685.0	546.0	858.0	3100.0	330.00	11000	850.0	670.0	1000.0	940.0			580.00	330.00	770.0	961.0			880.0			760.00		
Jul 1986	291.0	205.0	414.0	170.0	9.40	1300	220.0	170.0	270.0	66.0			26.00	12.00	35.0	70.6			140.0			62.00		
May 1987				5.3	0.73	73	0.9	0.7	1.1	1.8			2.70	1.40	4.1	1.2			2.0			6.60		
Jul 1987				5.2	0.86	79	0.9	0.7	1.1	1.8			2.30	0.89	3.8	1.1			2.0			2.80		
May 1988				3.4	0.59	51	0.9	0.7	1.1	1.7			0.65	0.18	1.2	1.1			1.6			0.36		
Jul 1988				3.4	0.59	51	0.9	0.7	1.1	1.7			0.73	0.30	1.3	1.1			1.6			0.36		

* Jul 86 value is from Jun 86

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII		Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
May 1986	378.6			990.0	500.0	2000.0	471.7								1042.0					
Jul 1986	15.2			430.0	200.0	1000.0	9.7								147.0					
May 1987	1.8						7.8								2.0					
Jul 1987	4.0						7.6								2.0					
May 1988	1.7						6.1													
Jul 1988	3.9						6.4													

TABLE IV.27. REVISED PREDICTIONS FOR SCENARIO CB
CONCENTRATIONS IN ANIMAL FEED (Bq/kg f.w.)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
SILAGE	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
harvest 1986	51.80	12.80	209.00							0.40						2.38			223.00			0.62		
harvest 1987	11.00	0.455	266.00							0.40						2.32			4.40			0.20		
harvest 1988										0.30						2.27			3.60			0.20		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII		Hinton/ECOSYS			Tarrant/SPADE2		
SILAGE	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
													(sprg)	(summ)						
harvest 1986	610.70						67.94								5.30					
harvest 1987	9.70						4.69								0.60					
harvest 1988	12.70						3.13								0.50					

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
SPRING BARLEY	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
harvest 1986	19.40	7.20	52.10	15.00	0.900	180.00				15.00			7.80	3.10	14.00	0.37			6.60			6.50		
harvest 1987	0.21	0.17	0.27	1.00	0.064	10.00				0.30			1.10	0.47	1.90	0.36			0.52			0.29		
harvest 1988				1.00	0.062	10.00				0.30			0.93	0.41	1.80	0.35			0.50			0.29		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII		Hinton/ECOSYS			Tarrant/SPADE2		
SPRING BARLEY	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
													(sprg)	(summ)						
harvest 1986	11.07			11.20	5.00	22.00	9.10								4.70					
harvest 1987	0.34			0.50	0.20	1.00	0.12								0.40					
harvest 1988	0.26			0.40	0.20	1.00	0.12								0.30					

TABLE IV.28. REVISED PREDICTIONS FOR SCENARIO CB
HUMAN INTAKE (Bq/d)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
monthly avg.:																								
May 1986				260.00	45.00	2000.00				27.00			31.00	12.00	57.00	38.80			26.00			26.00		
Jun 1986				190.00	20.00	1500.00				17.00			11.00	4.80	19.00	31.20			24.00			27.00		
Jul 1986				74.00	8.90	700.00				13.00			6.40	2.70	13.00	15.70			10.00			16.00		
Aug 1986				47.00	7.40	300.00				11.00			4.50	2.60	6.40	9.00			4.70			11.00		
Sep 1986				34.00	5.90	240.00				12.00			5.90	2.60	8.10	6.30			3.00			11.00		
quarterly avg.:																								
IV 1986				29.00	4.70	220.00				19.00			12.00	6.80	20.00	13.10			8.60			16.00		
I 1987				30.00	4.60	240.00				24.00			13.00	6.70	20.00	18.90			8.60			21.00		
II 1987	5.88	3.47	9.98	22.00	3.20	190.00				21.00			6.30	2.60	9.30	11.80			6.80			16.00		
III 1987	(*)			11.00	1.80	100.00				12.00			3.10	1.30	4.60	3.70			2.20			7.70		
IV 1987				6.90	1.10	50.00				2.00			2.50	1.30	4.30	1.70			0.80			3.90		
I 1988				5.30	0.91	33.00				0.80			2.40	1.00	4.20	1.20			0.80			1.90		
II 1988				4.60	0.82	32.00				0.60			2.30	0.86	4.00	0.90			0.50			1.40		
III 1988				3.90	0.67	25.00				0.50			1.00	0.40	1.60	0.80			0.50			0.91		
IV 1988				3.50	0.61	22.00				0.50			0.94	0.34	1.50	0.80			0.40			0.85		
I 1989				3.50	0.61	23.00				0.40			0.82	0.33	1.50	0.80			0.40			0.83		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII			Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
monthly avg.:																					
May 1986	20.86						18.36									39.00					
Jun 1986	14.65						9.26									31.00					
Jul 1986	8.68						7.65									22.00					
Aug 1986	6.43						3.56									19.00					
Sep 1986	4.94						2.93									19.00					
quarterly avg.:																					
IV 1986	8.28						2.49									21.00					
I 1987	9.86						2.71									23.00					
II 1987	7.99						1.90									21.00					
III 1987	4.32						1.70									13.00					
IV 1987	0.81						0.86									6.00					
I 1988	0.46						0.62									1.00					
II 1988	0.49						0.48														
III 1988	0.64						0.44														
IV 1988	0.53						0.42														
I 1989	0.36						0.37														

(*) value for 7.6. - 14.7.1987

TABLE IV.29. REVISED PREDICTIONS FOR SCENARIO CB
CONCENTRATIONS IN WHOLE BODY (Bq/kg)

	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
monthly avg.:																								
May 1986	3.21	2.74	3.76	60.00	14.00	520.00	5.50	4.80	6.20	3.40			2.90	1.90	4.20	4.45			9.20			7.00		
Jun 1986	3.99	3.42	4.65	138.00	29.00	1200.00	11.00	9.00	13.00	9.40			4.70	2.70	6.80	13.60			15.80			12.00		
Jul 1986	6.39	5.12	7.97	161.00	26.00	1300.00				11.00			5.20	2.90	7.40	19.40			16.20			14.00		
Aug 1986	7.27	6.65	7.95	151.00	25.00	1200.00	12.00	8.00	15.00	12.00			5.10	3.00	7.60	20.10			14.60			15.00		
Sep 1986	8.11	7.36	8.94	133.00	24.00	1100.00	13.00	8.00	15.00	12.00			5.70	3.10	8.10	19.20			12.80			15.00		
quarterly avg.:																								
IV 1986	10.10	9.36	11.00	104.00	19.00	800.00	14.00	11.00	17.00	16.00			6.80	2.80	9.10	19.30			15.50			17.00		
I 1987	11.40	10.60	12.30	78.00	14.00	580.00	21.00	16.00	26.00	22.00			9.10	3.50	15.00	26.60			16.60			22.00		
II 1987	11.30	10.70	11.90	63.00	11.00	450.00	18.00	14.00	22.00	26.00			12.00	3.80	21.00	29.70			15.70			24.00		
III 1987	11.00	10.30	11.70	46.00	7.10	390.00	15.00	11.00	19.00	23.00			12.00	2.20	26.00	22.00			11.30			19.00		
IV 1987	10.70	9.86	11.60	30.00	3.90	230.00	9.00			15.00			11.00	2.80	19.00	14.30			7.50			14.00		
I 1988	6.96	6.43	7.53	20.00	2.10	140.00	5.00	4.00	6.00	8.10			6.90	2.10	12.00	9.25			5.20			9.10		
II 1988	5.27	4.73	5.87	15.00	2.10	110.00	3.50	2.80	4.20	4.90			5.70	0.96	12.00	6.12			3.50			6.10		
III 1988	4.37	3.81	5.01	11.00	1.20	79.00	2.40	1.90	2.90	2.80			4.00	1.10	7.40	4.16			2.50			4.10		
IV 1988	4.27	3.73	4.88	8.60	0.95	61.00	1.90	1.50	2.30	1.70			3.50	0.59	6.40	3.00			1.82			2.80		
I 1989	3.36	2.91	3.89	7.50	0.86	54.00	1.40	1.20	1.60	1.10			2.70	0.45	5.20	2.36			1.43			2.10		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII			Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
monthly avg.:																					
May 1986	3.34			5.20	4.80	5.70	3.48									6.50					
Jun 1986	8.87			8.20	7.70	9.00	7.60									15.10					
Jul 1986	11.34			8.56	7.80	9.20	9.23									18.90					
Aug 1986	11.82			7.70	7.10	8.40	9.55									18.70					
Sep 1986	11.78			6.80	6.20	7.40	9.03									19.80					
quarterly avg.:																					
IV 1986	12.49			7.90	7.50	8.30	10.32									21.50					
I 1987	15.28			11.80	11.30	12.30	12.76									23.00					
II 1987	16.91			13.70	13.00	14.40	13.22									23.90					
III 1987	15.13			12.80	12.10	13.50	12.24									28.00					
IV 1987	11.13			11.20	10.60	11.80	10.21									23.50					
I 1988	7.57			8.30	7.80	8.80	7.73									13.60					
II 1988	5.51			6.40	6.00	6.80	5.81									8.30					
III 1988	4.45			5.30	4.90	5.70	4.50									5.40					
IV 1988	3.90			3.90	3.60	4.20	3.70									3.80					
I 1989	3.42			2.90	2.70	3.10	3.14									3.00					

TABLE IV.30. REVISED PREDICTIONS FOR SCENARIO CB
DISTRIBUTION OF WHOLE BODY CONTENT

fractile (%) *	observed			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
II 1987																								
97.5				22.0																				
68																								
50				130.0																				
32																								
2.5				920.0																				
I 1989																								
97.5				2.2																				
68																								
50				19.0																				
32																								
2.5				140.0																				

fractile (%) *	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII		Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
II 1987													(sprg)	(summ)						
97.5				4.2	4.0	4.4														
68				9.3	8.9	9.7														
50				11.9	11.4	12.4														
32				15.2	14.6	16.0														
2.5				33.6	32.0	35.3														
I 1989																				
97.5				0.5	0.46	0.54														
68				1.5	1.4	1.6														
50				2.2	2.0	2.4														
32				3.2	2.9	3.3														
2.5				9.8	9.1	10.6														

* fractile of a CCDF or (1-p), where p is a fractile of CDF.
CCDF = Complementary Cumulative Distribution Function
CDF = Cumulative Distribution Function

TABLE IV.31. REVISED PREDICTIONS FOR SCENARIO CB
EXTERNAL DOSE

	estimated			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
cloud exposure (nSv)	14.0	9.2	22.0	34.0	19.0	48.0				16.0						28.9			50.0			28.0		
ground exposure (mSv)																								
29-Apr-86 - 30-Apr-87				0.024	0.007	0.130				0.011						0.012			0.038			0.020		
29-Apr-86 - 30-Apr-88				0.036	0.010	0.200				0.019						0.020			0.069			0.037		
29-Apr-86 - 30-Apr-89	34.0	20.0	52.0	0.041	0.011	0.230				0.027						0.027			0.120			0.050		
29-Apr-86 - lifetime				0.056						0.180						0.168			0.760			0.230		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII *		Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
													(sprg	(summ)						
cloud exposure (nSv)	26.1			37.0	25.0	60.0									17.0					
ground exposure (mSv)																				
29-Apr-86 - 30-Apr-87	0.012			0.013											0.014					
29-Apr-86 - 30-Apr-88	0.020			0.021											0.025					
29-Apr-86 - 30-Apr-89	0.025			0.028											0.034					
29-Apr-86 - lifetime	0.055			0.230											0.241					

TABLE IV.32. REVISED PREDICTIONS FOR SCENARIO CB
INHALATION DOSE (nSv)

	estimated			Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
inhalation from cloud	2900	1800	4600	5500	3100	7800				5200						5140			19000			5100		
inhalation of resuspension																								
29-Apr-86 - 30-Apr-87										6.7									5.6			45.0		
29-Apr-86 - 30-Apr-88										8.5									6.7			47.0		
29-Apr-86 - 30-Apr-89										9.6						41.1			7.2			48.0		
29-Apr-86 - lifetime										25.0									31.0			75.0		

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII		Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
													(sprg	(summ)						
inhalation from cloud	4431			2120			10100								5000					
inhalation of resuspension																				
29-Apr-86 - 30-Apr-87							3.3								5.0					
29-Apr-86 - 30-Apr-88							6.8													
29-Apr-86 - 30-Apr-89							7.0													
29-Apr-86 - lifetime																				

TABLE IV.33. REVISED PREDICTIONS FOR SCENARIO CB
INGESTION DOSE (mSv)

	estimated values	Peterson/CHERPAC	Horyna/SCHRAADLO-T	Mueller/ECOSYS	Kanyar/TERNIRBU	Sohier/DOSDIM	Hu/HUMOD	Kliment/ENCONAN
29-Apr-86 - 30-Apr-87								
total:		0.3100		0.0990		0.0869	0.0430	0.0850
lower conf. interval		0.0470						
upper conf. interval		2.1000						
food type 1:		0.1500 milk		0.0210 milk		0.0591 milk	0.0250 lf. veg.	0.0349 milk
food type 2:		0.0590 beef		0.0130 beef		0.0121 meat	0.0152 milk	0.0204 meat
food type 3:		0.0250 grain		0.0100 rye		0.0096 tubers	0.0041 beef	0.0153 fruit
29-Apr-86 - 30-Apr-88								
total:		0.4200		0.1300		0.1010	0.0507	0.1200
lower conf. interval		0.0710						
upper conf. interval		2.6000						
food type 1:		0.1800 milk		0.0230 milk		0.0515 milk	0.0256 lf. veg.	0.0396 milk
food type 2:		0.0710 beef		0.0190 beef		0.0293 meat	0.0212 milk	0.0312 meat
food type 3:		0.0500 fruit		0.0170 pork		0.0101 tubers	0.0052 beef	0.0192 fruit
29-Apr-86 - 30-Apr-89								
total:	0.0620	0.4500		0.1400		0.1040	0.0558	0.1300
lower conf. interval	0.0580	0.0770						
upper conf. interval	0.0700	2.8000						
food type 1:		0.1900 milk		0.0240 milk		0.0416 milk	0.0259 milk	0.0494 milk
food type 2:		0.0720 beef		0.0190 beef		0.0260 meat	0.0224 lf. veg.	0.0325 meat
food type 3:		0.0630 fruit		0.0170 pork		0.0146 tubers	0.0059 beef	0.0208 fruit
29-Apr-86 - lifetime								
total:		0.7900		0.1600			0.0660	0.2300
lower conf. interval								
upper conf. interval								
food type 1:		0.2600 milk		0.0270 milk			0.0310 milk	
food type 2:		0.1600 fruit		0.0220 beef			0.0268 lf. veg.	
food type 3:		0.0950 beef		0.0190 pork			0.0071 beef	

TABLE IV.33. REVISED PREDICTIONS FOR SCENARIO CB
INGESTION DOSE (mSv)
(continued)

	Krajewski/CLRP	Galeriu/LINDOZ	Carrasco/PRYMA	Napier/HEDR	Napier/GENII (sprg)	Napier/GENII (summ)	Hinton/ECOSYS	Tarrant/SPADE2
29-Apr-86 - 30-Apr-87								
total:	0.0312		0.2000				0.1230	
lower conf. interval								
upper conf. interval								
food type 1:			0.1100 milk				0.0210 milk	
food type 2:			0.0500 lf. veg.				0.0170 lf. veg.	
food type 3:			0.0500 beef				0.0170 fruit	
29-Apr-86 - 30-Apr-88								
total:	0.0614		0.4000				0.1610	
lower conf. interval								
upper conf. interval								
food type 1:			0.1600 milk				0.0260 wheat	
food type 2:			0.1100 beef				0.0260 fruit	
food type 3:			0.0600 lf. veg.				0.0220 milk	
29-Apr-86 - 30-Apr-89								
total:	0.0719		0.5000					
lower conf. interval								
upper conf. interval								
food type 1:			0.1600 milk					
food type 2:			0.1400 beef					
food type 3:			0.0500 lf. veg.					
29-Apr-86 - lifetime								
total:	0.1030						0.1780	
lower conf. interval								
upper conf. interval								
food type 1:							0.0290 wheat	
food type 2:							0.0290 milk	
food type 3:							0.0260 fruit	

TABLE IV.34. REVISED PREDICTIONS FOR SCENARIO CB
TOTAL DOSE (mSv)

	Peterson/CHERPAC			Horyna/SCHRAADLO-T			Mueller/ECOSYS			Kanyar/TERNIRBU			Sohier/DOSDIM			Hu/HUMOD			Kliment/ENCONAN		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	low	up	mean	low	up	mean	low	up
29-Apr-86 -30-Apr-87																					
total:	0.3400						0.1100						0.1040			0.1010			0.1100		
pathway 1:	0.3100 ing						0.0990 ing						0.0869 ing			0.0430 ing			0.0847 ing		
pathway 2:	0.0240 ext						0.0110 ext						0.0123 ext			0.0380 ext			0.0198 ext		
pathway 3:	0.0055 inh						0.0052 inh						0.0051 inh			0.0190 inh			0.0051 inh		
29-Apr-86 -30-Apr-88																					
total:	0.4600						0.1600						0.1270			0.1390			0.1600		
pathway 1:	0.4200 ing						0.1300 ing						0.1010 ing			0.0690 ext			0.1216 ing		
pathway 2:	0.0360 ext						0.0190 ext						0.0204 ext			0.0507 ing			0.0384 ext		
pathway 3:	0.0055 inh						0.0052 inh						0.0051 inh			0.0190 inh			<1% inh		
29-Apr-86 -30-Apr-89																					
total:	0.5000						0.1700						0.1360			0.1950			0.1800		
pathway 1:	0.4500 ing						0.1400 ing						0.1040 ing			0.1200 ext			0.1296 ing		
pathway 2:	0.0410 ext						0.0270 ext						0.0267 ext			0.0558 ing			0.0504 ext		
pathway 3:	0.0055 inh						0.0052 inh						0.0051 inh			0.0190 inh			<1% inh		
29-Apr-86 - lifetime																					
total:	0.8500						0.3400						0.2770			0.8450			0.4600		
pathway 1:	0.7900 ing						0.1800 ext						0.1680 ext			0.7600 ext			0.2300 ing		
pathway 2:	0.0560 ext						0.1600 ing						0.1040 ing			0.0660 ing			0.2300 ext		
pathway 3:	0.0055 inh						0.0053 inh						0.0051 inh			0.0190 inh			<1% inh		

ext	external
ing	ingestion
inh	inhalation

TABLE IV.34. REVISED PREDICTIONS FOR SCENARIO CB
TOTAL DOSE (mSv)
(continued)

	Krajewski/CLRP			Galeriu/LINDOZ			Carrasco/PRYMA			Napier/HEDR			Napier/GENII		Hinton/ECOSYS			Tarrant/SPADE2		
	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	mean	mean	low	up	mean	low	up
29-Apr-86 -30-Apr-87													(spring)	(summer)						
total:	0.0477						0.2100								0.1420					
pathway 1:	0.0312 ing						0.2000 ing								0.1220 ing					
pathway 2:	0.0121 ext						0.0100 inh								0.0140 ext					
pathway 3:	0.0044 inh						0.0002 ext								0.0050 inh					
29-Apr-86 -30-Apr-88																				
total:	0.0855						0.4000								0.1920					
pathway 1:	0.0614 ing						0.4000 ing								0.1610 ing					
pathway 2:	0.0196 ext						0.0002 ext								0.0260 ext					
pathway 3:	0.0044 inh						6.8E-06 inh								0.0050 inh					
29-Apr-86 -30-Apr-89																				
total:	0.1020						0.5000								0.2020					
pathway 1:	0.0719 ing						0.5000 ing								0.1630 ing					
pathway 2:	0.0253 ext						0.0002 ext								0.0340 ext					
pathway 3:	0.0044 inh						7.0E-06 inh								0.0050 inh					
29-Apr-86 - lifetime																				
total:	0.1620														0.4240					
pathway 1:	0.1030 ing														0.2410 ext					
pathway 2:	0.0551 ext														0.1780 ing					
pathway 3:	0.0044 inh														0.0050 inh					

ext	external
ing	ingestion
inh	inhalation

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Research Co-ordination Meetings
Vienna, Austria: 2-6 May 1988, 5-8 December 1989,
4-8 March 1991, 2-6 March 1992, 5-9 July 1993

Consultants Meetings
Vienna, Austria: 21-23 November 1988, 17-20 April 1990,
10-12 December 1990, 21-25 October 1991, 20-22 May 1992,
16-20 November 1992
Madrid, Spain: 27-28 May 1989
Helsinki, Finland: 4-8 October 1993
Oak Ridge, USA: 28-31 March 1994