Presentation to the 5th Meeting of the EMRAS II Working Group "Tritium"

Influence of data uncertainties and model sensitivity on the estimate of tritium doses

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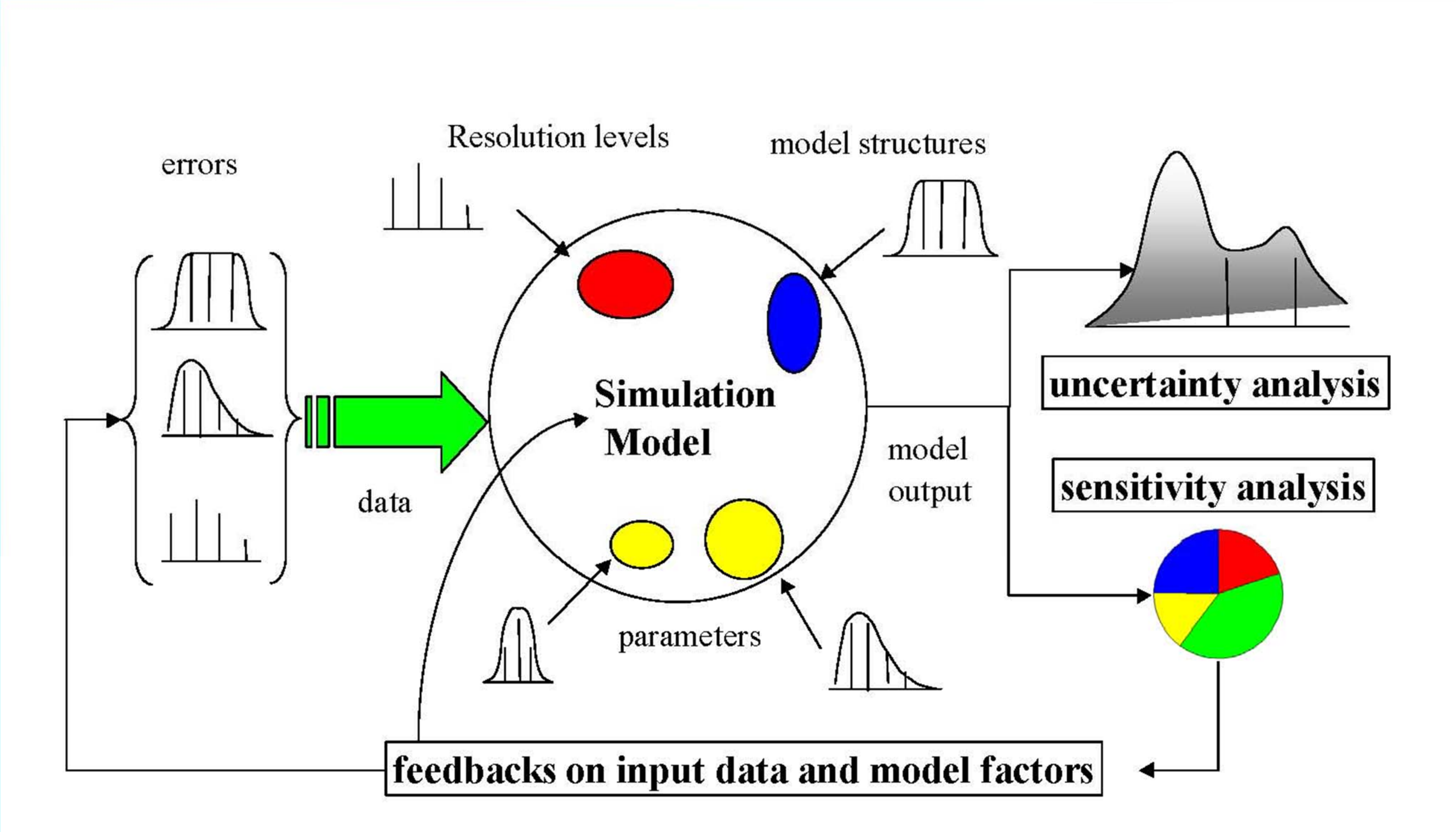
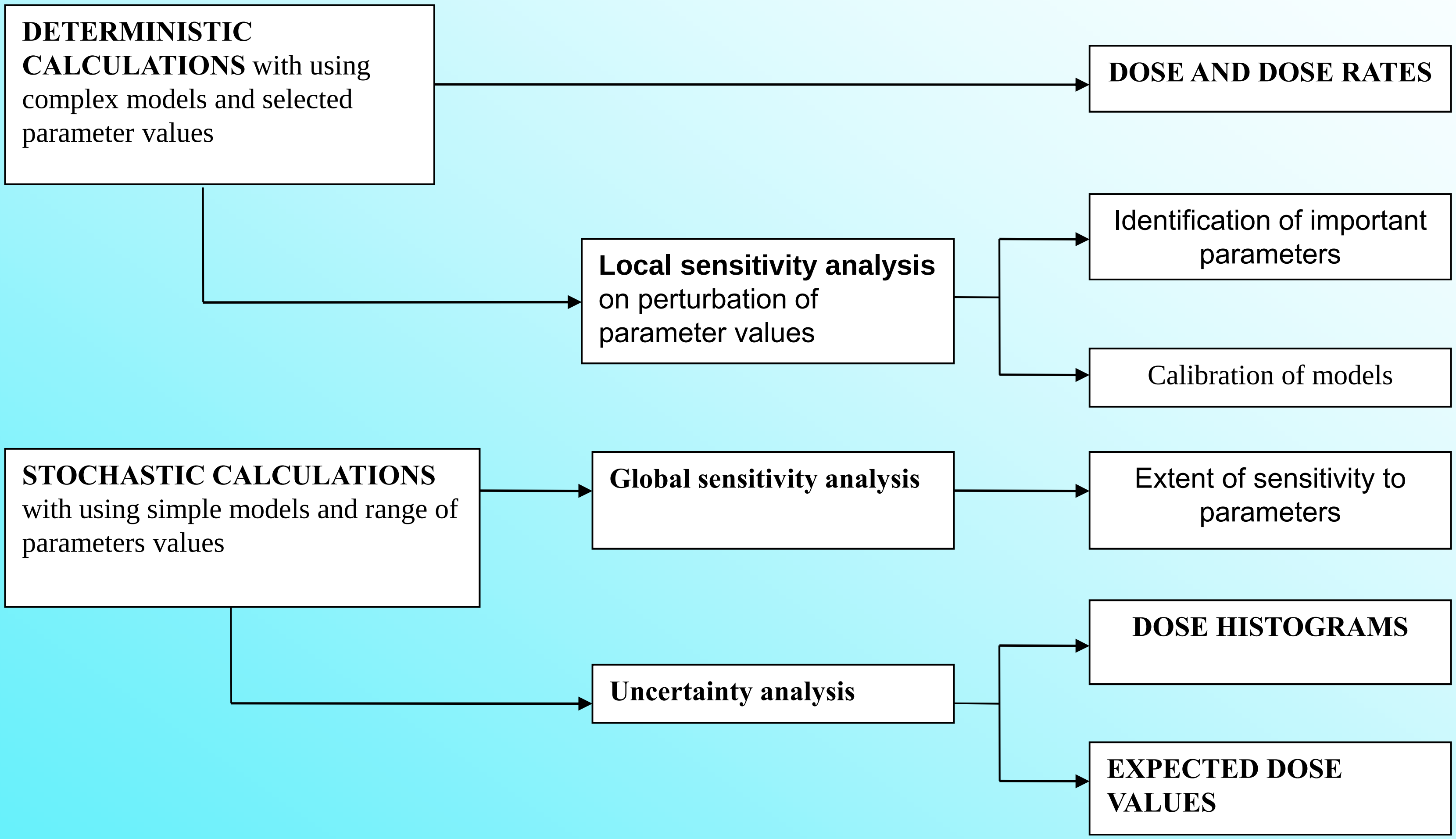
INTRODUCTION

- Definition of SU analysis
- Quantitative methods of SU analysis
- EPA Principles for Monte Carlo Analysis
- Example of SU analysis for discharges from NPP


errors
Resolution levels
model structures
Simulation
Model
data
parameters
model
output
uncertainty analysis
sensitivity analysis
feedbacks on input data and model factors

Local and global sensitivity analysis



Quantitative methods of uncertainty analysis

Direct quantitative methods exist only for uncertainty analysis of input data and model parameters.

Uncertainties of scenarios and conceptual models we can study only with using qualitative method.

Basic quantitative methods of uncertainty analysis:

- Monte Carlo method,
- Regressive models,
- Differential analysis,
- Geostatic methods.

Sensitivity analysis

- derive quantitative statements about the effect of parameter uncertainty on the model prediction
- rank the parameters with respect to their contribution to the uncertainty in the model prediction

Rank of parameters is important for

- determination of priority for acquiring of additional parameters
- reduction of number parameters (in uncertainty analysis)
- simplification of complex models with the minimum lost of accuracy

Quantitative methods of sensitivity analysis

Two basic methods: deterministic and stochastic.

Deterministic – estimate of partial derivation of response function for each input parameter (analytic solution or numerical approximation).

Stochastic – comparison of correlation coefficients between results of response function and basic model:

- Method of scattered (linear or non linear dependence),
- Regressive analysis (correlation coefficient),
- Variation of parameters.

Guiding Principles for Monte Carlo Analysis (EPA/630/R/97/001, March 1997)

Selecting Input Data and Distribution for Use in Monte Carlo Analysis:

1. Conduct preliminary sensitivity analyses or numerical experiments to identify model structures, exposure pathways, and model input assumptions and parameters that make important contributions to the assessment endpoint and its overall variability and/or uncertainty
2. Restrict the use of probabilistic assessment to significant pathways and parameters
3. Use data to inform the choice of input distributions for model parameters

Guiding Principles for Monte Carlo Analysis

4. Surrogate data can be used to develop distributions when they can be appropriately justified.

5. When obtaining empirical data to develop input distributions for exposure model parameters, the basic tenets of environmental sampling should be followed. Further, particular attention should be given to the quality of information at the tails of the distribution.

6. Depending on the objectives of the assessment, expert judgment can be included either within the computational analysis by developing distributions using various methods or by using judgments to select and separately analyze alternate, but plausible, scenarios.

Guiding Principles for Monte Carlo Analysis

Evaluating Variability and Uncertainty:

7. The concepts of variability and uncertainty are distinct. They can be tracked and evaluated separately during an analysis, or they can be analyzed within the same computational framework. Separating variability and uncertainty is necessary to provide greater accountability and transparency. The decision about how to track them separately must be made on a case-by-case basis for each variable.

8. There are methodological differences regarding how variability and uncertainty are addressed in a Monte Carlo analysis.

Guiding Principles for Monte Carlo Analysis

9. Methods should investigate the numerical stability of the moments and the tails of the distributions.

10. There are limits to the assessor's ability to account for and characterize all sources of uncertainty. The analyst should identify areas of uncertainty and include them in the analysis, either quantitatively or qualitatively

Guiding Principles for Monte Carlo Analysis

Presenting the Results of a Monte Carlo Analysis:

11. Provide a complete and thorough description of the exposure model and its equations (including a discussion of the limitations of the methods and the results).

12. Provide detailed information on the input distributions selected. This information should identify whether the input represents largely variability, largely uncertainty, or some combination of both. Further, information on goodness-of-fit statistics should be discussed

Guiding Principles for Monte Carlo Analysis

13. Provide detailed information and graphs for each output distribution.
14. Discuss the presence or absence of dependencies and correlation.
15. Calculate and present estimates.
16. A tiered presentation style, in which briefing materials are assembled at various levels of detail, may be helpful. Presentations should be tailored to address the questions and information needs of the audience.

CONCLUSION

Definition of basic term (SU, scatter, pdf, cdf, tests, …)

Database of experimental input data, parameters and models assumptions

Description of analytical and numerical methods for S/U analysis and computer codes (SimLab, GoldSim, …)

Description of technical procedure for

- reduction of uncertainty of selected outputs (also with reduce the uncertainty of model assumptions),
- simplification of model with the minimum lost of accuracy

Example

S/U analyses of discharges from NPP Mochovce

S/U analyses of discharges from NPP Mochovce

Introduction

Radioactive Doses (RD) model

Simple method of ranking

Sensitivity and uncertainty (S/U) analysis of model

Result of S/U analyses

Introduction

- The RD code for evaluation of radiological consequences of operation NPP follows the INTERATOMENERGO, ČSKAE methodology, IAEA and ICRP recommendations
- The code is a innovated version of standardized programme RDOJE II developed in 1985 year and includes programmes for preparation of input data files, computing codes producing outputs in the tabular form and programmes for graphical processing of outputs
- The RD code is designed for evaluation of normal operation of NPP impact on the environment, but its use is also suitable for accident assessment of releases to the hydrosphere and assessment of radiological consequences in the intermediate and late phase of the accident too.

Radioactive doses model

Database of programme data characterizing the affected area to 60 km distance includes (without abroad data):

- demographic and population data,
- data about production and consumption of agricultural and food products and their distribution (food basket),
- hydrological parameters of affected water flows, and
- radionuclides library, i.e. data sets characterizing radionuclides (dose factors, ...).

Radioactive doses model

Computer code RD includes computing programs for:

- calculation time integral of air and ground concentration – dry and wet depositions;
- calculation of intakes of all radionuclides with food from a unit monthly deposit by an updated model of the transfer of all radionuclides to a man through food chains considering seasonality;
- determination of the critical group of the public, critical way of exposure and critical radionuclides for particular ways of exposure;
- determination of risk and health effects resulting from RM releases for a given period in regional and global extent.

Radioactive doses model includes computing programs for

- calculation of individual equivalent doses (ID) or committed ID for 6 age categories of the public in 7 calculated organs for the following exposure ways:
- external exposure from atmosphere due to passing cloud (cloud shine) and deposited material (ground shine);
- external exposure from the hydrosphere due to bathing, boating, sunbathing and staying on the irrigated land;
- internal exposure from the atmosphere due to inhalation and ingestion, i.e. intake of RM via food chains: milk, meat, cereals, vegetables, fruits and other foodstuffs;
- internal exposure from the hydrosphere due to ingestion of drinking water, fishes and foodstuffs contaminated by the irrigation.

Simple method of ranking

Deterministic results of calculation are ranking depending on the value of contribution from:

- single way of exposure to Collective (CD) or Individual dose (ID) (cloud-shine, ground-shine, inhalation, ingestion, ...),
- single food chains to dose from ingestion (food contaminated by dry deposition and by the irrigation),
- single nuclides to food chain (from milk to man, meat to man, vegetables to man and etc. ...),
- single nuclides to each exposure way.

Rank results are completed in table and graphic form.

Example: Ranking of exposure way

1 Exposure from ingestion of contaminated water	2.917E-02 [Sv]	(83.8415%)
2 Exposure from food, contaminated by irrigation	3.601E-03 [Sv]	(10.3521%)
3 Exposure from contaminated offshore deposits	1.181E-03 [Sv]	(3.3944%)
4 Exposure from ingestion of contaminated fishes	3.112E-04 [Sv]	(0.8946%)
5 Exposure from food, contaminated by deposition	2.631E-04 [Sv]	(0.7564%)
6 Exposure from cloud	2.522E-04 [Sv]	(0.7251%)
7 Exposure from ground	7.975E-06 [Sv]	(0.0229%)
8 Exposure from inhalation	3.082E-06 [Sv]	(0.0089%)
9 Exposure from staying on the irrigated land	1.322E-06 [Sv]	(0.0038%)
10 Exposure from bathing	1.170E-07 [Sv]	(0.0003%)

Example: Ranking of nuclides for the food chain from Meat to Man

H 3	1.812E-04 [Sv]	(97.630%)
CS 137	2.277E-06 [Sv]	(1.227%)
CS 134	1.620E-06 [Sv]	(0.873%)
CO 60	2.476E-07 [Sv]	(0.133%)
ZN 65	1.406E-07 [Sv]	(0.076%)
I 131A	4.649E-08 [Sv]	(0.025%)
CO 58	1.612E-08 [Sv]	(0.009%)
SE 75	1.559E-08 [Sv]	(0.008%)
SR 90	1.432E-08 [Sv]	(0.008%)
FE 59	6.186E-09 [Sv]	(0.003%)
SR 89	4.272E-09 [Sv]	(0.002%)
AG 110M	2.513E-09 [Sv]	(0.001%)
SUM :	1.856E-04 [Sv]	(100.000%)

Sensitivity and Uncertainty analysis of model

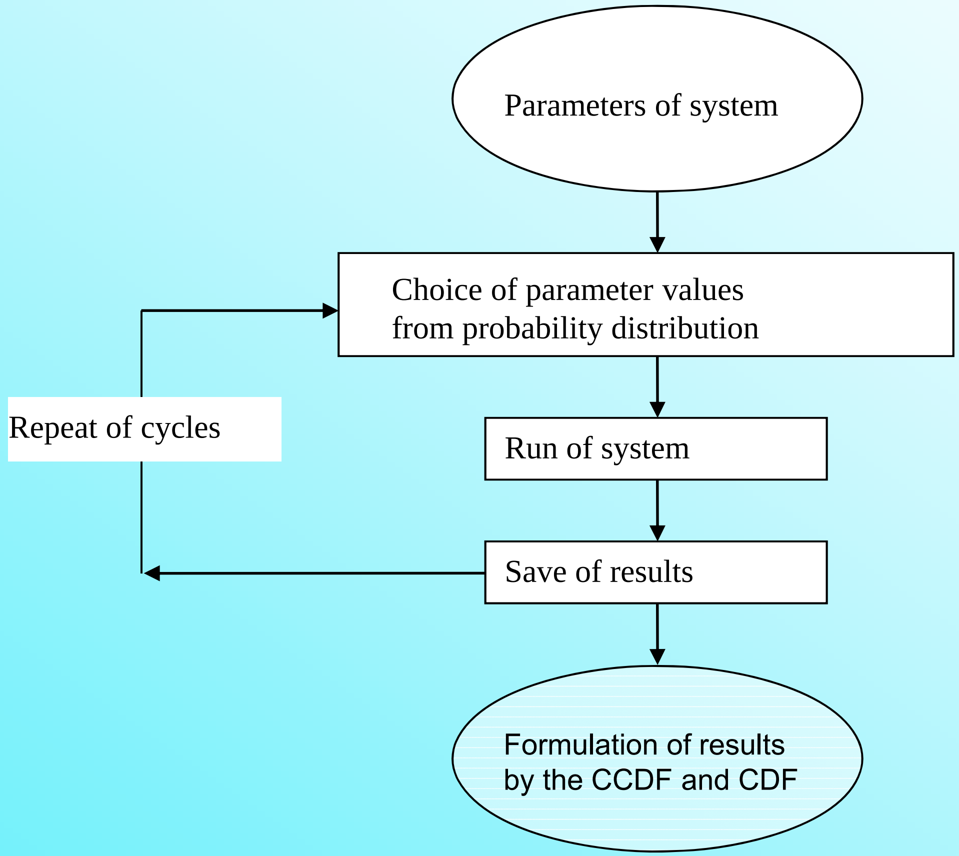
Definition of S/U analysis:

„perturbing each parameter in the model and determining the influence of the perturbation on the predicted quantity [IAEA, SS 100]“

S/U analysis:

- derive quantitative statements about the effect of parameter uncertainty on the model prediction
- rank the parameters with respect to their contribution to the uncertainty in the model prediction

Common chart of method Monte Carlo



Sensitivity and Uncertainty analysis of model

Monte Carlo analyses was performed with using the Latin Hypercube Sampling procedure.

Probabilistic model enables to use following types of pdf for input data:

- uniform distribution
- log - uniform distribution
- normal distribution
- log – normal distribution
- discrete distribution

Sensitivity and Uncertainty analysis of model

Sensitivity analyses are performed with using:

- Smirnov test
- Global Spearman rank correlation test.

Computer code developed in VUJE Inc. enables calculate following standard percentiles for CDF: 1, 2.5, 5, 50, 90, 95, 97.5 and 99 %.

Detailed description of S/U method we can find in:

- Evaluating the Reliability of Predictions Made Using Environmental Transfer Models, IAEA Safety Series No. 100. IAEA Vienna, Austria 1989.
- Andrea Saltelli and Col.: Sensitivity analysis in practice. A guide to Assessing Scientific Models. JRC of the EC, Ispra, Italy, p.219, 2004.

Sensitivity and Uncertainty analysis of model

- The Monte Carlo model was used for performing S/U analyses of code RD (version for NPP Mochovce)
- There were used following techniques for indication or quantification of global parameter sensitivity: the Smirnov “two sample” test and Spearman rank correlation test
- Uncertainty ranges of input values were simulated using the uniform probability distribution function
- From the complete set of released radionuclides there were simulated only uncertainties for releases of tritium and carbon into hydrosphere and atmosphere, because tritium and carbon have significant contribution to radiological doses (approximately 90%)
- Overview of used uncertainties of input data is given in the follow Table

Results of S/U analyses

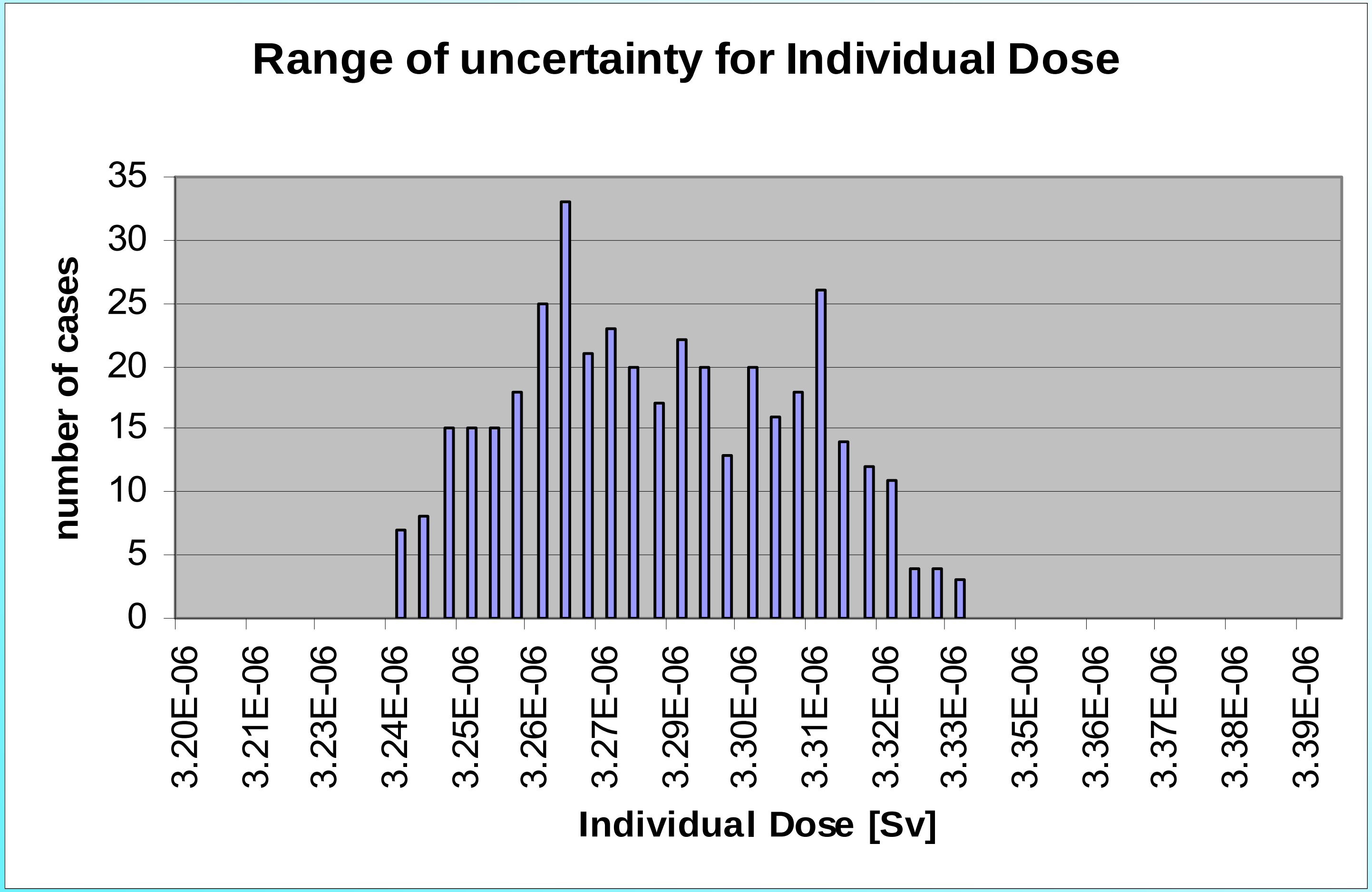
Uncertainties of Input data – NPP Mochovce

Name of parameter	Range of values	Units
Average flow rate for river	24.0 ÷ 75.0	m^3/s
Release of H^3 into the river	1.0E+13 ÷ 3.0E+13	Bq
Release of H^3 into the atmosphere	1.0E+14 ÷ 3.0E+14	Bq
Release of C^{14} into the atmosphere	1.0E+10 ÷ 1.0E+11	Bq
Velocity of dry deposition (H^3 a C^{14})	1.0E-04 ÷ 5.0E-03	m/s
Coefficient for wet deposition (H^3 a C^{14})	1.0E-06 ÷ 7.0E-05	h/(mm·s)

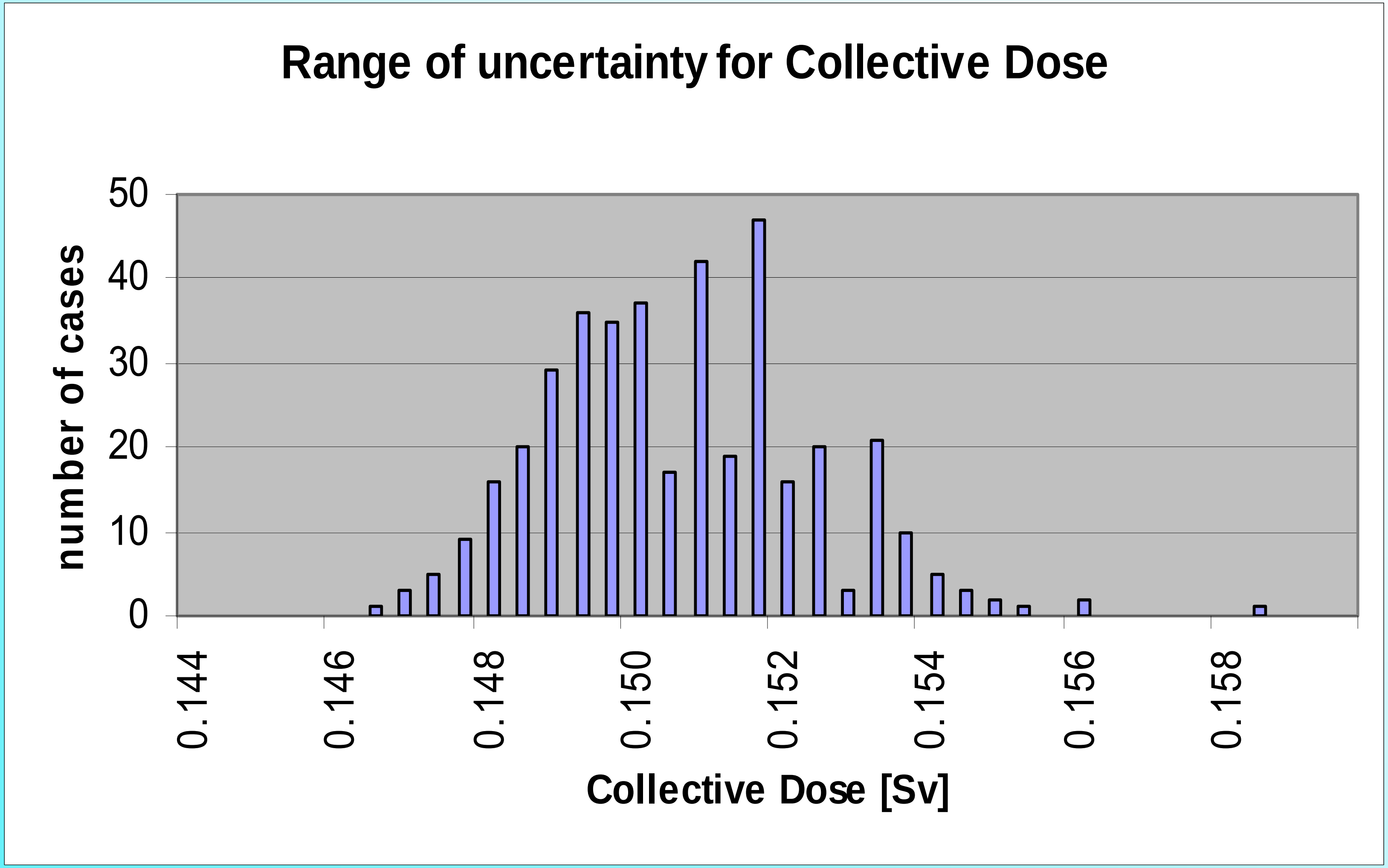
Uncertainties of Input data – NPP Mochovce

Name of parameter	Range of values	Units
Consumption of drink water – children	150 ÷ 200	Liter
Consumption of drink water – youth	200 ÷ 300	Liter
Consumption of drink water – adults	300 ÷ 400	Liter
Intensity of irrigation	2.0E-05 ÷ 5.0E-05	liter/m^2/s
Cattle – consumption of service water	40 ÷ 60	liter/day
Cattle – consumption of service water	30 ÷ 50	kg/day

Range of uncertainty and distribution function for ID



Range of uncertainty and distribution function for CD



Results of S/U analysis

From the sensitivity analyses results follow, that the model is most sensitive to the:

- releases of tritium and carbon into the atmosphere,
- velocity of dry deposition for aerosols,
- average flow rate for river,
- releases of tritium into the river and finally,
- consumption of green crop by the cattle

Thank you for your attention