SSI-rapport 87-32

Statens strålskyddsinstitut

Conny Hägg
Gunnar Johansson

BIOMOVS:

An International Model Validation Study

ISSN 0282-4434

Price SEK 10

Title page

NATIONAL INSTITUTE OF RADIATION PROTECTION
STATENS STRÅLSKYDDSINSTITUT

Document number
SSI-rapport 87-32

ISSN
0282-4434

Date
1987-11-16

Author

Conny Hägg and Gunnar Johansson

Division

Nuclear Energy

Title of the document

BIOMOVS: An International Model Validation Study

Abstract

BIOMOVS (BIOspheric MOdel Validation Study) is an international study where models used for describing the distribution of radioactive and nonradioactive trace substances in terrestrial and aquatic environments are compared and tested. The main objectives of the study are to compare and test the accuracy of predictions between such models, explain differences in these predictions, recommend priorities for future research concerning the improvement of the accuracy of model predictions and act as a forum for the exchange of ideas, experience and information.

Keywords (chosen by the author)

Environmental transfer models, validation, terrestrial, aquatic

Number of pages
8

BIOMOVS: AN INTERNATIONAL MODEL VALIDATION STUDY

C. Haegg and G. Johansson

National Institute of Radiation Protection

Stockholm - SWEDEN

ABSTRACT

BIOMOVS (BIOspheric MOdel Validation Study) is an international study where models used for describing the distribution of radioactive and nonradioactive trace substances in terrestrial and aquatic environments are compared and tested. The main objectives of the study are to compare and test the accuracy of predictions between such models, explain differences in these predictions, recommend priorities for future research concerning the improvement of the accuracy of model predictions and act as a forum for the exchange of ideas, experience and information.

INTRODUCTION

Up to now, model testing has focused on aspects of the prediction of the physical dispersion of contaminants in the atmosphere, surface water and ground water. Only limited attention has been given to the testing of models used to predict the accumulation of radionuclides in the biosphere, e.g. soils or terrestrial and aquatic food chains.

BIOMOVS (BIOspheric MOdel Validation Study) is an international cooperation study initiated in 1985 by the Swedish National Institute of Radiation Protection (NIRP). The study concentrates on the testing of models which predict the accumulation and remobilisation of radionuclides and other toxic trace substances in the biosphere. Emphasis is placed on terrestrial and aquatic pathways of importance in the assessments of exposure to human populations.

The study has two approaches. Approach A aims to test model predictions against independent sets of data, i.e. validation of the models. Approach B, on the other hand, aims to compare model predictions and associated uncertainties for some test scenarios that cannot be validated or are impracticable to validate, e.g. scenarios for waste disposals.

Results obtained from this study may be used in conjunction with results obtained from other model testing studies in order to enhance the reliability of model predictions. This is particularly beneficial when the predicted accumulation of stable and non-stable nuclides constitute the major uncertainty in the evaluation of human exposure and health risk.

The BIOMOVS study is directed by a coordinating group. Each organisation that formally participates in the study appoints one member to the group. The managing organisation is the NIRP and the NIRP together with Kemakta Consultants Co are acting as the project secretariat. At present, 22 organisations from 14 different countries (cf. Table 1) have joined the study. Of these, 12 organisations are represented in the BIOMOVS coordinating group (indicated with an asterix in Table 1). The International Atomic Energy Agency and the Nuclear Energy Agency of the Organisation for Economic Cooperation and Development participate as observers. Organisations that provide economic support, beside the participating organisations and the NIRP, are the International Union of Radioecologists and the Nordic Liaison Committee for Atomic Energy.

TABLE 1
Organisations represented in the BIOMOVS study

Organisation	Country
National Research Institute for Radiobiology and Radiohygiene (*)	Hungary
Comitato Nazionale per l'Energia Atomica-Disp (*)	Italy
National Cooperative for the Storage of Radioactive Waste (*)	Switzerland
National Radiological Protection Board (*)	United Kingdom
National Institute of Radiation Protection (*)	Sweden
Risoe National Laboratory (*)	Denmark
Technical Research Centre of Finland (*)	Finland
Tokai Research Establishment (*)	Japan
Department of Energy (*)	USA
Atomic Energy of Canada Limited (*)	Canada
Studiecentrum voor Kernenenergie, SCK/CEN (*)	Belgium
Department of Environment/ANS	United Kingdom
Ministry of Agriculture, Fisheries and Food	United Kingdom
Institute of Radiation Hygiene	West Germany
Central Electricity Generating Board	United Kingdom
Swiss Federal Institute for Reactor Research	Switzerland
Gesellschaft Fur Strahlen- und Umwelt Forschung	West Germany
Japan Atomic Energy Research Institute	Japan
Oak Ridge National Laboratory	USA
Laboratory of Radiation Research	The Netherlands
Empresa Nacional de Residuos Radioactivos(*)	Spain
Studsvik Energiteknik AB	Sweden

(*) member of the BIOMOVS coordinating group.

In this paper we will give a short background of why the BIOMOVS study was initiated and how it will be carried out. We also briefly discuss the present status of the study.

BACKGROUND AND SOME GENERAL CONSIDERATIONS

Mathematical models are extensively used for evaluating the environmental impact of releases of radionuclides from nuclear power plants, nuclear waste disposal, uranium ore mining etc. However, what can be studied by means of mathematical methods is not the reality, but more or less simplified and abstract ideas of the real situation. Thus, we study the behaviour of mathematical models which only approximate real world conditions. For reliable decisions to be made, especially when optimization is being carried out, the extent of uncertainty associated with model predictions must be quantified by some means.

The primary objectives of the BIOMOVS study are to estimate the extent of the uncertainty associated with model predictions of the transfer, accumulation and remobilisation of environmentally significant radionuclides or trace substances in the biosphere and to recommend procedures for improving predictive accuracy. These estimates and recommendations will be made for a variety of scenarios relevant to the release of some radionuclides and trace substances in the biosphere following, e.g. the operation of nuclear power plants and nuclear waste disposal.

We need a deep and genuine understanding of the processes in nature which in fact constitute the reality behind our models. The better the understanding, the less uncertainty there is in model predictions. A lack of understanding of natural processes may also lead to very uncertain predictions when extrapolating in space and time, a problem that arises in for example safety assessment studies. However, no fixed procedures exist for ensuring that all processes, or even all relevant processes, have been considered.

Thus, the representation of reality in a simplified form for modelling purposes is by no means easy and we can rarely specify a model which explicitly considers <u>all</u> processes. However, many processes can be taken into account <u>implicitly</u>. An example is the use of Kd-values when describing adsorption/desorption phenomena. Nevertheless, the best we can do is to try to specify a model that considers all <u>relevant</u> processes. In this case conceptual uncertainties in the model are <u>reduced</u> as much as is possible and the remaining significant uncertainties are linked to the mathematical formulation and those in the controlling parameters of the model. Unfortunately, it is difficult to achieve this situation and therefore the BIOMOVS study considers the two general types of uncertainties:

- uncertainties in the controlling parameter values and

- uncertainties in the model structure.

Uncertainties in the parameter values are the types of uncertainty that are generally considered, while uncertainties in the model structure are somewhat more difficult to consider. The best method for assessing these uncertainties is to test model predictions against <u>independent</u> sets of data, i.e. validate the models. This also gives the possibility of finding out if our scenario identification and conceptual understanding of nature are relevant.

Another way to improve our understanding is model intercomparision by subjecting scenarios to different experts in the field for analysis. Another method for improving our understanding of the uncertainties associated with model predictions are parameter uncertainty and sensitivity analysis. Parameter uncertainty analysis and model intercomparisions could be regarded as complementary methods. These methods both play a significant role when validation is impracticable or impossible.

It is being increasingly recognised that model predictions are of limited value unless accompanied by some indication of the associated uncertainty. An estimate of this uncertainty may be obtained by varying the control parameter values; either by random or stratified sampling techniques. Here, the parameter values are subjected to some distribution that generally is unknown and has to be chosen by the model user. Moreover, the degree of correlation between different types of parameters may also be unknown. As a consequense of this, a modelling study not only includes the choice of model structure and parameter values, but also many elements of judgement. Validation should cover all these aspects.

In the procedure of validation we must realise that the applicability of the model is limited by the validity of the scientific principles underlying the model. Therefore, a question we may ask ourselves is:

- to what degree shall the model predictions agree with experimental data before we can say that the model is validated?

It seems that no well defined distinction between a model that is said to be validated or not be validated exists. This decision has finally to be made by responsible decision makers, but it is of great importance from a scientific point of view to give guidance on how this distinction should be made. This is one question that will be discussed in the final report of the BIOMOVS study.

Another question that may be raised is:

- is it possible to apply a validated model to a system other than the one for which it is validated and state that the outcome of the model reflects the status of the new situation?

The situation is analogous to opening a door with a key. If the key is properly constructed it may open several doors, but we cannot forsee which door it will open. The BIOMOVS study aims to reduce this uncertainty and hence extend the applicability and reliability of biospheric assessment models. This special task is also to be discussed in the final report.

IMPLEMENTATION OF THE STUDY

The best method for testing models is, as discussed above, to compare their predictions for specific scenarios with field data. These field data-sets must be independent of the data used for developing non-site specific parameter values in the model. Examples of parameters which often are treated as non-site specific (or scenario independent) in biosphere models are, e.g.:

(i) element specific transfer factors such as solid/water distribution coefficients, milk and meat transfer factors, plant/soil concentration ratios and water/fish concentration factors and

(ii) element independent parameters such as deposition velocity, the effective mass per unit area of the root zone of soil and of the exchangable sediments of aquatic systems.

When model predictions are compared with independent sets of data, the model is attempting to reproduce values that are already known. In the BIOMOVS study, the known values will not be revealed until after the calculations have been carried out in order to avoid premature calibration of the model.

A comparision of the model predictions with an independent set of data provides a measure of the accuracy of the prediction with respect to the scenario and location from which the field data set was derived. This type of testing is generally referred to as "model validation" and within this study constitutes approach A.

On the other hand, when it is not possible to test models against independent sets of data, predictions and related uncertainty estimates can be obtained from different models for specific test scenarios. This procedure is suitable for clarifying discrepancies and similarities among model predictions. Conclusions may also be drawn about the extent of the expected uncertainty associated with these predictions. The disadvantage of this procedure is that no estimate of the accuracy of model predictions and associated uncertainties is possible.

When formulating specific assessment questions for the purpose of comparing model predictions, it is necessary to provide a standard set of data for input parameters that are normally determined on a site-specific basis. These parameters include such factors as meteorology, length of growing season, turnover time and flowrate of water etc. If such detailed information is supplied the discrepancies in model predictions should be affected primarily by differences in the site independent data adopted for use with the model, the model structure and in the modellers' estimates of uncertainty about the prediction of the model.

For each scenario a site specific source term must be quantified, e.g. concentration of radionuclides in air surface water or ground water. It may also be of interest for some test scenarios to use a given concentration of a radionuclide in sediment or surface soil to simulate a situation that follows an accidental release or decommissioning of a nuclear power plant or an intrusion into a radioactive waste repository.

This alternative test procedure is referred within the study as approach B. This approach is capable of addressing a much larger number of scenarios than approach A.

PRESENT STATUS OF THE STUDY

In this section only a brief overview of the progress of the BIOMOVS study is given. A more comprehensive presentation of some of the results will be given by other participants at this symposium (ref. 1-4).

Figure 1 shows schematically the time schedule for the study. It can be seen that four work shops have been held so far. The results from these work shops are summarised in progress reports nos 1 - 4 (ref. 5). For approach A there is a short time-lag when compared with approach B owing to the time needed for compiling data sets suitable for validation.

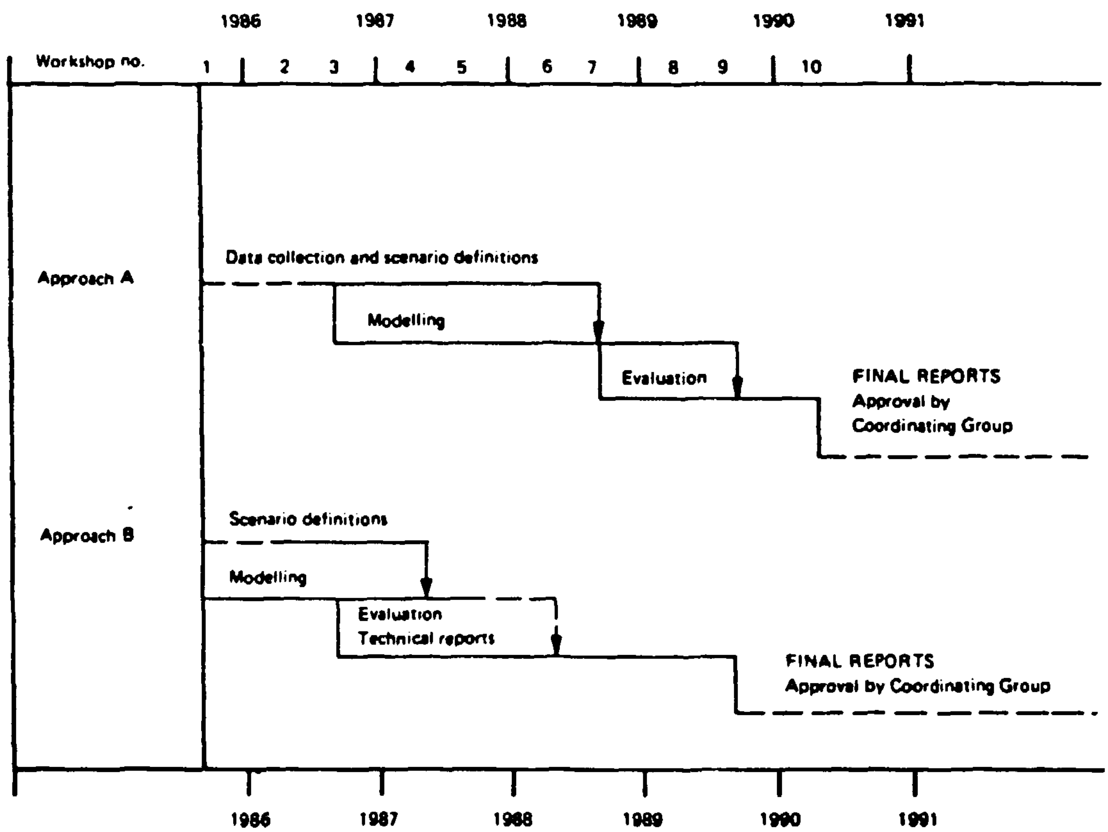

Figure 1. Approximate time schedule for the BIOMOVS study.

However, the great activity among scientists after the Chernobyl accident has led to a large body of suitable data. In order to take advantage of this situation, several new scenarios have been proposed.

The scenarios in the study have been chosen to assure that pathways of importance will be addressed. The choice of scenarios should also make it possible to critically test and compare different models. A thorough description of the scenarios is given in progress reports nos 1 - 4 (ref. 5).

Approach A. Within approach A, i.e. validation of models, five scenarios are treated. They are:

- release of mercury into a river,

- radioactivity in the environment around Sellafield (postponed),

- iodine-131 and caesium-137 in milk, beef and barley after the Chernobyl accident,

- migration of caesium in soil and

- "the Chernobyl lake".

Two scenarios are already in the "phase of validation", namely; "release of mercury in a river" and "iodine-131 and caesium-137 in milk, beef and barley after the Chernobyl accident". For the latter scenario, twelve independent sets of data have been contributed and a more or less ideal situation exists for validating the models. Some results from this scenario will be presented by Koehler et al. at this symposium (ref. 1).

The scenario "release of mercury into a river" has recently been extended to include independent data sets from three rivers. This has been done in order to find out if the models can address other similar systems.

For the scenarios "migration of caesium in soil" and "the Chernobyl lake", the compilation of independent sets of data is taking place.

Approach B. Within approach B, i.e. intercomparision and testing of models, the following scenarios are treated:

- irrigation with contaminated groundwater,

- release into a lake from a river,

- ageing of a lake,

- transport of contaminated groundwater to soil and

- transport of contaminated groundwater to a river.

The scenario "release into a lake from a river" and "irrigation with contaminated groundwater" are the first to be completed in the study and some results will be presented at this meeting by Bergstroem (ref. 2) and Grogan et al. (ref. 3), respectively. For the other B-scenarios, only preliminary results exist. The scenario "release into a lake from a river" and "ageing of a lake" treat waterborne radionuclides that reach water reservoirs and are related to assessment studies for radioactive waste and mining facilities. However, in these scenarios the interface between the biosphere and geosphere was not modelled. In order to address this problem, the two scenarios "transport of contaminated water to soil and to a river" were formulated. These two scenarios deal with groundwater borne radionuclides that reach the biosphere via surface soil or sediment. Some preliminary results will be presented at this meeting (ref. 4).

REFERENCES

1. Koehler, H. and Nielsen S., From model intercomparision to model validation - an example from the BIOMOVS study, "Methods for Assessing the Reliability of Environmental Transfer Models Predictions", Athens, October 5-9, 1987.

2. Bergstroem U., Intercomparision of model calculation of the turnover of Ra-226 within an aquatic ecosystem, ibid.

3. Grogan H. and van Dorp F., The reliability of environmental transfer models applied to waste disposal, ibid.

4. Bergstroem, U., Sundblad, B., Argarde, A.-C. and Ericsson, A.-M., Comparison of two model approaches for the geosphere/biosphere interface, ibid.

5. BIOMOVS progress reports. Can be ordered from the BIOMOVS project secretariat: Kemakta Consultants Co, Pipersgatan 27, S-112 28 Stockholm, Sweden.

This paper has been submitted to the International Workshop on Methods for Assessing the Reliability of Environmental Transfer Models Predictions, Athens, Greece, 5-9 October, 1987.

HITTILLS UTGIVNA SSI-rapporter 1987

Rapport-nummer	Titel (undertitel)	Författare
01	Radon chamber for soil gas detectors	Per Andersson, SGAB
02	Kärnkraftindustrins - aktivitetsutsläpp - yrkesexponeringar (Första kvartalet 1986)	Huvudenheten för kärnenergi
03	Mätstationer för gammastrålning Årsrapport 1985-1986	Per-Einar Kjelle
04	Larmkriterier för SSIs fasta mätstationer	Per-Einar Kjelle
05	Projekt Tjernobyl - Lägesrapport 2	
06	Dosbidrag från livsmedel	Per Andersson Mats Holmberg Kjell Nyholm
07	Alarm criteria for the gamma monitoring stations (Översättning av 87-04)	Per-Einar Kjelle
08	Gamma monitoring stations Annual reports 1985-1986 (Översättning av 87-03)	Per-Einar Kjelle
09	"Va va de dom sa"? i radio och tv om Tjernobyl och Hur upplevde vi nyhetsinformationen?	Olle Findahl Göte Hanson Birgitta Höijer Inga-Britt Lindblad
10	Medicinsk beredskap; Reserapport från AMA-konferens i Washington	Bo Lindell
11	Granskningspromemoria: Markdeponeringsanläggning vid Forsmarksverket	Curt Bergman Gunilla Ericsson Conny Hägg
12	Kärnkraftindustrins - aktivitetsutsläpp - yrkesexponeringar (Andra kvartalet 1986)	Huvudenhet för kärnenergi
13	Radiation doses in Sweden as a result of the Chernobyl fallout (Översättning av kapitel 2, 87-05)	
14	Kärnkraftindustrins - aktivitetsutsläpp - yrkesexponeringar (Tredje kvartalet 1986)	Huvudenhet för kärnenergi

HITTILLS UTGIVNA SSI-rapporter 1987

Rapport-nummer	Titel (undertitel)	Författare
15	Industrial Nuclear Gauges	Torkel Bennerstedt
16	Projekt Tjernobyl - Långsiktig begränsning av cesiumintag via livsmedel	
17	Radon i bostäder Lägesrapport 1987	
18	Mätning av uran i bottensediment från Vinterviken	Curt Bergman Manuela Notter Jorma Suomela
19	Kärnkraftindustrins - aktivitetsutsläpp - yrkesexponeringar (Fjärde kvartalet 1986)	Huvudenhet för kärnenergi
20	Hur drabbade Tjernobylnedfallet en svensk kommun?	Klas Bergman Britt Hedberg-Vikström
21	After ICRP 26	Bo Lindell
22	Förenklad metod för analys av strontium-90 i mjölk	Jorma Suomela
23	Tjernobyl - radioaktivitet i avloppsreningsverksslam	Per Andersson
24	Long term limitation of cesium intake from foodstuffs (Sammanfattning och översättning av 87-16)	
25	Decommissioning policy in Sweden	Curt Bergman Ragnar Boge Jan Olof Snihs
26	Granskningspromemoria: Markdeponeringsanläggning vid Studsvik Energiteknik AB	Gunilla Ericsson Conny Hägg Curt Bergman
27	Patientstrålskydd vid Diagnostisk Radiologi	ICRP
28	Forskningsplan externt förlagd forskning budgetåret 1987/88	Leif Moberg
29	Interkalibreringsmätningar av gammastrålande nuklider	Jorma Suomela

HITTILLS UTGIVNA SSI-rapporter 1987

Rapport-nummer	Titel (undertitel)	Författare
30	Kärnkraftindustrins - aktivitetsutsläpp - yrkesexponeringar (Första kvartalet 1987)	Huvudenheten för kärnenergi
31	Medicinska konsekvenser av kärnkraftolycka	Sten-Erik Olsson Peter Reizenstein Leif Stenke
32	BIOMOVS: An International Model Validation Study	Conny Hägg Gunnar Johansson