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Report period: 1 January 1996 to 31 December 1997

J. Ehrhardt, A. Weis (Eds.)
Institut für Neutronenphysik und Reaktortechnik
Projekt Nukleare Sicherheitsforschung

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Abstract

The RODOS project aims at the development of a comprehensive real-time on-line decision support system for off-site emergency management in case of nuclear accidents in Europe. The second phase of the project is being carried out with financial support of the Nuclear Fission Safety Research Programme within the European Commission's 4th Framework Programme (1994-1998). Currently, about 40 institutes from about 20 countries in Eastern and Western Europe are involved in the project. Main objective of the R&D work is the development of a quality assured, fully operational, customised and comprehensive version of the RODOS system that is generally applicable throughout Europe with appropriate interfaces to plant safety, radiological and meteorological networks, and associated evaluation, validation and training packages.

The report describes the status of the RODOS project and system and the results achieved under the five separate parallel running RODOS contracts with the European Commission by the end of 1997.

Zwischenbericht für das RODOS Projekt

Kurzfassung

Zielsetzung des RODOS Projekts ist die Entwicklung eines umfassenden Echtzeit- und On-line- Entscheidungshilfesystems für den externen Notfallschutz bei kerntechnischen Unfällen in Europa. Die zweite Projektphase wird finanziell gefördert durch das Forschungsprogramm „Sicherheit der Kernspaltung" des 4. Rahmenprogramm der Europäischen Kommission (1994-1998). Gegenwärtig sind etwa 40 Institute aus etwa 20 Ländern in Ost- und Westeuropa am RODOS Projekt beteiligt. Hauptzielsetzung der F&E- Arbeiten ist die Entwicklung einer qualitätsgesicherten, operationellen, anpassungsfähigen und vollständigen Version des RODOS Systems zum generellen Einsatz in Europa mit geeigneten Schnittstellen zu kerntechnischen Anlagen, radiologischen und meteorologischen Netzwerken, sowie zugehörigen Auswertungs-, Validierungs- und Trainingspaketen.

Der Bericht beschreibt den Status des RODOS Projekts und Systems sowie die Ergebnisse, die bis Ende 1997 im Rahmen der fünf parallel laufenden RODOS Verträge mit der Europäischen Kommission erzielt wurden.

Preface

This report describes the status of the RODOS project and system by the end of 1997. In particular, it comprises the results achieved within the period January 1996 to December 1997 under five RODOS contracts abbreviated by the capital letters A to E (see Chap. 2).

The Mid-term Report was compiled and edited by J. Ehrhardt and A. Weis, FZK; the Chaps. 1, 2, 4, 5, 6 and 7 were written by the editors, with comments received and incorporated from the co-ordinators of the C- and D- contracts, K. Sinkko, STUK, and B. Chaumont, IPSN, and from the Working Group Leaders. The sub-chapters of Chap. 3 were produced by Working Group Leaders and co-ordinators responsible for the work areas described, based on reports and documents provided by the individual contractors of the A-, B-, C-, D- and E-contracts:

Chap. 3.1	O. Schüle, FZK
Chap. 3.2	T. Mikkelsen, RISØ
Chap. 3.3	W. Raskob, FZK
Chap. 3.4	R. Heling, KEMA
Chap. 3.5	S. French, University of Manchester
Chap. 3.6	C. Steinhauer, FZK
Chap. 3.7	M. De Cort, JRC Ispra
Chap. 3.8	M. De Cort, JRC Ispra
Chap. 3.9	B. Chaumont, IPSN
Chap. 3.10	G. Geriard-Dubreuil, MUTADIS
Chap. 3.11	O. Schüle, FZK

1 Prime objectives of research

Experience gained after the Chernobyl accident clearly demonstrated the importance of improving administrative, organisational and technical emergency management arrangements in most of the East and West European countries. The technical aspects comprise, among others, qualitatively and quantitatively extended monitoring capabilities, fast communication networks for exchanging radiological information, and decision support systems for off-site emergency management. The primary objectives of the RODOS project (Real time On-line DecisiOn Support) are:

- to develop a comprehensive and integrated decision support system that is generally applicable across Europe,

- to provide a common platform or framework for incorporating the best features of existing decision support systems and future developments,

- to provide greater transparency in the decision process as one input to improving public understanding and acceptance of off-site emergency measures,

- to facilitate improved communication between countries of monitoring data, predictions of consequences, etc., in the event of any future accident,

  and, the overriding consideration,

- to promote, through the development and use of the system, a more coherent, consistent and harmonised response to any future accident that may affect Europe.

The RODOS project is being carried out under the auspices of the European Commission's Nuclear Fission Safety Programme and currently involves about 40 institutes from about 20 countries in Eastern and Western Europe. R&D work performed within what has come to be known as the first phase of the RODOS project, came to an end in the fall of 1995 with the issue of a first pilot version of RODOS (PV 2.1) for test-operational use in emergency centres. The applicability of this version was still limited to the early and intermediate phases of emergency response and to distances of several tens of kilometres from an accidental release.

The second phase, which started with the 4th Framework Programme at the beginning of 1996, is scheduled for completion in mid 1999; its main objective is

the development of a quality assured, fully operational, customised and comprehensive version of the RODOS system that is generally applicable throughout Europe with appropriate interfaces to plant safety, radiological and meteorological networks, and associated evaluation, validation and training packages.

In order to achieve the common objectives of an operational RODOS system for application in the European Union and elsewhere in Europe, functions, models, methods and data bases have to be further developed, completed and adapted to different regional and climatic conditions.

The work programme will extend the applicability of the system to encompass all stages of an accident and all distance ranges within Europe, and make improvements in existing functions where there is a demonstrable need. Particular attention will be given to the following aspects:

- development of a software package to predict the characteristics of potential and actual releases from in-plant information on the status of the nuclear facility;

- interfacing the RODOS system with on-line data from meteorological measurements/forecasts and radiological monitoring networks;
- completion of the model chain for describing atmospheric transport from the vicinity of the release to far distant areas;
- development of improved methods for the assimilation of judgement, model predictions and measurements;
- completion and customisation of radio-ecological modelling for terrestrial and aquatic pathways and their data bases including natural and semi-natural environments;
- further improvement and adaptation of models for quantifying the extent, duration and consequences of emergency actions and countermeasures, in particular in agriculture;
- development of an integrated approach for the handling of uncertainties and their effective communication to decision makers;
- customisation of RODOS for application in Central, Nordic and East European countries, in particular collection of climatological, geographical, hydrological, agricultural, demographic and economic data;
- acceleration of the integration of RODOS into the emergency management arrangements in the respective countries;
- verification of the applicability of individual modules and program packages of the RODOS system in the various parts of Europe and testing its functionality in emergency exercises under realistic conditions;
- validation of models and methodologies and employment of quality software engineering techniques;
- development and performance of training courses for RODOS users and people involved in emergency management, such as radiological advisors and decision makers;
- application of the RODOS system in various exercise settings including the evaluation of exercises.

Effective working arrangements between the project partners in the West and East have been established and a full integration, in one co-ordinated working programme, has been achieved already within the first phase of the project. Interconnections have already been successfully established for R&D purposes between the RODOS systems installed in the partner institutes via fast communication lines (INTERNET, ISDN) and linked to national radiological monitoring systems. This process will continue with a view to enhancing both the amount and quality of information that can be effectively exchanged following an accident. This will contribute greatly to a timely and coherent response to any future accident that may affect Europe.

2 Contracts, management structure and working arrangements

Within the Radiation Protection Research Action of the European Commission's 3rd Framework Programme, the RODOS project was initiated in 1990 to develop a comprehensive real-time on-line decision support system for off-site emergency management for general application in Europe. About 10 EU institutes were initially involved in the project but this number has since increased significantly. About the same number of institutes from Belarus, Russia and the Ukraine were formally integrated within the project in 1992 under the auspices of a collaborative programme on the consequences of the Chernobyl accident between the EC and the State Committees on Chernobyl Affairs in the respective countries. Institutes from Poland (in 1993), Hungary, Romania and the Slovak Republic (in 1994) have joined the project under the European Commission's PECO programme. The basic hardware and software components of the RODOS system have been transferred to institutes in these East European countries with support from the EC. They are committed to co-operating actively in the further development of RODOS with a view to bringing it into operational use.

The German Federal Ministry for the Environment, Nature Conservation and Reactor Safety (BMU) was also a major sponsor of the development of RODOS until the end of 1997, in particular in its RODOS/RESY variant. This variant differs only in the sense that it contains a sub-set of the wider range of models and data currently implemented in RODOS; this subset limits the applicability of RODOS/RESY to the immediate vicinity of a nuclear installation and to the early phase of emergency response.

The system is been further developed under the auspices of the Nuclear Fission Safety Research Programme within the Commission's 4th Framework Programme (1994-1998) on a cost shared basis between the Commission and the participating institutes and/or their national sponsors. This is being carried out within five separate, but fully integrated, contracts with the EC (Table.2.1). Four of these contractors are being supported by the Nuclear Fusion Safety Programme and the fifth by the INCO Copernicus Programme. The list of contractors for each contract is given in Table 2.2. All contracts will end on 30 June 1999. Scientific responsible officer from the European Commission is G. N. Kelly, DGXII-F-6, Brussels.

FI4P-CT95-0007 ("A-contract")	
RODOS: a real-time on-line decision support system for off-site emergency management in Europe	
Start: 1 January 1996	Co-ordinator: J. Ehrhardt, FZK
FI4C-CT96-0006 ("B-contract")	
Customisation and further development of RODOS for operational use	
Start: 1 May 1996	Co-ordinator: J. Ehrhardt, FZK
FI4P-CT96-0053 ("C-contract")	
Completion and customisation of the modelling in RODOS	
Start: 1 January 1997	Co-ordinator: K. Sinkko, STUK
FI4P-CT96-0048 ("D-contract")	
Computer package for source term estimation in accidental cases of light water reactors	
Start: 1 January 1997	Co-ordinator: B. Chaumont, IPSN
IC15-CT96-0318 ("E-contract")	
Enhancement of the EU decision support system RODOS and its customisation for use in Eastern Europe	
Start: 1 January 1997	Co-ordinator: J. Ehrhardt, FZK

Table 2.1: RTD contracts of the RODOS project

A-contract:

FZK	Forschungszentrum Karlsruhe, D
GSF	Forschungszentrum für Umwelt und Gesundheit GmbH, D
UoM	School of Informatics, University of Manchester, UK
NRPB	National Radiological Protection Board, UK
RISØ	RISØ National Laboratory, DK
DMI	Danish Meteorological Institute, DK
SMHI	Swedish Meteorological and Hydrological Institute, S
NCSR	National Centre for Scientific Research "Demokritos", GR
NNC	NNC Limited, UK
ICCET	Imperial College Centre for Environmental Technology, UK
JRC	Joint Research Centre Ispra, I
IPEP	Institute of Power Engineering Problems, Belarus
NRPI	National Radiation Protection Institute, Czech Republic
NRIRR	National Research Institute for Radiobiology and Radiohygiene, Hungary
IAE	Institute of Atomic Energy, Poland
IAP	Institute of Atomic Physics, Romania
TYPHOON	Scientific Production Association TYPHOON, Russia
NPPRI	Nuclear Power Plants Research Institute, Slovak Republic
IMMS	Institute of Mathematical Machines and Systems, Cybernetics Centre, Ukraine

B-contract

FZK	Forschungszentrum Karlsruhe, D
NRPB	National Radiological Protection Board, UK
KEMA	KEMA Nederland,NL
MOL	SCK/CEN Mol, B
UoM	School of Informatics, University of Manchester, UK
CEPN	Centre d'Etude sur l'Evaluation de la Protection dans le Domaine Nucl., F
MUTADIS	MUTADIS Consultants, F
INAPG	Institut National d'Agronomie Paris-Grignon, F
GRADIENT	Universite de Technologie Compiegne, F

C-contract:

STUK	Radiation and Nuclear Safety Authority, FIN
VTT	Technical Research Centre of Finland, FIN
IPSN	Institute for Nuclear Safety and Protection, F
EdF	Electricite de France, F
ECN	Netherlands Energy Research Foundation, NL

D-contract:

IPSN	Institute for Nuclear Safety and Protection, F
FZK	Forschungszentrum Karlsruhe, D
STUK	Finnish Centre for Radiation and Nuclear Safety, SF
VTT	Technical Research Centre of Finland, SF
ETHZ	Swiss Federal Institute of Technology, CH

E-contract:

FZK	Forschungszentrum Karlsruhe, D
RISØ	RISØ National Laboratory, DK
UoM	School of Informatics, University of Manchester, UK
CRCM	Republican Centre of Radiation Control and Environmental Monitoring, Belarus
IPEP	Institute of Power Engineering Problems, Belarus
NRPI	National Radiation Protection Institute, Czech Republic
UTIA	Institute of Information Theory and Automation, Czech Republic
NRIRR	National Research Institute for Radiobiology and Radiohygiene, Hungary
KFKI	Atomic Energy Research Institute, Hungary
IAE	Institute of Atomic Energy, Poland
IFA-IFIN	Institute of Physics and Nuclear Engineering, Romania
TYPHOON	Scientific Production Association TYPHOON, Russia
NSI	Nuclear Safety Institute, Russia
NPPRI	Nuclear Power Plants Research Institute, Slovak Republic
RIARAE	Russian Institute of Agricultural Radiology and Ecology, Russia
IMMS	Institute of Mathematical Machines and Systems, Cybernetics Centre, Ukraine

Table 2.2: Contractors of the RODOS project

Given the scale of the project and the large number of geographically dispersed participants, particular attention has been given to the arrangements for the management of the project. A matrix approach has been adopted with overall co-ordination being achieved through the RODOS Management Group comprising representatives from the EC, the co-ordinators of the respective contracts and independent members (Figure 2.1).

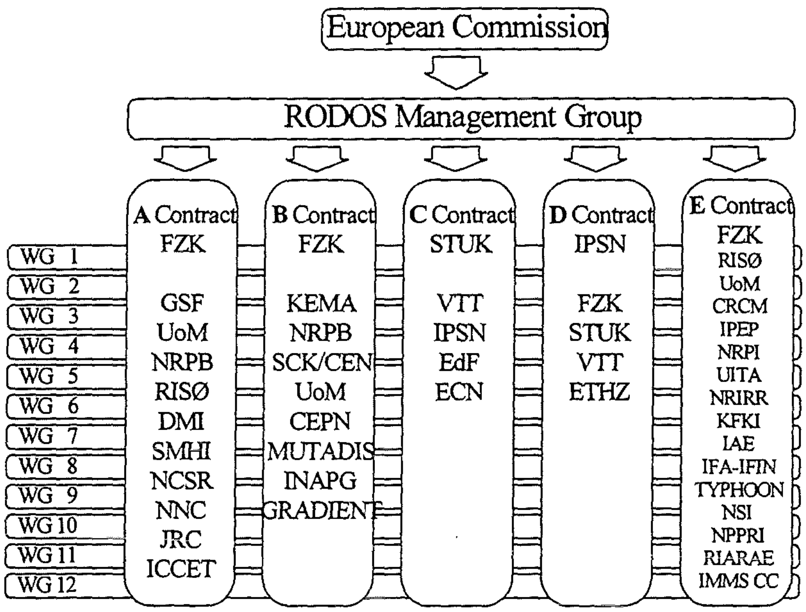


Figure 2.1 Matrix structure of the RODOS project management

The RODOS Management Group was established by the Commission's Services to assist them in the management and overall co-ordination of the RODOS project. Currently, the RMG comprises the following members: J. Ehrhardt (FZK, D), G. Fraser, (EC DGXI-A-1, L), S. French (UoM, UK), G. N. Kelly (EC DGXII-F-6, B), J. Lochard (CEPN,F), S. Lorthioir (IPSN, F), T. Mikkelsen (RISØ, DK) and V. S. Shershakov (SPA TYPHOON, Russia). The RMG is responsible for monitoring and reviewing progress; approving the work schedule; approving procedures for documentation, quality assurance, uncertainties, etc.; resolving issues referred to it by RODOS Working Groups or individual contractors; and setting priorities for the next phases of the RODOS project. Normally, two regular meetings take place per year, a few weeks before the deadline for half year reporting of the co-ordinators; ad-hoc meetings are held on the occasion of RODOS contractors meetings. Since its establishment at the beginning of 1993, the RMG has met 13 times, and the minutes of the meetings have been registered and distributed to all contractors.

The RMG secretariat is operated by FZK (Ms. A. Weis). Its main tasks are to register all RODOS documents (see below), to maintain the WWW RODOS homepage (http://rodos.fzk.de) and the listservers, to update the address list of all scientists involved in the project together with their communication links, to register and to distribute WG and RMG documents, to help organise meetings, and to act as a focal point for all kinds of external and internal requests.

The more detailed technical work within the overall RODOS project is managed horizontally by twelve Working Groups on special topics. The main aims of the WGs are to co-ordinate work in a specific R&D area of the RODOS project, to prepare detailed working programmes within the defined milestones and deliverables of the project, and to identify problems and issues which need broader discussion. The membership of the WGs is drawn from the participating institutes and may change with time, according to the scientific expertise required for the problems under discussion and interaction with other areas. Working Group Leaders (WGLs) have been appointed jointly by the co-ordinators of the RODOS contracts in agreement with the RODOS Management Group. The results of the WG meetings are reported to the RMG via the responsible co-ordinators.

Twelve Working Groups have been established and the corresponding Working Group Leaders are:

- **WG1 "System development and quality assurance"** (O. Schüle, FZK):
  Further development of the RODOS software framework including RoGIS (the geographical information system), the databases, on-line facilities, and user interfaces; quality assurance of modules by static analysis of code, third party testing and verification; organisation of validation exercises of the models and peer review of the methodology.

- **WG2 "Meteorology and atmospheric dispersion"** (T. Mikkelsen, RISØ):
  Completion of the meteorological and atmospheric dispersion model chain for all distance ranges and its coupling to local synoptic stations and weather forecasts of the national weather services.

- **WG3 "Countermeasures and consequences"** (W. Raskob, FZK):
  Further development of the simulation models for emergency actions and countermeasures for operational use and completion of the consequence models for quantifying the benefits and drawbacks of actions, including the corresponding data bases.

- **WG4 "Hydrological modelling"** (R. Heling, KEMA):
  Development of a model chain for calculating the behaviour of radionuclides in the hydrosphere, including run-off processes, river systems, lakes, irrigation, contamination of aquatic foodstuffs and corresponding dose assessments.

- **WG5/6 "Data assimilation, uncertainties and evaluation techniques"** (S. French, UoM):
  Development of methods, models and software products for early estimation of the source term from off-site measurements, for making best use of off-site monitoring data and model results to provide a consistent picture of the present and future radiological situation, and for quantifying the associated uncertainties. Development and integration of software tools for evaluating alternative countermeasure scenarios under the aspects of their feasibility and the subjective judgements of consequences by people involved in decision-making including socio-psychological and political implications.

- **WG7 "Training and Exercises"** (C. Steinhauer, FZK):
  Structuring and development of training courses for future RODOS users and, more generally, for radiation protection and emergency management using the RODOS system.

- **WG8 "International data exchange"** (M. De Cort, JRC):
  Coupling between RODOS and international radiological information systems, such as ECURIE or EURDEP.

- **WG9 "European database"** (M. De Cort, JRC):
  Installation of a data base with demographic, geographic and economic data covering the whole of Europe including the CIS, accessible by RODOS and other systems and projects of the EC.

- **WG10 "Source term based on plant status"** (D. Winter, IPSN):
  Development of methods, models and software products for early estimation of the source term from in-plant data and information.

- **WG11 "RODOS users group"** (K. Sinkko, STUK):
  Forum for the exchange of experience between the users of the RODOS system. The aim of the Working Group is to reinforce feedback between users, modell and system developers in order to enhance the quality assurance aspects of the system and its use.

- **WG12 "Implementation of the ETHOS approach"** (G. Heriad Dubreuil, MUTADIS):
  Decentralised management of the risk from long-term contamination at the local level as a complement to the RODOS system.

The allocation of contractors to Working Groups is given in Table 2.3.

	WG1	WG2	WG3	WG4	WG5/6	WG7	WG8	WG9	WG10	WG12
FZK	X		X	X	X	X	X		X	
GSF			X		X					
UoM	X				X					
NRPB			X		X					
RISØ		X								
DMI		X								
SMHI		X								
NCSR		X		X						
NNC					X					
JRC							X	X[1)]		
KEMA				X						
MOL					X					
CEPN										X
MUTADIS										X
INAPG										X
GRADIENT										X
STUK			X	X		X			X	
VTT				X					X	
IPSN			X			X			X	
EDF						X				
ECN						X				
ETHZ									X	
NRPI	X		X							
NRIRR	X		X		X					
IAE	X	X	X		X		X			
IFA-IFIN	X		X							
TYPHOON	X	X	X	X	X		X			
NPPRI	X		X	X	X					
IMMS CC	X		X	X	X	X	X			
UTIA	X		X							
KFKI	X		X		X	X				
ICCET	X									
IPEP	X		X	X		X				
CRCM	X		X			X	X			
NSI		X								
RIARAE			X		X					

status: 3 July 1997 **1) and all contractors**

Table 2.3 Allocation of contractors to Working Groups

Minutes of each WG meeting are prepared by the responsible WGLs, registered at the RMG secretariat and distributed to all contractors involved in the WG and to the European Commission. In addition, the WGLs prepare every half year a status report, in which the activities performed and the progress achieved are described and compared with the working programme set out in the Technical Annexes of the contracts.

Four principal contractors are responsible for oversight and monitoring progress in different areas:

- meteorology and atmospheric dispersion (WG2): RISØ National Laboratory

- system development, countermeasures and consequences, training and exercises (WGs 1, 3, 4, 7, 8, 9,11): Forschungszentrum Karlsruhe.

- data assimilation and uncertainties, evaluation techniques, quality assurance (WGs 1, 5/6): University of Manchester.

- implementation of the ETHOS approach in the CIS Republics (WG12): CEPN.

Various arrangements have already been put in place and a number of principles are adhered to in order to achieve the delivery of a quality assured RODOS system to support decision makers. Three support teams have been set up by the RMG who will guide the contract partners during the whole contract period:

- software developer support team at FZK: assist the model developers in integrating existing software, handle problems and questions concerning the design, development and integration of modules, and discuss and advise on problems of modularisation.

- user support team at FZK: help the users of RODOS with all problems and questions arising during the use of RODOS, such as installation and maintenance, the Operating System OSY, the modules.

- quality assurance team at ICCET and UoM: set guidelines for the software development process (e.g. validation and testing), monitor the quality of the RODOS system, provide developers with support in quality assurance methodologies, and develop standard documentation templates and formats.

Documentation is produced alongside, in many cases before, the production of the software. All contractors who develop modules must explain how they will evaluate and validate both the software modules and the scientific models implemented in the software. In addition to the internal evaluation and validation by a contractor, all deliverables will be subject to peer review by other contractors and, in some cases, an external group of scientists.

Full contractors meetings are organised at changing places approximately once a year. The main purposes of such meetings are to communicate the status of the project and system development for achieving a broader and common understanding of the project goals and priorities, to enable discussions within and between WGs and to come to agreed working arrangements between the partners, to identify delays and to conclude how they will be remedied, and generally to strengthen the solidarity within and committment to the RODOS project.

Information of common interest is exchanged through the RODOS Newsletters, issued by FZK. Normally, two issues appear per year, and up to now, eight RODOS Newsletters have been produced and distributed to the contractors and other interested parties. A register of all documents produced by the contractors is kept by the RMG secretariat at FZK. Templates for all types of reports exist; each document has a unique code, distinguishing between minutes of meetings, technical notes or draft reports for internal exchange, and publications. In a series of special RODOS reports, important overview articles and RTD results are published; until now three such reports exist.

A RODOS brochure has been produced as a means for promoting to a wider audience the structure, content and main features of the RODOS project and system. It consists of a folder with individual inserts provided by contractors or WGs, which are continuously updated and replaced. The first version of the RODOS brochure was produced at the University of Leeds; the second version was printed at FZK and is updated and distributed by the RMG secretariat.

3 Progress achieved and deliverables

RODOS has been designed as a comprehensive system incorporating models and databases for assessing, presenting and evaluating accident consequences, over all distances, taking account of the mitigating effect of countermeasures. Its flexible coding enables it to cope with differences in site and source term characteristics, in the availability and quality of monitoring data, in national regulations and emergency plans, etc. To facilitate its application over the whole of Europe, the software has been developed as a transportable package to run on workstations with a UNIX operating system; in particular, the software framework supports the integration of application software developed externally by each institute participating in the project. The modular structure of RODOS enables the exchange of models and data, thus facilitating the adaptation of the system to the specific local, regional or national conditions of interest.

The basic concept and design of RODOS were specified and agreed upon by participants at the outset of the project. The conceptual RODOS architecture (see Fig. 3.0.1)is split into three distinct subsystems, which are denoted by ASY (Analysing Subsystem), CSY (Countermeasure Subsystem) and ESY (Evaluating Subsystem). The interconnection of all program modules, the input, transfer and exchange of data, the display of results, and the interactive and automatic modes of operation are all controlled by the specially designed Operating SYstem (OSY). Each of the subsystems consists of a variety of modules developed for processing data and calculating endpoints belonging to the corresponding level of information processing. The modules are fed with data stored in four different databases, comprising real-time data with information coming from regional or national radiological and meteorological data networks, geographical data defining the environmental conditions, program data with results obtained and processed within the system, and facts and rules reflecting feasibility aspects and subjective arguments.

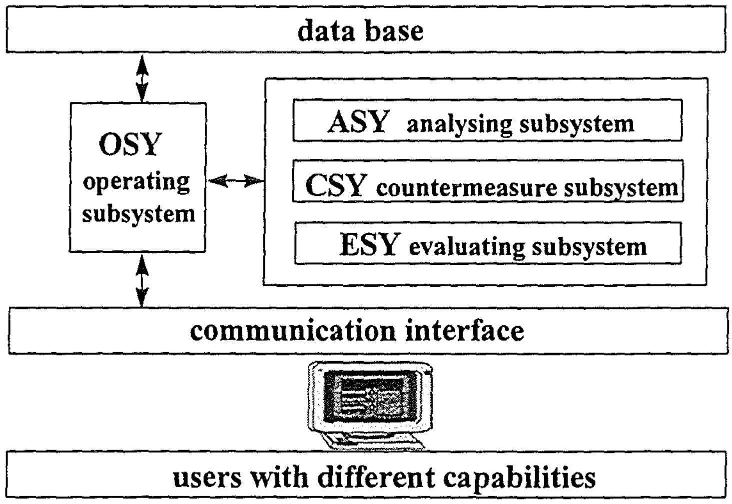


Fig. 3.0.1 Conceptual structure of RODOS

The content of the subsystems and the databases will vary, depending on the specific application of the system, i.e., the nature and characteristics of a potential accident. The timing of decisions will greatly influence what information is available and how information can be aggregated. At different points in time various modules will have to be linked (with at least one each from ASY, CSY and ESY) in order to produce the required output. For example, after the passage of the plume, meteorological forecasts are no longer necessary for the region considered or, after evacuation, models for simulating sheltering or relocation in the same area are no longer needed. RODOS can be run, in parallel, in two distinct modes of operation, automatic and interactive.

The dialogue between RODOS and a user is performed via various user-interfaces tailored to the needs and qualification of the user. The access rights of different user groups determine the type of user-interface, which allows increasing access to models, data and system parameters in a hierarchical structure. At the lowest level of access, there is an easily understood but very limited interface for training courses on emergency management; at the highest, the full spectrum of interface tools is available for system developers familiar with the system content and structure.

The following chapters 3.1 to 3.11 describe in detail the status of the system development and, in particular, what has been achieved by the contractors of the five RODOS related contracts within the first R&D phase of the 4th Framework Programme of the European Commission.

3.1 System development and quality assurance

3.1.1 The modular design

The RODOS system is based on the Client-Server principle. It is built of modules, which are connected via a Communication Interface. Each of these modules can either be a

- Server, which provides special services to other modules, or a
- Client, which requests services from other modules,
- or both.

Well defined data structures allow the exchange of data between the client and the server and facilitate the data handling in the database as well as for the user.

This modular design is one of the key features of the RODOS system. It allows the easy extension of the system by adding new modules for special applications and the flexible control of the calculations. All program control, data management, input and output is done by the appropriate modules of the Operating Subsystem OSY. The task of the modules of the Analysing, Countermeasure and Evaluation Subsystems is just performing the model calculations for providing the required results.

3.1.2 Automatic and interactive mode

The dialogue between RODOS and a user is organised in two different modes. In the so-called "automatic mode" the system automatically presents all information which is relevant to decision making and quantifiable, in accordance with the current state of knowledge in the real cycle time (e.g., 10 minutes in the early phase of emergency response). For this purpose, all the data entered into the system in the preceding cycle (either on-line or entered by the user) are taken into account in the current cycle. Interaction with the system is limited to a minimum amount of user input necessary to characterise the current situation and adapt models and data.

The cycle time mentioned above refers to the system cycle, i.e. the time intervals, within which all relevant information is updated and new calculations are performed. The cycle time does not necessarily reflect the time periods, within which new meteorological or radiological data are fed into the system. For example, meteorological forecast data may enter the system every six hours, new measurement data on foodstuff contamination may be available once per day. Nevertheless, a cyclic update of calculations every hour (e.g. with the countermeasure and consequence modules) is reasonable, as the basic data - extension and contamination of the radioactive cloud - have changed. It is also possible to feed the system with 'delayed' data, which refer to a time point in the past; precondition is that the data file contains the relevant time information.

Either in parallel to the automatic mode or alone, RODOS can be operated in the "interactive mode". In this dialogue mode, the user of the system and RODOS communicate via a menu interface. Editors specially developed for this purpose allow specific modules to be called; different sequences of modules to be executed; input data and parameter values to be changed; and the output and representation of results to be varied.

3.1.3 The operation subsystem

The interconnection of all program modules, the input, transfer and exchange of data, the display of results, and control of the interactive and automatic modes of operation of the system are all controlled by the Operating Subsystem OSY, which comprises the central part of the software Environment of RODOS (see Fig. 3.1.1). The main duties of OSY are the correct control of system operation, data management, and the exchange of information among various modules, as well as the interaction with users in distributed computer systems. The flexibility of the whole system is defined by OSY and is independent of the development of program modules.

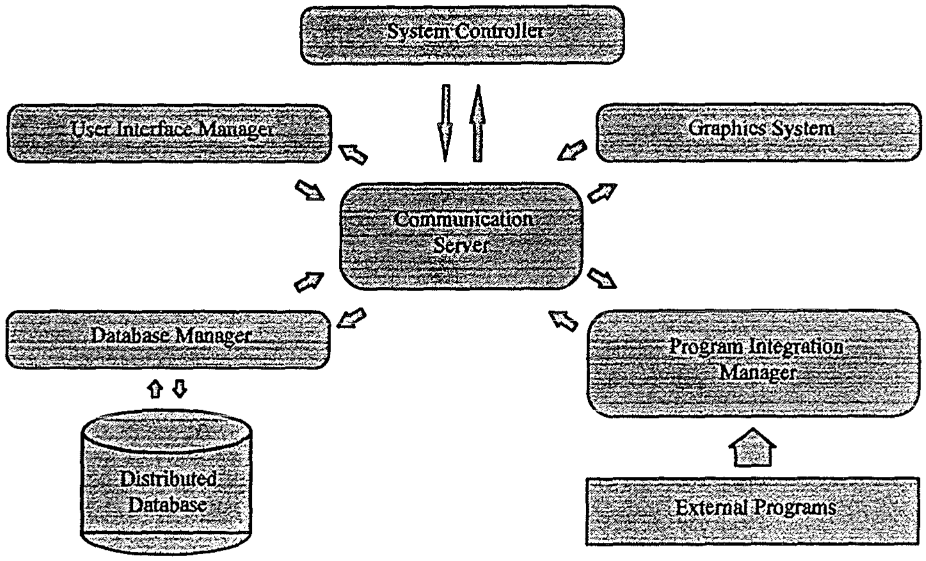


Figure 3.1.1: The modules of the Operating Subsystem OSY

3.1.4 The communication server and system controller

The exchange of messages between the modules of the RODOS system is controlled by the Communication Server. Each module can send messages to and receive messages from other modules. The messages contain fields which define the type, sender and recipient of the message. On start-up, each module sends a message to the Communication Interface, telling it the message patterns which should be sent to this module

The System Controller handles the program flow in the RODOS system. It uses information stored in the Program Database to decide which modules have to be called.

Both the Communication Server and the System Controller were developed early in the RODOS project but have been updated since. In particular, the better understanding of the Automatic Mode and its requirements led to a major improvement of the System Controller. In future, only minor updates of these two modules will be necessary.

3.1.5 The user interface manager

The RODOS system has a unique user interface to manage the interaction between the users and the various modules of the RODOS system. This interface provides the basic functionality to control the input parameters and the execution of the modules (e.g. definition of model parameters or start, hold, stop the modules) and can be separated into two parts:

- The Main Dialogue Windows
- The Application Initialisation Windows

The user interface of the RODOS system is designed to be configurable and thus can be adapted to various needs of the users.

The main dialogue windows

All main controls of the RODOS System are located in the Main Dialogue Windows. Following the current standard for user interfaces, the Main Dialogue consists of several windows with icons and menus for the access of the control functions. The user can selectively open or close these windows to create his preferred working environment.

Based on the experience and user feedback with the initial version of the Main Dialogue, the new improved version was developed and first delivered with RODOS Version 3.0.

The application initialisation windows

The modules of the RODOS System get their data from the Database Manager, which manages both, the basic data sets and the user defined data. On start-up of an application, the user can select and modify the input data with the Application Initialisation Windows. These windows have a hierarchical structure, leading the user to the appropriate input controls.

The management of the Application Initialisation Windows is done by a tool of the Operating Subsystem OSY. Based on a description language for the input windows, these windows are created by this tool on request during runtime. The description of the windows is stored in normal ASCII files in the system and has to be provided by the developer of the application. It can be easily adapted to other needs or languages.

The Application Initialisation Windows were first introduced in RODOS Version 2.0. Experience has shown, that a more flexible design of these input windows is needed, in particular the possibility to define conditional window controls, to check input data for consistency and to allow user input during runtime of the application. This will be done in the near future.

3.1.6 The Graphics System

The Graphics System (see Fig. 3.1.2) must handle all graphics output from various modules of the system, such as displaying results on geographical maps, histograms or function plots. Due to these requirements, the Graphics System must be connected to the Program Database containing the results of the modules and the Geographical Database with map data. The first connection is established using the Database Manager to transfer the result data, so the Graphics System behaves just like any other module of the RODOS System. On the other side, the connection to the Geographical Database is realised more closely, making the Graphics System a part of the Geographical Information System RoGIS.

All graphics data (graphics objects) managed by the Graphics System is organised in layers, allowing the user to selectively display parts of the information available in the Graphics System. Incoming data from the modules has to be translated to graphics objects suitable for displaying by the internal converter. This is the only part which has to be modified if new data formats are provided by the modules. An internal interpreter parses incoming messages and starts the appropriate actions, such as loading data from the Database Manager or providing data for editing to the user.

The Graphics System has a user interface which gives the user the possibility to interact with the graphics data (e.g. zoom the output, modify graphics data). This design and realisation of the user interface is closely related to the ArcView user interface of the ArcInfo Geographical Information System, thus allowing the user to easily learn the usage of the Graphics System. An import and export facility of the Graphics System also allows the exchange of data with ArcInfo products.

The first version of the Graphics System was part of the Main Dialogue Window. Starting from Version 3.0 of RODOS, the Graphics System is an independent module of the Operating Subsystem OSY. This new version of the Graphics System is largely complete and only needs some minor updates (e.g. new result data formats) in the future.

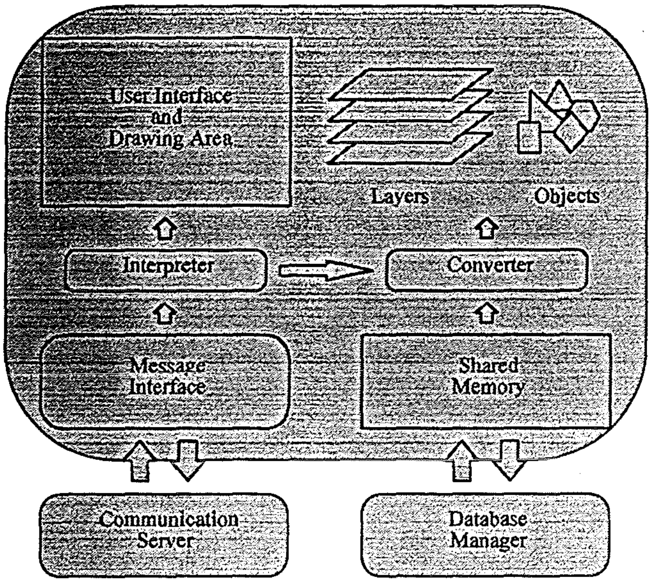


Figure 3.1.2: The Graphics System

3.1.7 The databases

General aspects

Systems like RODOS have to manage, process and evaluate a large amount of data of different kind and quantity, such as geographical, meteorological, radiological and economic data, messages, criteria, statistics, and expert knowledge (facts, rules, preferences). They may be stored in different databases and computers with their own data structures and formats. In addition, the concept of developing RODOS distinguishes a stepwise progress with versions of improving functionality and for applications with differing complexity. Therefore, it is impossible to realise from the beginning a data bank for all applications and data-specific aspects.

This led to the concept of a distributed database allowing for a decentralised data management and the parallel execution of multiple task operations (see Fig. 3.1.3). A corresponding Database Integration Server transforms the different data formats in the format of the RODOS operating system and converts the system queries by means of the embedded SQL-interface, and thus increases the flexibility and efficiency of data access.

Each of the databases of the RODOS system is a stand-alone database system, which has its own interface and can be developed independently. Currently the following databases are part of the RODOS System:

- Program Database containing all information of the modules and their input data.
- Basic Database with basic data sets
- Geographical Database RoGIS with map data
- Real-Time Database for online data

The implementation of the databases in RODOS uses a special subset of SQL commands which are translated into specific SQL implementations. Currently the database systems HPAllbase and Ingres are supported; in the future ORACLE will also be supported.

The Database Manager

The Database Manager gives the programs of the RODOS system access to the data stored in the different databases with a unique interface format. It converts the requests from the modules into a request to the appropriate database and enables multiple clients to access multiple database servers.

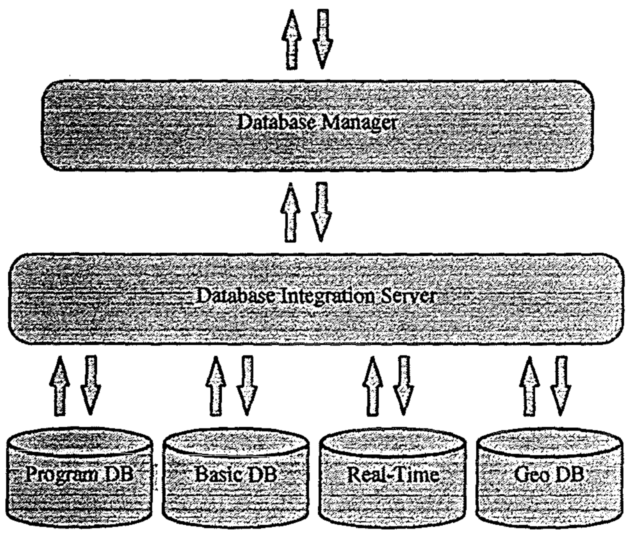


Figure 3.1.3: The Distributed Database

The actual version of the Database Manager in RODOS Version 3.0 is designed to cope with the Program, Basic and Real-Time Databases, providing a unique interface to the data stored in these databases for the modules of the RODOS System. Minor changes in future will allow a more easylier access to the data in the Program Database without knowledge of the data structures used in the modules. Also the access of data during runtime of modules will be improved.

The Program Database

The Program Database contains parameters and results of the application software implemented in RODOS. This database, in particular its structures are connected to the modules of the RODOS System. The data structures of the modules used for the exchange of data are mirrored in the Program Database.

Editors allow the user to enter, modify or delete the content of the database. On start-up of a model chain, the user can alter the program parameters defined in the Program Database for this specific run using the Application Initialisation Windows described earlier. The developers of the modules can enter, modify and delete the database structures with a special editor.

The Basic Database

The Basic Database contains data which is independent of the existing modules of the RODOS System. In particular information on the power plants, physical constants and intervention levels.

Editors allow the user to enter, modify or delete the contents of the Basic Database. The developers of the modules can add new structures using a special editor.

In RODOS Versions before 3.0, the Basic Database and the Program Database were both connected. Run-time and storage considerations led to the splitting of these two databases.

The geographical information system RoGIS

The geographical information system RoGIS builds a system for handling various geographical and statistical information and organising the access and interchange of data with other environmental databases.

RoGIS is designed as a stand alone program package and includes all necessary tools for organising the database and for handling various sets of data. Its structure allows easy integration of different kinds of data structures. As part of the RoGIS system, an interface package gives stand-alone programs access to the data stored in RoGIS.

An Interface to ArcInfo using the shape file format allows RoGIS to share data with this popular geographical information system, in particular to export results data from RODOS for further analysis with other GIS tools. Various other formats used for geographical data can be translated into the RoGIS input format using a library of translation modules.

In addition to the map data, RoGIS also provides environmental data on grids. This data is supplied to the modules using a unique interface. A library with translation modules is provided. This helps the suppliers of environmental information to convert their data into RoGIS input format.

Version 3.0 of RODOS contains RoGIS as an independent package, which can be installed in addition to the RODOS System. The Graphics System is designed to work in both configurations, with and without RoGIS. In the future releases, RoGIS will become an integral part of the RODOS System.

The Real-Time Database

The Real-Time Database comprises all kinds of environmental monitoring data and measurements. Therefore, it has to be connected to various on-line networks with environmental data (e.g. radiological measurements, weather forecasts) with different data formats. This is done via a configurable Data Interface, allowing connection to a wide range of measurement networks to the Real-Time Database without rewriting the interface programs.

The functionality of the interface is described with a special language which contains all necessary constructs to map the input data to the internal data structure of the Real-Time Database.

Within the Real-Time Database are tools to verify and display the real-time data stored in the database.

Beginning with Version 3.0 of RODOS, the Real-Time Database is part of the RODOS System. Using the configurable interface, the RODOS System installed in an emergency centre must be adapted to the available networks and data structures. Configurations of the Data Interface for the data formats used in Germany (e.g. IMIS) and for meteorological data are already available.

Remote databases

The concept of distributed databases in the RODOS system allows the integration of Remote Databases, situated at different places. These remote databases can be either stand-alone or the databases of another RODOS system. An on-line connection to these databases is used to transfer the data.

The development of these Remote Databases is part of the development efforts for the near future. In addition with the ongoing implementation of RODOS in various countries, tests of the functionality will demonstrate the application of this feature for emergency management.

3.1.8 Connection to networks

Systems like RODOS need a constant flow of real-time data for the models to analyse the current situation and to make predictions. As the RODOS System itself does not include a measurement network, it uses existing sources of meteorological and radiological data. The physical exchange of data can be organised using either normal Internet capabilities, phone lines or ISDN connections. A process located either on the computer of the data provider or the RODOS computer transfers the real-time data to the RODOS computer for translation and storage into the Real-Time Database using the Data Interface (see Fig. 3.1.4).

In addition to the connection to networks providing real-time radiological and meteorological data, RODOS Systems at different locations can be connected using the Remote Database facility described above.

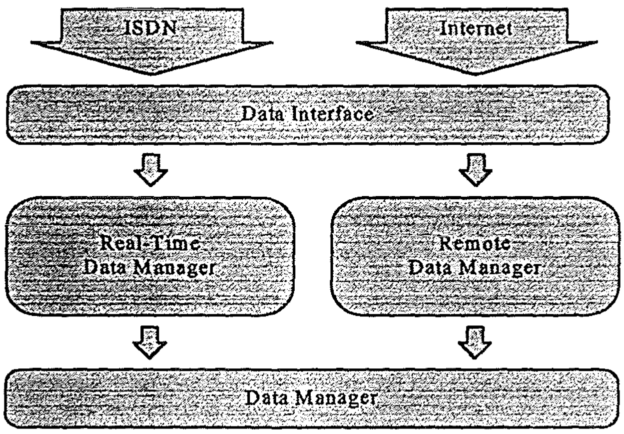


Figure 3.1.4: Online Connections of RODOS

RODOS will be coupled in Germany to the on-line information networks KFÜ (nuclear reactor remote monitoring systems) of the power plants and the integrated measurement system IMIS of the Federal Republic of Germany. The data will be delivered in 10-minute (KFÜ) or 3-hour (IMIS) intervals via ISDN. Tests with this configuration have been made at FZK.

3.1.9 Integration of external programs

The modular structure of the RODOS system and the Client-Server principle allows the integration of new modules in the system. Because the program control, data management, user input and graphical output is entirely handled by the Operating Subsystem OSY, the model developer can concentrate on the contents of his model.

Adding new modules to the RODOS system is done in several steps:

- Define the services which are provided by the new module (e.g. calculation of organ doses).
- Enter information needed for the program flow into the Program Database (e.g. input data needed by the module, data produced by the module). This will allow the System Controller to integrate the module into the program flow.
- Define the input and output data structures of the module.
- Create the Application Initialisation Windows for user inputs.
- Code the module, using a template for the message interface.
- Test the module in the RODOS system.

Most of the steps described above are done using the integration tools provided by the RODOS System. These tools help the model developer to define the sub-modules, data structures and the input windows.

The integration of already existing stand-alone programs into the RODOS system is done in a similar way. Normally, such a program defines a whole model chain. It is therefore split into its modules, which are integrated into RODOS as described above.

A special environment (RODOS/2) to test and debug the modules outside the RODOS System is also provided by the RODOS System. This environment allows the model developers to do most of the coding and testing in their favourite programming environment, in particular to check their modules with special input data during the validation process. A document describing the integration process and the essential parts of the Operating System OSY is available for the model developers.

As most of the developers of models within RODOS still lack the experience with client-server applications and the modern programming paradigms used in RODOS, considerable effort from the System Development is needed to integrate the models into RODOS. This situation should change in the future when the RODOS System will be available in most of the contractors institutes and the model developers learn to use the integration tools provided with the RODOS System.

3.1.10 Adaptation to national conditions

The RODOS System is provided by the developers in an English version with default data. Installing the system in an emergency centre makes it necessary to adapt

- the language specific parts (e.g. menus, messages),
- the demographic, geographic and environmental data,
- the national regulations (e.g. intervention levels).

All of these are accessible via the databases or configuration files. Special procedures to convert existing data, such as geographical or environmental data, to the RODOS input formats is provided with the system.

The procedures for adaptation to national conditions were discussed with the system administrators and a summary document describing the procedures is available. Further versions of RODOS starting with Version 3.0 will only have minor differences in their user interfaces and no changes in the data formats used. So the adaptation efforts for new releases are small.

3.1.11 Quality assurance

Introducing quality assurance (QA) procedures into RODOS, which started as a research project, has been a difficult process. In particular finding the best way between rigid QA, different cultures in each institute and the lack of manpower and time led to many discussions. The current approach includes

- preparing a set of guidelines on coding standards to be applied in future by RODOS contractors,
- setting up procedures by which software may be submitted for checking and analysis,
- suggesting schemes of program testing, and
- suggesting methods by which the different versions of a model can be tracked and recorded.

Quality assurance questionnaire

A survey of current QA practices was conducted. This consisted of a questionnaire circulated to the RODOS contractors, followed up by personal discussions. The responses have been co-ordinated and compiled in a RODOS document - "Report on the Quality Assurance Questionnaire". It was apparent from this survey that there was large variation in the attention paid to quality assurance, with very few contractors having thorough procedures in place.

Coding guidelines

The area of coding standards is somewhat controversial, because different people have different ideas about what is important or not, especially concerning the layout of the code on the page or the screen. Within RODOS, it was decided to introduce a set of programming guidelines, rather than a strict specification. Also a layout style will not be imposed on programmers, because the problems of imposing this retrospectively could well outweigh any benefit, even using one of the "prettifying" packages available in the public domain; however, within any software package, the style must be consistent.

Static testing

Static testing means that the code is analysed and tested in its source form, in much the same way as a compiler checks code and fails if it finds any errors. Static testers checkcode in much greater detail, often prompting the programmer to confirm their intentions. They are also able to provide metrics on the software. RODOS is setting up a service, known as the QA Wrapper, whereby contractors can submit their software for static testing via Internet.

Version control

Version Control has two aspects, tracking the development, and controlling releases. When code is changed during its development, some record should be kept of what instigated the modification, what was modified and by whom, and how the modification was tested. This is of course difficult in a Research and Development environment, where ideas abound and should be allowed to flow, but it is equally important from time to time to pause, take stock, and decide what is being kept, and what discarded; at this point, the modification can be documented.

The second aspect of Version Control is controlling which version of the program has been released (or in the case of RODOS incorporated into the OSY), keeping track of the capabilities of the version, and the differences from previous releases.

RODOS QA plan

As a result of the Working Group 1 meeting in Budapest in March 1997, and other discussions, the following QA disciplines have been stressed both for further developments and existing software:

- The documentation must include a functional specification, data interfaces and model description,
- Version control should be used.
- Model verification and validation should be documented.
- Source code must be submitted for static testing.

3.1.12 Further development

The RODOS Operating System has reached a rather stable version with most of the requested functionality included already in version 3.0. Thus, the system development can concentrate on the tasks which deal with the installation of RODOS in emergency centres and the interconnection of RODOS Systems.

Main tasks for the System Development in relation to the installation in emergency centres is the design and coding of backup and recovery procedures to cope with system crashes during RODOS operation using redundancy software.

In addition, the experience with the actual RODOS Operating System and its interaction with the external programs showed some points for further improvement. In particular these are:

- Extension of the data access from external programs

Extension of the input windows for program data

3.1.13 References

The main documents describing the Operating Subsystem OSY and the integration of external modules into RODOS are

1. RODOS(WG1)-TN(96)03: RoGIS - The Geographical Information System for RODOS; O. Schüle (FZK)
2. RODOS(WG1)-TN(96)04: The Graphics System of the RODOS Operating Subsystem; O. Schüle (FZK)
3. RODOS(WG1)-TN(96)06: A Guide for the Integration of External Programs; M. Rafat (FZK/DTI), O. Schüle (FZK)
4. RODOS(WG1)-TN(96)07: RODOS System Manual - Prototype version 2.1; G. Benz, C. Haller, M. Rafat, T. Sauder (FZK/DTI), O. Schüle (FZK)
5. RODOS(WG1)-TN(96)10: RODOS/RESY Prototype version 2.0 User Guide; J. Päsler-Sauer, O. Schüle, C. Steinhauer (FZK)
6. RODOS(WG1)-TN(96)13: The RODOS Database Adapter; M. Rafat (FZK/DTI)
7. RODOS(WG1)-TN(96)14: Conversion Guide and Tutorial for RODOS-SQL Syntax; M. Rafat (FZK/DTI)

8. RODOS(WG1)-TN(96)15: The RODOS Database Generator; M. Rafat (FZK/DTI)

All of these documents are continuously updated and made available for downloading via the Internet.

3.2 Meteorology and atmospheric dispersion

A set of atmospheric transport and dispersion models suitable for real-time atmospheric dispersion calculations, within the **RODOS** system have previously been selected by Mikkelsen and Desiato (1993) (1), cf. Table 3.2.1.

TABLE 3.2.1: THE **MET-RODOS** MODULE: Associated models and data
Near-range flow and dispersion models, including pre-processors: • Meteorological pre-processor (**PAD**) • Mass Consistent Flow model (**MCF**) • Linearized flow model (**LINCOM**) • Puff model with gamma dose (**RIMPUFF**) • Near-range segmented plume model (**ATSTEP**)
Complex terrain models (stand alone system): • Prognostic flow model (**ADREA**) and Lagrangian dispersion model (**DIPCOT**)
Mesoscale and Long-range Models: • Eulerian K-model (**MATCH**) nested with puff radiation dose models (**RIMPUFF**)
On-line Weather Forecast data: • Numerical Weather Prediction data (**DMI-HIRLAM** and **SPA -TYPHOON**)

With the goal to create a fully operational system by mid 1999, these models and their associated pre-processors have been system-integrated as a comprehensive meteorological module in the Version 3.0 of the **RODOS** system. The module is called **MET-RODOS** and involves models and pre-processors contributed by several partners associated with the **RODOS** projects Working Group 2 (see Table 2.3).

3.2.1 The MET-RODOS module

An overview of **MET-RODOS** is presented in Figure 3.2.1(a-c). The processing "hard-core" of the module is centred about the following three sub-systems:

- The Local-Scale Pre-processor **LSP**,
- The Local-Scale Model Chain **LSMC**, and
- The Long-Range Model Chain **LRMC**

The **MET-RODOS** module has, in addition, real-time access to the following data bases:

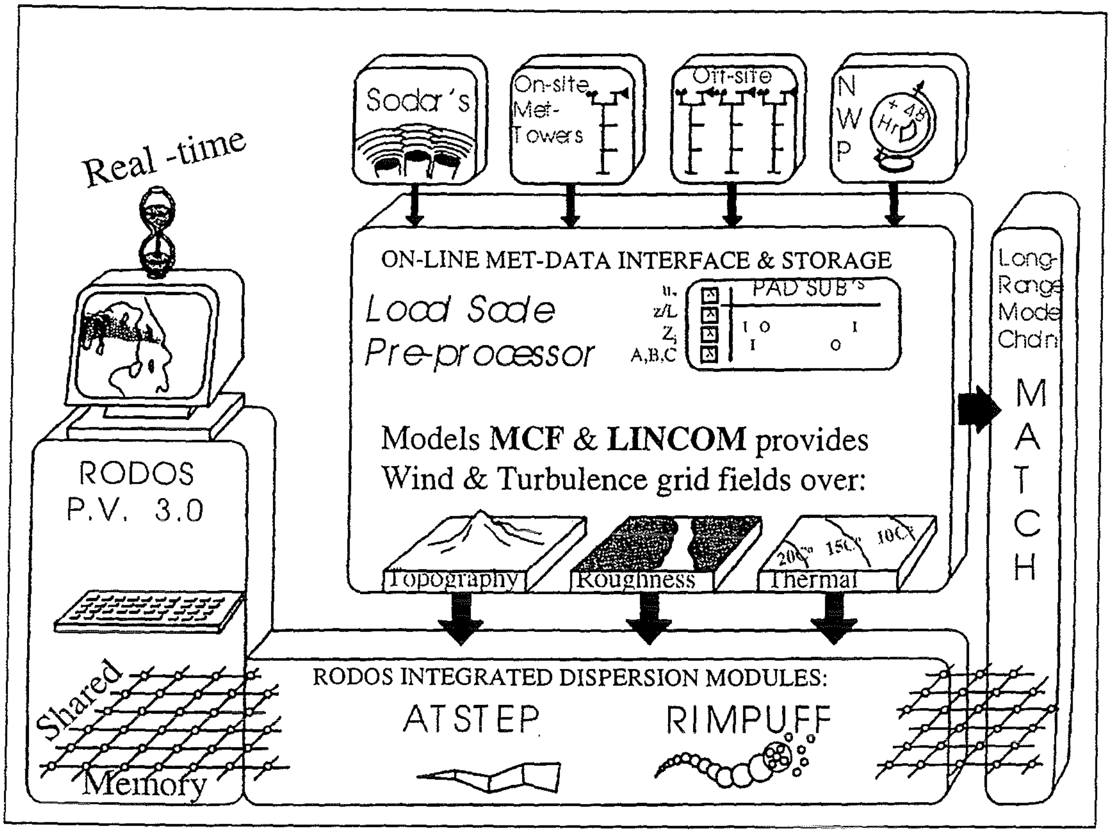
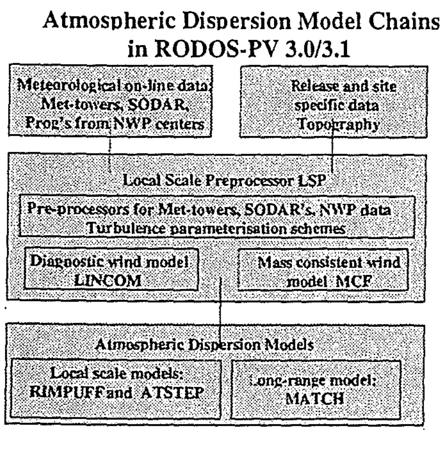
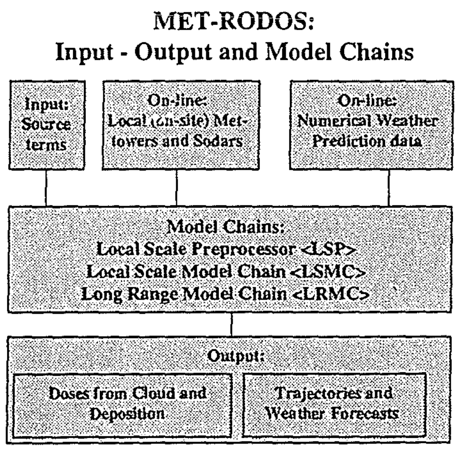


Figure 3.2.1. (a) The MET-RODOS system integrated with RODOS P.V. 3.0 via shared-memory.





(b) MET-RODOS Atmospheric Dispersion Model Chains. (c) MET-RODOS input/output and model chain structure.

- The On-Line Meteorological-Tower Data Base **OLMTDB**,
- The Real-Time Numerical Weather Forecast Data Base **RTNWPDB**.

LSP, the local scale pre-processing program, maintains the local-scale system with actual and forecast local scale wind fields and corresponding micro-meteorological scaling parameters by real-time pre-processing and use of the local scale wind models.

LSMC, the local scale model chain, contains a suite of local scale mean wind and dispersion models, from which case-specific models are selected depending on the actual topography and atmospheric stability features in question. It provides ground level air concentrations (in [Bq/m^3]) and concentration of deposited isotopes (in [Bq/m^2]), and ground level gamma dose rates (in Grays per second [Gy/s]) for subsequent use by the **RODOS** system. When clouds are reaching the outer bounds of the local scale domain (20 km), diffusion specific parameters such as cloud size, content and position is passed on to the long-range model chain **LRMC**.

LRMC, the long range model chain, manages the trajectory and dose rate assessments on national and European scales in **MET-RODOS**.

TOWERDB, the On-line Met-Tower Data Base, maintains and updates the on-line meteorological met-tower measurements available to the system.

FCASTDB, the real-time numerical weather forecast data handles the real-time numerical weather forecast data available to the system.

Integration with RODOS

The modular structure of **MET-RODOS** has allowed it to become an integral part of the **RODOS** system. The meteorological modules set-up and time control, data management, user input and graphical output will eventually be handled in the **RODOS** Operating Subsystem (OSY).

As indicated in Figure 3.2.1a **MET-RODOS** communicates with RODOS via shared memory and real-time data bases. **MET-RODOS** inputs its source terms directly from the **RODOS** real-time data base while meteorological data are down loaded via on-line network connections to the **RODOS** real-time environmental data bases. **MET-RODOS** generated output (i.e. dose rates from air and ground deposited material) is stored in the **ROGIS** data base. The **MET-RODOS** system set-up and run time control is being implemented in the **RODOS** menu-driven control system.

On-line meteorological input data

Real-time application of an atmospheric dispersion based nuclear emergency system requires on-line access to real-time measurements of the local dispersion meteorology. Such data are often available from an on-line connected met-tower located in the vicinity of the release point. It is usually instrumented with wind and temperature sensors. For off-site assessments of releases, and for distances beyond the local (10 to 20 km) scale, similar on-line estimates from the regional (100-km scale) wind and temperature conditions can also be used by **MET-RODOS** for now-casting of plume spread in real time. Such networks of on-line regional scale meteorology is already available in some European countries (such as Hungary) via real-time measurements made from an operational network of on-line automatic meteorological stations.

Real-time numerical weather prediction data

Real-time on-line numerical weather forecasts produced at remote meteorological institutes are also integrated as part of **MET-RODOS**. For installations without access to local meteorological weather stations, **MET-RODOS** is able to make local-scale predictions based on meteorology from numerical weather prediction data alone. With local met-tower data available, on the other hand, numerical weather prediction data serve the system with forecast weather (prognose mode), for both local and long range dispersion and trajectory estimates.

Numerical weather prediction data for Europe are currently accessible via computer networks at high spatial and temporal resolution (10-20 km horizontal grid resolution at hourly time intervals up to + 48 hours). High-resolution Numerical Weather Prediction (NWP) data are produced around the clock at many national and international operational meteorological centres. Following the establishment (in 1995) of the EU approved ECOMET organisation of the European National Meteorological Services (NMS) European customers can obtain real-time access to NWP data from collaborating NMS's at EU approved prices. During the **RODOS** development and implementation phase 1996-1997, NWP data have been obtained on-line from the Danish Meteorological Institute (DMI), the Swedish Meteorological and Hydrological Institute (SMHI), and the SPA-Typhoon centre in Obninsk, Russia. An agreement is being negotiated (with DMI) for real-time on-line delivery of NWP products for the remainder of this project (mid-1999). A subsequent section describes the **DMI-HIRLAM** model and the on-line data transfer and integration of **DMI-HIRLAM** NWP products into **MET-RODOS**.

Also, global weather forecast data (+120 Hr forecasts; 1.5 degree resolution), for example as produced at the joint European Centre for Medium-Range Weather Forecasts (ECMWF), can now be obtained on a commercial basis from the European National Meteorological Services.

The local scale model chain, LSMC

The running of **ATSTEP** or **RIMPUFF** requires, in addition to the standard meteorological parameters wind and temperature, determination of the dispersion controlling scaling parameters, such as stability category or the Monin-Obukhov stability measure, and determination of the mixing height.

To serve this purpose, extensive pre-processing software has been included in the local scale model chain. On-line incoming meteorology - from either automatic meteorological stations and/ or from weather forecast model nodes near or inside the local-scale model domain - are real-time pre-processed into gridded mean wind and turbulence quantities (including the above mentioned atmospheric stability measures) at all grid points belonging to the local scale grid. A typical local-scale grid contains 41 x 41 or 81 x 81 grid points, for an area of 20 x 20 km.

The local scale pre-processing is performed within the local scale pre-processing unit, **LSP**, which invokes a set of nine pre-processing routines (the so-called **PAD** sub-routines) running in conjunction with the fast diagnostic local-scale and turbulence model **LINCOM**.

The local-scale model chain also handles the local scale dispersion, deposition and gamma radiation models, and it produces input to or "source-terms" for the long range model chain.

Local scale pre-processor, LSP

Figure 3.2.1(a-c) shows the Local Scale Pre-processing unit, **LSP**, interfacing on-line accessible meteorological information from met-towers and from NWP centres to the local scale dispersion models **ATSTEP** and **RIMPUFF** and to the long-range model chain with **MATCH**.

The **LSP** unit provides the necessary model input parameters for running both local and the long range dispersion models. The starting point is parsing and binning of the (at random) on-line incoming meteorological data, which automatically are checked for consistency and transferred to the **RODOS** real-time database (Ehrhardt et al. 1997). It holds separate partitions for both the On-line-Met-Tower Data Base **TOWERDB**, and the Real-Time Numerical Weather Forecast Data Base, **FCASTDB**.

Continuously running in background **LSP** accesses the real-time database (every 10 min) and processes all new meteorological data available, including new met-tower measurements and new forecast data, into gridded wind and scaling parameter fields on the local scale grid. They are continuously stored as time-stamped grid files in shared memory.

Pre-processor for atmospheric dispersion, PAD

Mikkelsen and Desiato (1) described nine subroutines known as **PAD,** which process primary meteorological observations into atmospheric stability measures and scaling parameters as required by the similarity theory-based flow and dispersion models of **MET-RODOS**. These subroutines have now become integral part of **LSP** for real-time operational use.

Initially, the following static input parameters must be available to the **LSP**: gridded (typically 500m x 500 m) values of land use or aero-dynamical surface roughness and terrain height.

At the beginning of each local-scale meteorological updating period - which is typically between 10 minutes and 1 hour for most meteorological tower station-based systems, the **PAD** subroutines then automatically start processing any newly arrived primary meteorological data from tower measurements or from NWP. The list of primary input data typically include: cloud cover (in octaves), net radiation, horizontal wind direction and (if possible) wind vane fluctuations horizontal,vertical, vertical temperature profile (minimum 2 points), and wind speed measurements (minimum at one (10 metres) height).

Depending on the set of available input data for a given 10 minute period, **LSP** from time to time automatically selects the subset of the most suitable **PAD** -subroutines, and processes the required atmospheric stability measures such as stability category, Monin-Obukhov stability length scale, mixing heights: (mechanical, convective), and also the turbulence scaling parameters, such as heat-flux, shear-stress and variances (horizontal, vertical), and also the mean profiles of wind and temperature.

Linearized wind model: LINCOM(-hill, -z0, and thermal)

Detailed modelling of the wind and turbulence field on the local scale is important for prediction of the trajectory-directions - and the time of arrival - of radioactive clouds traversing hilly terrain and heterogeneous surfaces (e.g., over land-water-land interfaces).

To determine the advection, diffusion and deposition rate of the radioactive clouds in real-time, local scale wind and turbulence fields are modelled within **LSP**. The integrated **LINCOM** model system provides the local model chain with a fast diagnostic flow model system, which is based on the solution of a set of linearised momentum and continuity equations, with a first order spectral turbulent diffusion closure. The wind and turbulence fields are modelled under influence of: the local topography (hills); the vertical thermal stratification of the atmosphere and the surface aero-dynamic roughness (z_0).

In the flow model **LINCOM**-hill, Troen and de Baas (2) developed the concept for neutral stratified, pressure-gradient driven winds over hilly terrain. Moreno et al. (3) extended the concept in order to include effects of thermally driven flows (such as valley breeze and nocturnal drainage flows in **LINCOM**-thermal. Astrup et al. (4) extended this wind modelling system to include the effects of local changes in the surface aerodynamic roughness (**LINCOM**-z_0). In addition to changes in the mean wind introduced by the inhomogeneities in the surface roughness, the "z_0" option models the local turbulence levels (i.e., the surface sheer-stress field (u_*)) over the local scale grid.

The **LINCOM** model suite has also been fully integrated in **LSP**. Together with **PAD, LSP** provides the local scale model system with "model-intelligent" interpolated/ extrapolated wind fields and turbulence fields at all grid points, and these gridded fields are subsequently available to **ATSTEP** and **RIMPUFF** to advect, deposit and diffuse the plumes and puffs.

Figure 3.2.2(a-c) shows LINCOM-z_0 generated mean and turbulence winds over Northern Zeeland (from Astrup et al. (5)).

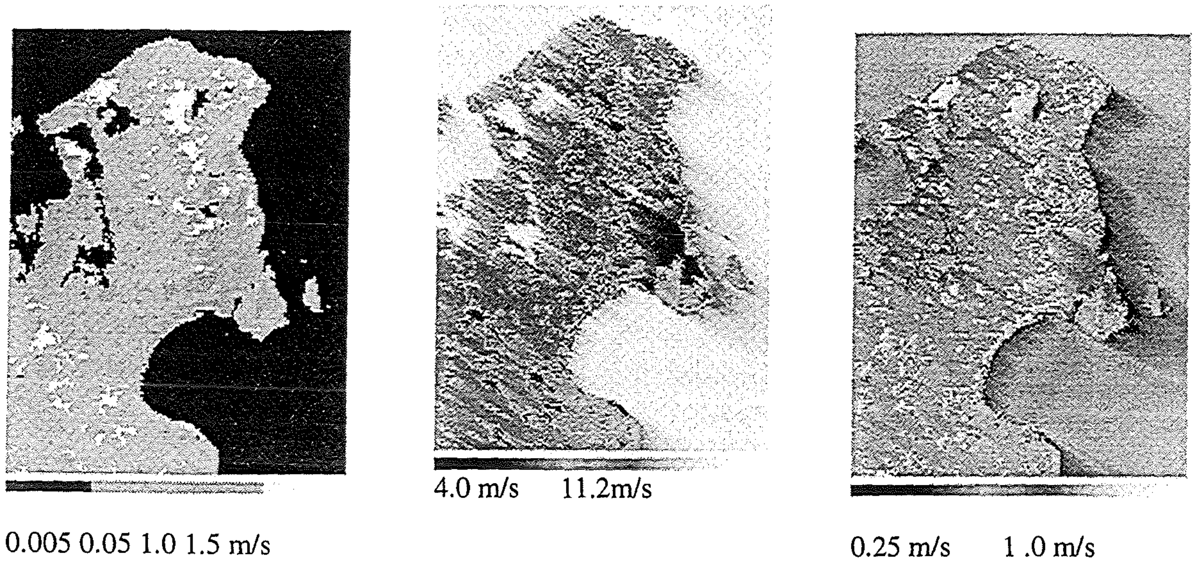


Figure 3.2.2: **Over Northern Zeeland - Denmark:**
(a) Roughness distribution (z_0) on a 1km x 1km grid; (b): LINCOM-Z_0 **mean wind field** (U);
(c) LINCOM-Z_0 **generated turbulence wind field** (u_*).

The mass consistent wind model MCF

A mass-consistent-flow model, MCF, has been integrated in the LSP module. MCF has complementary properties to the LINCOM system: while the Navier-Stokes-equation based LINCOM system must be initialised with data from a single point (e.g., from a met-tower or from a single node point in the forecast model), the mass consistent MCF code complies better with simultaneous inputs from a network of met-towers.

MCF generates mass-consistent interpolated wind fields over the entire local scale domain under the constraints of minimum flux divergence (6).

As with the LINCOM models, applications with MCF should focus on gentle rolling but not steep terrain. A user's guide for the LSP module is under preparation that will assists the user in selecting the most suitable wind model (LINCOM or MCF) for a given application, and depending on the available meteorology.

Diffusion, deposition, and gamma dose models

The local scale model chain integrates the puff dispersion model RIMPUFF and the segmented plume model ATSTEP. A separate (outside MET-RODOS) stand alone system for dealing with more severe complex terrain and sea-breeze circulation is under development DEMOKRITOS (see later). The long range model chain is established by nesting the outputs from the local scale model chain to the Eulerian long-range model MATCH.

The puff dispersion model RIMPUFF

RIMPUFF (7, 8, 9) is a fast operational puff diffusion code, developed for real-time simulation of atmospheric dispersion during accidents. It accounts for changes in meteorological conditions (in both time and space)while an accident evolves. The dispersion model is provided with a puff-splitting feature for modelling of dispersion over hilly terrain, which involves channelling, slope winds and inversion layer effects. A Gaussian puff-based gamma dose module has been added (10).

The diffusion parameterisation in **RIMPUFF** is formula-based and modular. The puff advection steps and diffusion growth rates are during each time step (typically 10 seconds) determined by the puffs' local wind and turbulence levels as provided by **LSP**.

RIMPUFF can accommodate almost any user-specified formula-based parameterisation scheme for its horizontal and the vertical dispersion parameters Φ_y and Φ_z. It has 6 optional sigma parameterization schemes included within the **RODOS** framework. They are, based on the so-called split horizontal and vertical Φ-method, combinations of:

Mode 1-2: Karlsruhe-Jülich height dependent Φ_y and Φ_z (1 hour averaged plume sigma's)

Mode 3-4: Risø instantaneous (no averaging) true puff-diffusion sigma's Φ_y and Φ_z.

Mode 5: Similarity-theory based plume-sigmas (Φ_y and Φ_z) - averaging time 10 minutes to 1 hour.

Mode 6: German-French-Commission (GFC) proposed horizontal Φ_y's, - for variable averaging-time ranging between zero (instantaneous puff) and 1 hour (plume sigma's).

RIMPUFF is equipped with standard (Briggs) plume rise formulae and has usual inversion-height and ground-level based reflection options.

A fast set of subroutines for the calculation of the ground-level gamma dose rates from both airborne and deposited radioactive isotopes have been added (10, 11).This feature plays an important role within **RODOS** for data assimilation and back-fitting procedures in conjunction with real-time radiological (gamma) monitoring data.

Deposited activity is also modelled with **RIMPUFF**. Dry deposition rates are treated differently for iodine vapour (elemental iodine) and iodine contaminated aerosols, and different deposition velocities can be specified depending on land use. Figure 3.2.3 shows a **RIMPUFF** calculated footprint of deposited activity from a Caesium-137 plume traversing Northern Zeeland. During the plume passage, the deposition rate is varied depending on the local surface characteristics (land, water, forest, urban , etc.).

For dry deposition of aerosols, the deposition velocity is, under certain conditions, limited by the atmospheric turbulence (12). An experimental version of **RIMPUFF** (13) will take the turbulence-limited deposition velocity into account. It will be based on calculation of the atmospheric resistance (U/u_*^2) as provided by the model chain **LINCOM-z_0** model. Implementation of this option in **MET-RODOS** has yet to be decided.

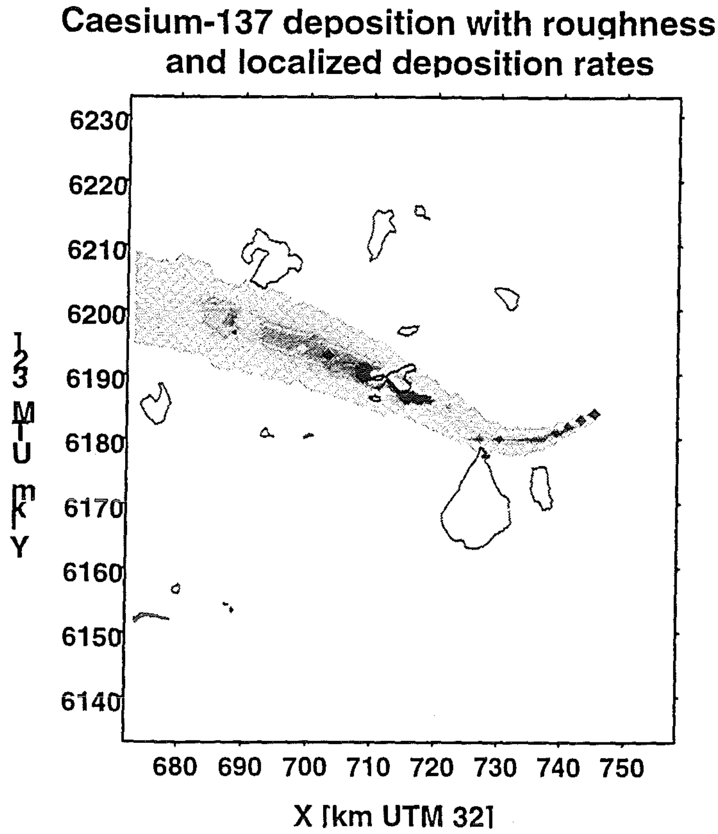


Figure 3.2.3: **Footprint of a depositing ^{137}Cs plume (from RIMPUFF) over Northern Zeeland. The deposition rates vary locally according to land use.**

The segmented plume dispersion model, ATSTEP

ATSTEP (14, 15) is a segmented Gaussian plume model with properties of a simplified puff model. It is capable of calculating the dispersion of a segmented plume during (steadily) changing meteorological conditions.

It was the first atmospheric dispersion model fully integrated with the **RODOS** system. Because of its simplicity, it is extensively used in connection with demonstration and training of the **RODOS** system. It is also used as a tool for generating hypothetical data sets to be used with expert elicitation on local scale radiological accidents, and as a benchmark reference for **RIMPUFF**.

Due to its relatively long advection time steps (10 to 30 minutes, as opposed to 10-30 seconds for **RIMPUFF**) - and to its correspondingly elongated plume-segments, **ATSTEP** requires much fewer computation loops compared to **RIMPUFF** for simulation of a given accident. Its shortcomings, however, compared to **RIMPUFF**, show in connection with inhomogeneous or non-stationary conditions, including terrain, where detailed wind and turbulence structures are required from a wind and turbulence model (e.g. LINCOM).

ATSTEP has a cloud gamma dose module that is simpler than that in **RIMPUFF**. **ATSTEP** calculates the gamma-dose rate as proportional to the local air concentrations by assuming submersion and by use of cloud-correction and dose-conversion factors; **RIMPUFF** uses a full cloud integration for each time step.

Tests have shown that the two dispersion models produce comparable results if the meteorology is “well-behaved” (i.e. quasi-stationary met-conditions and no hilly or heterogeneous terrain). This is because they both produce a meandering Gaussian plume in these conditions.

CPU requirements on a HP 700 Series workstation are about 300 seconds for both **ATSTEP** and **RIMPUFF** to produce a + 12 hour plume release with half hourly updates.

ATSTEP and **RIMPUFF** interface identically with "shared memory" in **RODOS**. They both provide ground-level air concentrations (in Bq/m^3) concentrations of wet and dry deposited isotopes (in Bq/m^2) and ground level gamma dose rates (in Gy/s) for display and subsequent use by other modules of the **RODOS** system.

The long range model chain, LRMC

The European-scale long-range dispersion model selected for system-integration with **MET-RODOS** is the operational **MATCH** code developed by the Swedish Meteorological and Hydrological Institute (SMHI). This particular code has previously demonstrated its potential with real-time back-fitting and data assimilation (16).

MATCH (17) is a 3-dimensional Eulerian atmospheric transport model. It is based on a terrain following vertical co-ordinate and a mass conservative, positive, definite advection scheme, with small phase and amplitude errors. The model has modules for nesting local scale outputs, vertical turbulent diffusion, and deposition processes. It has a submersion-based gamma dose module. It can handle an arbitrary number of radionuclides and their daughter products.

Automatically given its inputs on "source terms" by **RIMPUFF** on the border between the local and long range scale (20 km from the source), **MATCH** has been integrated and runs now in **RODOS** on meteorological **NWP** data downloaded from **DMI-HIRLAM** and stored in the Real-Time Numerical Weather Forecast Data Base **FCASTDB**. That seamless interface of an Eulerian long-range model with the outputs from **RIMPUFF** has been previously demonstrated by Brandt et al. (18).

MATCH is configured to work with a subset of the **DMI-HIRLAM** specific terrain following vertical layers. Vertical diffusion is for the convective case described from a determination of the turn-over-time for the boundary layer based on similarity theory, and for the neutral and stable case from ordinary eddy diffusivity K-theory. This requires intensive integration with **DMI-HIRLAM** model outputs, (cp, the description of downloaded NWP data in the next section).

MATCH is operational at SMHI where it is nested with the Swedish version of **DMI-HIRLAM**. It has recently been evaluated with data from the real-time large scale tracer experiment **ETEX** (see later).

Real-time interactive visualisation based on VIS 5D

Output from the model chains (ground level concentrations and dose rates) is available to the shared memory data bases of **RODOS** and can be displayed using the **RODOS** Graphics System.

However, in order to provide **MET-RODOS** users with full three-dimensional graphical access to the vast amount of weather information, including the local-scale and the long-range wind fields, turbulence fields and three-dimensional diffusion data available from the module, **MET-RODOS** has been interfaced to the interactive visualisation program **VIS5D**. This program gives **MET-RODOS** users access to a real-time display and animation feature based on available weather forecasts, winds and dispersion predictions.

VIS5D is a system for interactive visualisation of large 5-D gridded data sets such as those produced by **DMI-HIRLAM**. **VIS5D** provides instant images of vector plots, iso-surfaces, contour line slices, coloured slices, volume rendering, etc., of data in a 3-D grid and rotates and animates the image in real time. **VIS5D** is set up in **MET-RODOS** to visualise the **DMI-HIRLAM** provided medium and long-range meteorological forecast data downloaded in the real-time numerical weather prediction data base **FCASTDB**. It can be set up to run immediately after a new set of NWP forecast data have been downloaded and archived in the data base. **VIS5D** also features real-time display and animation of long-range trajectories (forward and backward).Trajectories associated with source point within the European Continent have, in this way, been made readily available in **MET-RODOS**. The **VIS5D** source code is public domain freeware, further information is available from the **VIS5D** Home Page at:(http://www.ssec.wisc.edu/~billh/vis5d.html).

3.2.2 The stand-alone complex terrain module

RODOS also allows external software to be used for the evaluation of dispersion of air pollutants. It is envisioned that **RODOS**, in its final (1999) version, will be able to include modules for very complex topography. NCSR "Demokritos" have engaged in flow and diffusion modelling over terrain more complex than the models directly integrated in **MET-RODOS** can handle. NCSR "Demokritos" are providing a stand-alone system based on the particle diffusion model system **ADREA/DIPCOT**. It is combined with a prognostic flow model. This is a full prognostic, primitive-equation based non-hydrostatic flow model that accounts for self-generating thermally induced circulation caused by differential heating, such as local sea-breezes, valley slope and drainage winds etc. The modelling system consists of:

- **Pre-processors:** **DELTA/GAIA** description of topography
- **DELTA/HELIOS** determination of illuminated/shaded ground surfaces.
- **FILMAKER** meteorological data.
- **Meteorology: ADREA-diag** diagnosis of meteorological fields
- **ADREA-I** prognosis of meteorological fields
- **Dispersion:** **DIPCOT-I** Lagrangian model
- **ADREA-d** Eulerian model

The models **DELTA/GAIA**, **FILMAKER** and **DIPCOT-I** have so far been integrated into **RODOS** Version 1.3. The model **DELTA/GAIA** has also been integrated into RODOS 2.1. The integration of **DELTA/GAIA** and **FILMAKER** in RODOS PV 3.0 is underway. The integration of all modules will be completed by the end of the RODOS Project.

3.2.3 The DMI-HIRLAM numerical weather prediction model and data transfer

The High Resolution Limited Area Model, **DMI-HIRLAM**, consists of a primitive-equation based NWP model, using a grid-point representation with second-order difference approximations for the spatial derivatives. The horizontal grid is a regular, spatially staggered, latitude/longitude grid (the Arakawa C grid) in a rotated spherical co-ordinate system. The vertical co-ordinate is a terrain-following hybrid co-ordinate, which near the surface is identical with the sigma co-ordinate ($\Phi = p/p_s$) and approaches the pressure, p, with increasing height (the surface pressure is denoted p_s). The **DMI-HIRLAM** project was initially started by the Nordic countries and the Netherlands (19, 20, 21). The project has since been joined by Ireland, and partly by France and Spain.

The **DMI-HIRLAM** model Sass (22) is operational at the Danish Meteorological Institute (DMI). It runs operationally around the clock on two different limited areas. The boundary fields for the large-area version (GRV) are obtained from the global model run by the European Centre for Medium-Range Weather Forecast (ECMWF). The small-area version (DKV) is nested in the GRV version which provides the boundary values. The horizontal resolution is 0.42 deg. (46 km) for GRV and 0.21 deg. (23 km) for DKV. The time steps are 4 and 3 minutes for GRV and DKV, respectively, and the forecast lengths are 48 and 36 hours, respectively. Both models output data each 3 hours. The GRV and DKV models have the same vertical resolution (31 hybrid levels). The models have nine model levels available for resolving a typical day-time boundary layer with a height of 1500 m. The **DMI-HIRLAM** forecasting system consists of pre-processing, analysis, initialisation, forecast, post--processing and verification. Both model versions are run with their own 6 hourly dataassimilation cycle.

Different versions of **DMI-HIRLAM** run operationally around the clock at several European meteorological services from where for example local wind, precipitation and stability forecasts are available for on-line transfer to **RODOS** via for example dedicated (private) fast point-to-point digital telephone networks (ISDN), or via existing computer networks (Internet).

On-line transfer of **DMI-HIRLAM** data have been tested in Denmark between DMI (Copenhagen) and Risø (Roskilde), and between Risø and the University of Leeds (UK) with the following dataset, cf. Table 3.2.2 and Table 3.2.3:

TABLE 3.2.2::ON-LINE TRANSFER OF **DMI-HIRLAM** DATA TO **MET-RODOS**	
European scale grid:=	(141 lat's x 136 long's) @ 13 (ground + 12 vertical layers).
Time frames:	13 (0,+3,+6,... 36 Hrs) @ ~ 9 Mbyte each (uncompressed).
Total amount to transfer:	13 time steps @ 9 MB ~117 Mbyte.
Compression:	reduction factor ~½: ~ 60 Mbyte.
On-line transfer time):=	point-to-point,Internet
Point-to point:	by standard ISDN telephone line @ 2x 64 Kbit/s: ~1 hour.
Internet:	via FTP: ~2-3 hours, depending on load.

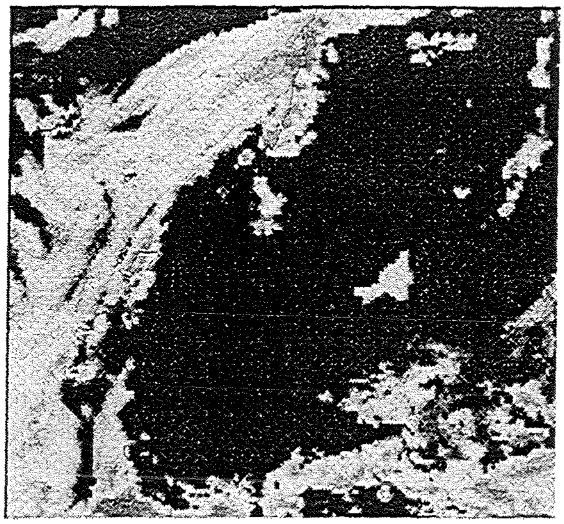
TABLE 3.2.3:DMI-HIRLAM DATA SETS TO **MET-RODOS** CONTAINS:	
ground level fields: =	precipitation intensity, boundary-layer height, latent plus sensible heat flux, momentum flux.
multi-level fields:=	geopotential heights,wind speeds,wind direction, virtual potential temperature.

Figure 3.2.4a shows **DMI-HIRLAM** predicted boundary layer heights over Europe on August 20 1996 at 1300 UTZ as it appears downloaded in **MET-RODOS** using **VIS5D** graphics.

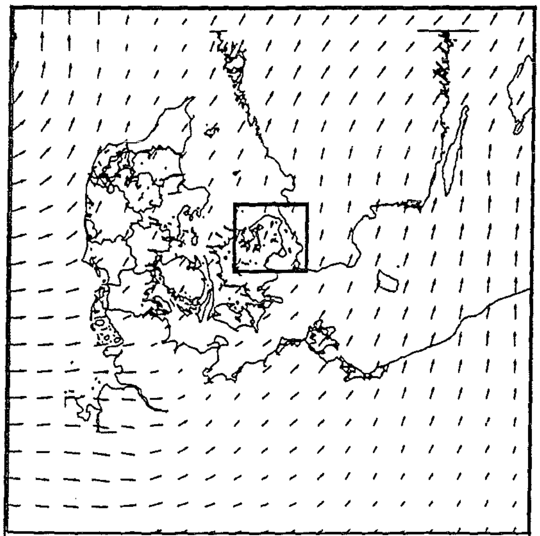
Figure 3.2.4b shows the corresponding predicted precipitation field over Europe at the same time.

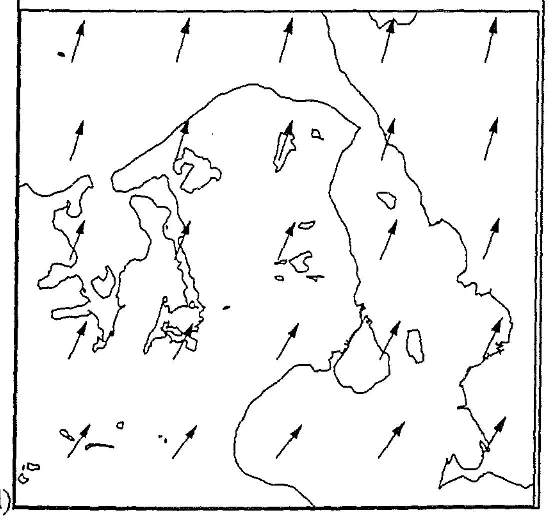
Fig.3.2.4c shows a sub-set (40 x 40 grid points or ~1000 km x 1000 km) of the 10 metre surface winds over "greater" Denmark at the same time. The inserted "black box" over Northern Zeeland and Copenhagen defines the other bounds of the local-scale nested grid shown in Figures 3.2.2 a-c.

(a)



(b)





(d)

Figure 3.2.4.

(a) DMI-HIRLAM predicted boundary layer heights over Europe on August 20. 1996 at 1300 UTZ as it appears in MET-RODOS using VIS5D graphics.

(b) DMI-HIRLAM precipitation field over Europe on August 20. 1996 at 1300 UTC.

(c) Sub-set (40 x 40 grid poins or ~1000 km x 1000 km) of surface (10 m) winds over Denmark on August 20. 1996 1300 UTC. The inserted "box" over Northern Zeeland defines the bounds of the local scale model chain nested grid in (d).

(d) DMI-HIRLAM vind vectors over the local scale grid (Northern Zeeland- Denmark).

3.2.4 Modes of operation

This section discusses the envisioned strategy for daily operation of the **MET-RODOS** system. For the local scale, transfer of new +36 hours forecast for a subset of a few NWP grid points (updated forecasts are available every +6 hours) is operationally feasible in less than a minute. For the long range (European scale), a new +36 hour forecast can be down-loaded to **MET-RODOS** in approximately 1 hour transmission time by use of a single-ended 64 Kbit point-to-point ISDN telephone line. This can be reduced to ~½ hour by use of a double-ended (2 x 64 Kbit/s) ISDN line.

It is envisaged that the local-scale atmospheric model chain can be operated "around the clock" in an emergency centre and automatically be updated with new meteorology from both tower networks and forecasts in the "status "normal".

Display windows of dispersion from potential local sources can, in this way, be visualised instantly (calculated on the basis of a "unit release"), so that the present "dispersion situation" is always at hand for **RODOS** operators and decision makers. This continuous "Normal" operation also ensures continuous exercising of the data transfer systems and some quality assurance of the meteorological measurements involved.

In case of a nuclear emergency or during exercises, the RODOS system is set to the status „Emergency" and started in its automatic mode by a remote signal or by the operator. In this automatic mode it provides in time cycles of 10 min real-time on-line diagnoses of the atmospheric dispersion and deposition of the released radioactive material. In addition, every 30 min a prognostic run is started for calculating the spatial contamination patterns to be expected within the time period covered by the forecast meteorological fields. The following cases can be distinguished:

- If the release has already started (within the last 24 hours), **lsmc** starts to run from the time of start of release based on the stored measured data, and will first generate a nowcast (i.e., a calculation for the time span from start of release till actual time). When the nowcast has been generated, **lsmc** will automatically continue (without restarting) with diagnostic and prognostic calculations based on available downloaded HIRLAM data (+48 hours).

- If the release starts "now", **lsmc** runs with on-line measured wind data in "the persistency time interval" of the order of 1-2 hours, then changes to forecast data. The optimal time period for use of local meteorological data depends on the result of a local survey of the predictability of the HIRLAM wind and direction data for the specific site in question (At Risø this time period is about 2 hours).

- If the release is predicted to come at some future time (less than 2 hours), **lsmc** starts with the on-line measured wind data from the expected release time, and changes to forecast data (without restarting) at the end of the persistency time period.

- If the release is predicted to come at some future time (more than 2 hours), **lsmc** starts directly with forecast meteorological data at the expected release time.

In parallel to the automatic mode, the user can start at any time an interactive prognostic calculation. An overview of the different time phases, modes of operation and distance ranges is given in Table 3.2.4.

accident phase	module	modes of operation				
		160 km X 160 km			larger distances	
		auto Diag	auto Prog	interact. Prog	auto Prog	interact. Prog
pre-release phase	cycle time	10 min	30 min		60 min	
	LSMC LRMC	X	X	X	 X	 X
release phase	cycle time	10 min	30 min		60 min	
	LSMC LRMC	X	X	X	 X	 X

Table 3.2.4: Time phases, modes of operation and modules

3.2.5 Model evaluation history

Codes and modules selected for the atmospheric model chain have all previously been evaluated experimentally during full- scale field tests, in addition they are now being quality assured, integrated and documented according to the specifications set out by the overall RODOS concept (23, 14).

Near-range models - evaluation

Non-homogeneous terrain (land-water-land):

RIMPUFF has previously been extensively evaluated with data from several non-homogeneous terrain experiments, e.g., the Øresund Experiments during 1982-1984 (7).

Hilly terrain:

A comprehensive field study "MADONA" (after: Meteorology And Diffusion Over Non-uniform Areas) was conducted over gently rolling hills near Porton Down in England in 1992. Several accident simulations were recorded at high temporal resolution and with high spatial details using remote lidar sensing techniques for comparison of data with modelled diffusion patterns. A computerised near-range atmospheric dispersion model training module has especially been developped for RODOS (24, 25). The MADONA data set is available on CD-ROM (26).

Mountainous terrain:

A series of 14 full-scale dispersion experiments were carried out during the 1990 Guardo trials in Northern Spain. They now form part of the experimental data base for evaluation of the near-range model chain over complex terrain. Actual wind and turbulence and smoke plume measurements (using lidar remote sensing) were recorded in real-time and used, as input data, for a series of simulations made with the combined local scale model chain, PAD-LINCOM-RIMPUFF (27).

Long-range models - evaluation

Two long-range "European Tracer EXperiments" (ETEX) were conducted in 1994 in continuation of the Atmospheric Transport Model Evaluation Study (ATMES). Sponsors were the EC, the World Meteorological Organisation (WMO) and the International Atomic Energy Agency (IAEA). ETEX was conducted to evaluate existing operational meteorological long-range models to forecast, in real time, air concentrations from a ground-based point source. A tracer gas cloud was monitored by 168 sampling stations as it dispersed over Europe over a four day period.

The MET-RODOS long-range transport model, MATCH, participated in the ETEX evaluation procedures (28), cf. Figure 3.2.5. Also the Danish Emergency Response Model of the Atmosphere (DERMA), (29), participated in these model evaluations based on DMI-HIRLAM data. In a preliminary model evaluation study based on measurements from 86 sampling stations during ETEX-1 this model obtained very high scores compared to most others. This is indicative of high performance of the DMI-HIRLAM long-range forecast system.

The performance of the complex terrain models (Demokritos) have been evaluated for selected situations by comparison of its predictions against well documented experimental campaigns. This is achieved through guidelines and statistical methods as those set out by J.S. Irwin (30). Furthermore, databases with experimental data sets are available as the Model Validation Kit (31, 32) which also includes recommended methods for model evaluation.

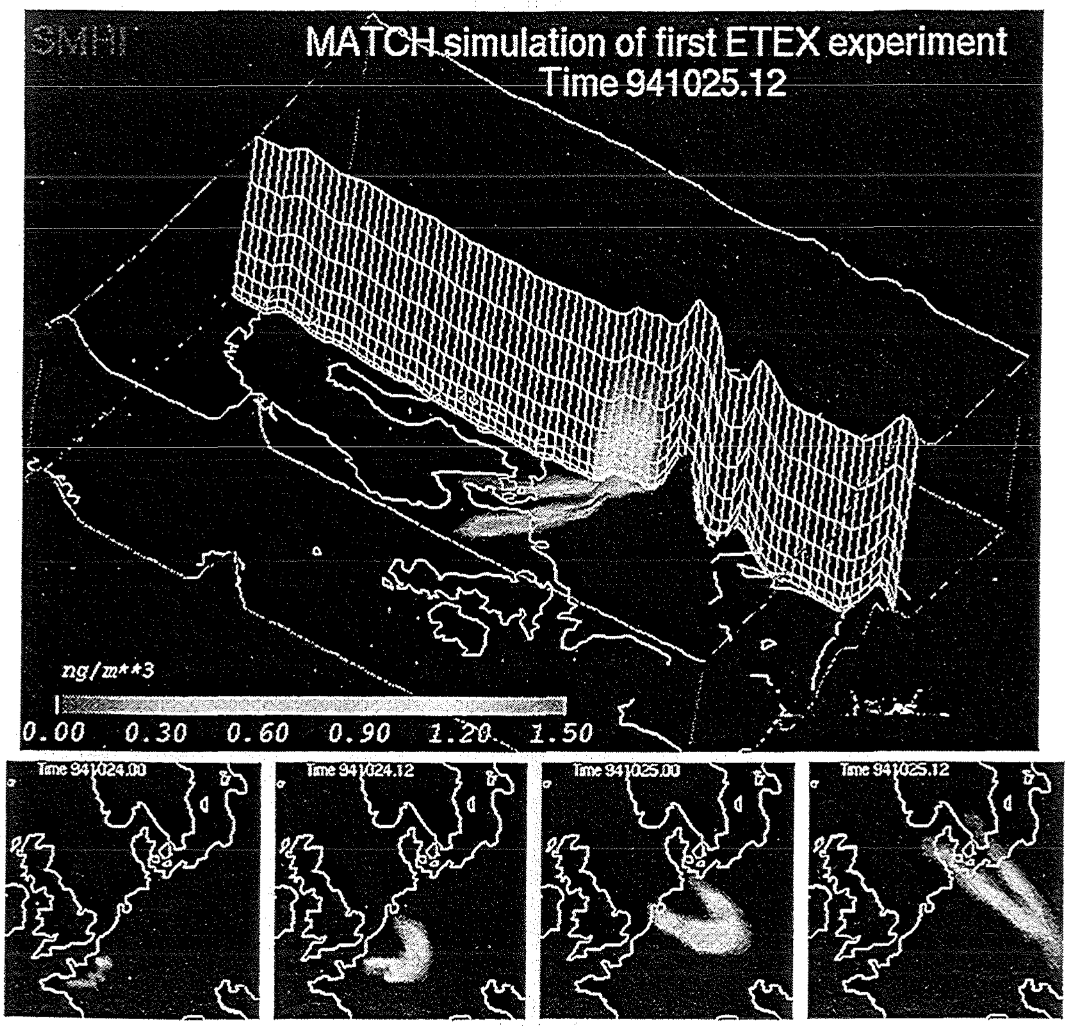


Figure 3.2.5: MATCH simulation of the ETEX-1 tracer cloud which shows both horizontal and vertical extend at 12 UTC on October 25 1994 [941025.12], corresponding to 44 hours after the start of release near Rennes in France. The ETEX cloud's vertical distribution is shown in a North-South

vertical cross-section, which also reveals the vertical grid of the MATCH model. Concentration are in [ng/m^3], see legend. The four smaller figures inserted below show the position of the cloud at four consecutive 12-hour intervals: [941024.00; 941024.12; 941025.00; and 941025.12]

Based on the above mentioned protocols and experimental data sets, the evaluation of the Demokritos models DELTA/GAIA, FILMAKER, ADREA and DIPCOT is in progress. The nuclear accident release exercise, INEX-2, concerns an hypothetical release of radioactive material from a nuclear power plant in Finland and it is performed as a joint venture between NCSR "Demokritos" and SMHI. The Demokritos Transport Code System covers the short-range dispersion (first 30 km), whereas SMHI performs dispersion calculation in the long range, see Figure 3.2.6.

Complex -terrain models - evaluation

A fast set of subroutines for the calculation of the ground-level gamma dose rates from both airborne and deposited radioactive isotopes have been added (10, 11).This feature plays an important role within **RODOS** for data assimilation and back-fitting procedures in conjunction with real-time radiological (gamma) monitoring data.

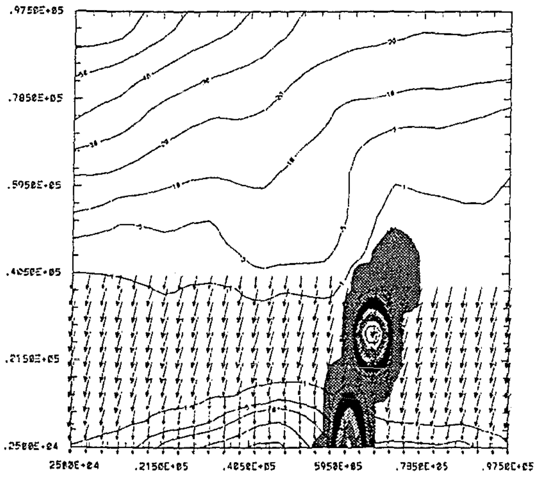


Figure 3.2.6. The nuclear accident release exercise INEX-2 modelled by combining the Greek complex terrain module with match. The Demokritos system calculates the short-range dispersion (first 30 km). **MATCH** then takes over and models the dispersion on the long-range (Europe).

Deposited activity is also modelled with RIMPUFF. Dry deposition rates are treated differently for iodine vapour (elemental iodine) and iodine contaminated aerosols, and different deposition velocities can be specified depending on land use. Figure 3.2.3 shows a RIMPUFF calculated footprint of deposited activity from a Caesium-137 plume traversing Northern Zeeland. During the plume passage, the deposition rate is varied depending on the local surface characteristics (land, water, forest, urban , etc.).

For dry deposition of aerosols, the deposition velocity is, under certain conditions, limited by the atmospheric turbulence (12). An experimental version of RIMPUFF (13) will take the turbulence-limited deposition velocity into account. It will be based on calculation of the atmospheric resistance (U/u_*^2) as provided by the model chain LINCOM-z_0 model. Implementation of this option in MET-RODOS has yet to be decided.

From the above mentioned exercises it has been concluded that the major dispersion features of the released tracers are more or less reproduced by the models, even in cases of highly complex topography. The concentration levels are predicted rather well, indicating a reasonable estimation of the wind direction and turbulent diffusion.

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3.3 Countermeasures and consequences

An important task of RODOS is to predict the radiation exposure of the population during and after an accidental release of radionuclides to the environment as well as the evaluation of potential countermeasures. The transfer of radionuclides from the plume to terrestrial foods , as well as the resulting radiation exposure, are modelled in the Deposition Module, the Food Chain Modules, and the Dose Modules. Besides the main Terrestrial Food Chain Module, which considers the direct transfer of radionuclides from atmosphere onto agricultural crops, additional modules have been developed for those pathways which require special modelling approaches (see Figure 3.3.1). The estimation of doses, via all exposure pathways which might be of importance during and after the passage of the radioactive plume, is performed in the subsequent Dose Modules; the endpoints are the collective and individual doses for all pathways and people of different ages.

Input to the Deposition Module is from the Atmospheric Dispersion Modules (ADM), and mainly comprises activity concentrations in the air and wet-deposited activity. The results of the deposition calculation, deposited activity onto plants and soil, are input to the Terrestrial Food Chain and Dose Module, FDMT. Special modules are under development for semi-natural (forest) pathways, FDMF, and for the transfer of tritium through foodchains, FDMH. The deposition pattern within the considered region is also input to the hydrological chain in which the transfer of radionuclides through aquatic systems is modelled. The resulting contamination of water and fish is input to the Aquatic Food Chain and Dose Module, FDMA, which simulates the transfer of radionuclides from contaminated water and fish to man and the resulting radiation exposure. A dose combination module is under development which combines results from all four food chain and dose modules. The results of all food chain and dose modules are transferred to the RODOS graphical system for presentation to the user as maps, time dependency plots, frequency distributions, etc. Foodstuff contamination and doses are also transferred to the Countermeasure Subsystem CSY as a basis for the evaluation of areas where countermeasures are recommended.

Early emergency countermeasures are typically limited to areas within a few tens of kilometres of the nuclear power plant, and to times ranging from a few hours before the start of a release to several hours after the passage of the radioactive cloud. For a given situation, the area with emergency actions may be defined by dose intervention levels and/or emergency zones. To determine if there is a need for early countermeasures to be implemented and to provide information on the impact of these measures is the role of the early countermeasure module, ECM:EMERSIM.

In the longer term, which can extend from a few days out to several tens of years or more, the countermeasures of interest for the terrestrial environment are: decontamination, restricted access measures (for example relocation of the population), and the implementation of agricultural countermeasures. Countermeasures that could be implemented in the aquatic environment are also being considered. LCMT:FRODO (Late Countermeasures Module: Food, Relocation and decontamination Options) has been developed for longer term terrestrial countermeasures and a prototype module for simple aquatic countermeasures, LCMA:FRODO (Late Countermeasures Module: Aquatic) will be implemented into RODOS by the middle of 1998.

Customisation of the FDM and the LCM to countries where RODOS might be installed in future has started. To this purpose, so-called radioecological regions are being defined, i.e. regions with relatively uniform radioecological conditions for which the same set of model parameters can be used. Data is being collected for the model parameters appropriate to each radioecological region to enhance or replace the default data within the RODOS database for FDM and LCM.

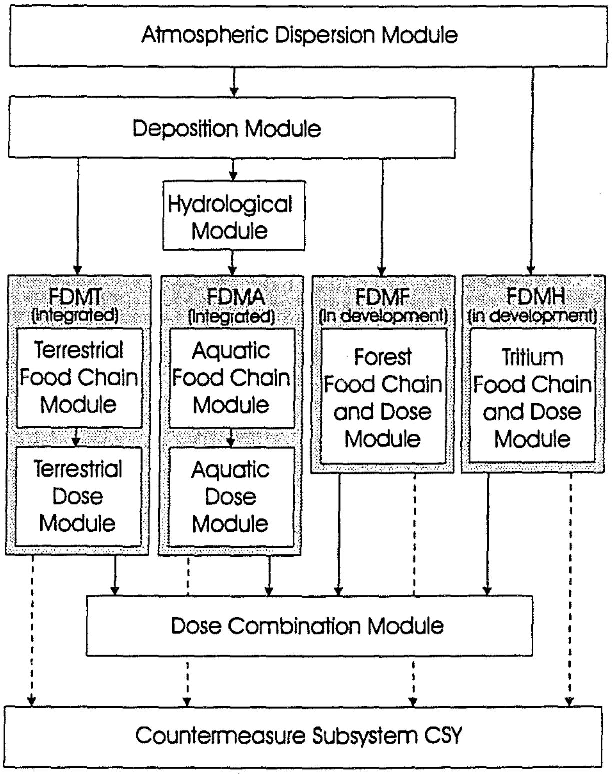

Figure 3.3.1: Structure and data flow of the Food Chain and Dose Modules in RODOS

3.3.1 Food chain modelling

FDMT and FDMA are based on the dynamic radioecological model ECOSYS-87 (2). The assessment of the activity in foodstuffs is performed in several steps:

(1) Calculation of activity deposition on soil and different species of agricultural plants: dry and wet contamination are considered separately. Wet deposition is calculated from the total wet deposition and an interception parameter describing that the fraction of activity retained on the plants depends on the amount of rainfall and on the seasonal stage of development of the plant canopy. Dry deposition on plants is calculated using a deposition velocity, which depends on the nuclide considered, the plant type, and also on the stage of the plant development. An irrigation module has been developed to simulate the activity deposition onto crops by using contaminated irrigation water.

(2) Calculation of the time-dependent activity in the edible parts of plants: contamination of plants results from foliar and root uptake of radionuclides and - in case of partly eaten plants like potatoes and cereals - from translocation of nuclides from the leaves to the edible part of the plant. Calculation of contamination from foliar uptake considers resuspension and activity loss due to growth dilution, weathering effects and physical decay. The estimation of root uptake is based on soil-plant transfer factors and takes into account the reduction of radionuclides available through migration of nuclides in deeper layers, fixation to the soil and physical decay.

(3) Contamination of animal products: activity intake by animals is considered by season-dependent feeding practices, with up to five different feedstuffs per animal. Plants or products processed from plants or animal products can be considered as feedstuffs. Activity transfer from feedstuffs into animal products is estimated by using transfer factors and biological half-lives. Radionuclide intake through soil ingestion is included by applying an additional soil-plant transfer factor.

(4) Contamination of feedstuffs and foodstuffs: time- dependent activities in feedstuffs and foodstuffs are calculated by considering activity enrichment or dilution during processing and culinary preparation. Furthermore, physical decay during processing and storage times is taken into account. The contamination of feed- and food-stuffs through aquatic pathways is considered by including contamination of animal feeding water, drinking water and fish.

The dynamics of the agricultural food chain transfer processes (e.g., seasonality in plant growing) lead to a very pronounced seasonal dependency of the radiological consequences. For example, the same concentration of Cs-137 in air can lead to a variation of the ingestion dose of two orders of magnitude, depending on the date of deposition.

Transfer processes in semi-natural ecosystems, like forests, need special emphasis and therefore an extra Forest Food Chain and Dose Module is under development for RODOS. Mushrooms, berries and game are considered in this module, FDMF. The model distinguishes between different species of forest products and also considers time dependent transfer rates between the individual compartments of the forest ecosystem. Forest products can contribute significantly to radiation exposure, in particular in the long term in regions where consumption of forest products is high. This is because

- forests are very effective interceptors of radioactive aerosols,
- caesium and strontium show a high mobility in forest ecosystems, e.g. translocation within plants is high, and
- migration in forest soils is generally very slow, because the litter and the organic layers of soil heavily bind caesium, but also make them available to plants and trees, owing to the fact that numerous microbial activities transform forest soils.

This persistence of contamination in forest ecosystems is amplified by the fact that very few possibilities exist to use efficient countermeasures or rehabilitation techniques.

The behaviour tritium, differs from all others considered in RODOS. Tritium, once deposited, exchanges very fast with all other compartments of the ecosystem as it behaves like water. In addition, the metabolic processes inside the plant - fixation of tritium in the edible parts - depend strongly on the presence of light. Therefore, the consideration of the diurnal cycle, in particular daytime and night time, must be included in a tritium module. After reviewing the key processes and main uncertainties involved in the present tritium modelling, the module FDMH has been outlined as follows:

- a submodule which reads site specific information and meteorological data,
- a submodule which assesses, for each plant type, the present stage of development of the canopy,
- a submodule which calculates the concentration of tritiated water (HTO) and organically bound tritium (OBT) in plants and soil at the time of the accident,

- a submodule which calculates the concentration of HTO and OBT in plant and soil according to the meteorological forecast for the next three days, and

a submodule which assesses the long term (one year) behaviour of HTO and OBT in the environment.

3.3.2 Dose estimation

All exposure pathways which might be of importance during and after the passage of the radioactive plume, are considered in the RODOS Dose Modules:

(1) external exposure from radionuclides in the plume,

(2) external exposure from radionuclides deposited on the ground,

(3) external exposure from radionuclides on the skin and clothes of people,

(4) internal exposure due to the inhalation of radionuclides,

(5) internal exposure due to the inhalation of radionuclides from resuspended soil particles, and

(6) internal exposure due to ingestion of contaminated foodstuffs.

The first four pathways are relevant in the early phase, i.e., during the passage of the plume, while in the long-term only (2), (5) and (6) contribute to the exposure of people.

In RODOS two types of individual doses are calculated:

- Potential doses which give an upper limit of individual doses.

- Expected doses which give a best estimate of the average exposure.

The assessment of external exposure from radionuclides in the plume is based - for large distances from the source - on the time-integrated activity concentration in air, assuming a semi-infinite homogeneous cloud. For locations in the vicinity of the emission source, a three-dimensional integration over the contribution of all parts of the plume is performed in the atmospheric dispersion module of RODOS; the resulting kerma in air is passed to the Dose Module, which estimates the organ doses and/or effective dose from it.

The external exposure from nuclides deposited on ground and other surfaces of the human environment is calculated on the basis of the total deposited activity onto a standard surface (lawn). Correction factors considering different shielding and deposition patterns (especially in urban areas) are used for calculation of expected doses. For both external exposure pathways (cloud and ground) age dependent dose conversion factors are used, based on Monte Carlo calculations using human phantoms. The major problem in estimating expected doses comes from large variations of the reduction effects due to staying in different environments outside and inside houses and to habits of people. It is not possible to consider all actual conditions in the dose estimation. The estimated doses can, Therefore, only be average doses for an average population. For all external exposure pathways, potential doses are estimated by assuming that people stay outdoors over a lawn all the time, i.e., no shielding or filtering effects by buildings are assumed. As an additional pathway of external exposure, irradiation from radionuclides deposited onto the skin and clothes is considered in a simplified approach. External exposure from forests is modelled separately by considering the individual contributions from canopy and soil.

Inhalation doses are estimated from the concentration of activity in air by using age-dependent inhalation rates and dose factors. Long term inhalation of resuspended material is considered, but the database for the applied model is relatively poor. Potential inhalation doses assume that people stay outdoors, while expected doses consider lower concentrations of activity inside buildings and the average fractions of time when people stay in- and outdoors.

Ingestion doses are calculated from the time-dependent concentrations of activity in foodstuffs, by applying age- and season-dependent consumption rates and age-dependent dose conversion factors. A special problem with ingestion doses is that many foodstuffs are produced at a location different from that where they are consumed. Realistic consideration of food transport is hardly possible, especially in the case of an emergency, which may involve unpredictable changes of the transport pattern. In addition, spontaneous changes of peoples' consumption rates can easily occur. Therefore, only potential ingestion doses (i.e., assuming full local production of all foodstuffs and long-term-average consumption rates) are calculated in RODOS.

In RODOS collective doses are also estimated in order to quantify the effectiveness of different possible countermeasures for mitigating the radiological consequences. The collective dose of a certain population is commonly considered as the sum of individual doses of all people belonging to the population. For large populations it is not possible to take this definition as a basis for calculating the collective dose, since it is not possible to consider the living conditions of all individuals for estimating their individual doses. Within RODOS, especially the relative changes of the collective doses due to application of countermeasures are of concern. This justifies the application of an approximating method for estimation of the collective doses: the individual doses for average adults are multiplied with the total number of inhabitants living in a certain area.

In the case of ingestion doses, the summing up of individual doses is complicated by the fact that foodstuffs are normally not totally produced in the area where they are consumed (or vice versa). For a reliable estimate of the collective ingestion dose for a population, it would be necessary to know where all the foods have been produced and what the level of their contamination is. This knowledge is not available, in general. Therefore, another approach to calculating the collective ingestion dose is applied in RODOS: the collective dose is assumed to be that which would result from consumption of all foodstuffs produced in a certain area, irrespective of where and if they are actually consumed.

3.3.3 Early countermeasures

The module ECM:EMERSIM determines the areas with early emergency actions, simulates these actions and calculates the individual doses with and without countermeasures. Different spatial and temporal patterns of countermeasure combinations can be chosen and evaluated. In addition, doses from the exposure pathways inhalation of the plume, external gamma irradiation from the plume, external gamma irradiation from the material deposited onto the ground and the external gamma irradiation from radionuclides on the skin and clothes of people can be calculated.

The reduction in external gamma dose during sheltering is based on location factors describing the protection offered by buildings whilst staying indoors. For evacuation it is assumed that, before and during evacuation, people receive the dose appropriate for the location at which they live. After the completion of the evacuation it is assumed that no further dose is received. The principal endpoints evaluated by ECM:EMERSIM are doses received from each exposure pathway and the sum of these doses as a function of time and spatial grid point.

The module can be run in two modes. In the first, there is no user input into the definition of the action scenario and default dose intervention levels are used for evaluating the implementation of emergency actions such as sheltering, evacuation and distribution of iodine tablets. In the calculated intervention areas, the three emergency actions are considered separately. In the second mode, the areas can be defined indirectly using dose intervention levels chosen by the user or directly by graphical input of areas that the user wishes to consider.

To improve the modelling of evacuation, the module ECM:EVSIM is under development to estimate the time evolution of the spatial distribution of the population during the early countermeasure phase. The model takes into account traffic flow, speed and density in order to estimate temporal changes in population distribution within the area being considered. It also contains an analysing module that evaluates the efficiency of the simulated evacuation. This module will be extended by the capability to take into account the time dependency of the changing dose fields when selecting the appropriate evacuation route. However, the whole module is implemented as a stand alone tool.

3.3.4 Late countermeasures

LCM:FRODO links closely with other modules of RODOS, particularly the Foodchain and Dose Modules (FDM) which provide input on activity concentrations in air, foods and animal feedstuffs and deposition rates as a function of location, nuclide and time, and models to calculate doses from the relevant exposure pathways without countermeasures (3, 4). In addition, LCM requires information on the countermeasures criteria to be considered and databases on the effectiveness of countermeasures in reducing doses and activity concentrations in foods; a database of default values have been provided for use with LCM.

Terrestrial countermeasures

The general approach to the modelling of countermeasures within LCMT:FRODO is illustrated below.

Prediction of need for intervention: extent and duration

↓

Prediction of effectiveness of decontamination and agricultural countermeasures: days - years

↓ ↓

Real-time identification of countermeasures that may be effective in short - medium term (< 1 year)

↓

Dismissal of options not worth further investigation

Identification of countermeasures that may be effective in long term and worth further investigation

The initial aim of the module is to determine if there is a need for intervention, i.e., whether, on the basis of user-supplied criteria, there is a need for the implementation of relocation or food restrictions. If intervention is indicated, the objective is to provide the information that underpins an assessment of possible courses of action to determine if intervention can be avoided or, if this can not be achieved, whether its duration and extent can be reduced. The interaction between countermeasures can be considered to varying extents. For example, the effect of decontamination on the extent and duration of relocation and the need for and duration of food restrictions can be considered. LCM is being extended to look at a wide range of combinations of agricultural countermeasures so that strategies of countermeasures for individual foods can be evaluated within RODOS. The implications of relocation on the further use of agricultural land in the relocated area are also being addressed.

LCM:FRODO provides information to allow early screening of possible strategies, identifying those which may be effective in the short term and those which may be effective in the long term, and therefore worthy of further investigation. This screening process also allows the dismissal of options which are clearly not worthy of further investigation. Early screening is a valuable part of any decision support system, in that it allows the more detailed consideration of options to be focused on those most likely to be of benefit. In the long term, LCM would contribute to the development of practical, site-specific advice on countermeasure strategies alongside measurement programmes and experimental research.

The principal endpoints evaluated within LCMT:FRODO include, for each countermeasure, the extent (area, quantities of food, population numbers) and duration of restrictions, doses received and saved and additional data required for evaluating the costs of countermeasure implementation. A selection of key results are transferred to the RODOS graphical system for presentation to the user in the form of maps, plots of information as a function of time etc. For agricultural countermeasures, a mode of running LCM called the 'decision mode' has been defined to provide information on a number of countermeasure options and combinations of these options for a single food to the Evaluating subsystem (ESY) of RODOS, to enable countermeasure strategies to be evaluated using a wide range of information including effectiveness, costs, health effects and feasibility considerations.

Modelling of Relocation

Within LCMT, endpoints related to the imposition of relocation in the presence or absence of land decontamination are modelled. Two types of relocation are considered, temporary and permanent, where permanent relocation is the removal of people from an area with no expectation of their return; however, the land may be released at a later stage and resettled by different individuals. Temporary relocation is the removal of people from an area for an extended but limited period of time. The model uses criteria for the imposition and relaxation of relocation, defined in terms of dose or ground contamination levels.

Modelling of Decontamination

Decontamination is considered as a means to prevent or reduce the extent of relocation, and as a countermeasure in its own right, both to reduce doses due to external exposure from deposited material and to reduce ingestion doses. The impact of decontamination is modelled using a dose reduction factor for a given decontamination technique; this factor is used to modify all doses following decontamination. The impact of decontamination on relocation can be evaluated for decontamination occurring either before or after relocation is implemented. The capability of the module to look at decontamination strategies, particularly with regard to the effectiveness of different techniques over a range of timescales, is under development along with the required databases of information.

The effect of the decontamination of agricultural land on the need for, or reduction in, food restrictions is evaluated. Decontamination of agricultural land by ploughing and soil removal is considered and the effectiveness of the two techniques is assessed in terms of the reduction in activity concentrations found in food following decontamination. A robust approach is taken, such that a single reduction factor is used for all crops.

Modelling of Agricultural Countermeasures

Within LCMT, endpoints related to the imposition of countermeasures on food are evaluated. The criteria for banning the consumption of food are defined in terms of activity concentrations in foods, which the user of the system can change. The predicted activity concentrations in foods are compared with the criteria as a function of time, nuclide and spatial grid point, to determine whether a restriction is required. If a restriction is not required for a food, then no further measures are considered. If restrictions are required, a number of countermeasure options are considered for each food. If, following the implementation of a countermeasure option restrictions are still required, the user of the system will be informed of this requirement, together with the length of the restriction that would be required before activity concentrations fell to below the chosen criteria.

The countermeasures considered are:

- The banning of foods linked with food disposal or the stopping of food production.

- Food processing and the storage of food.

- Changes in the dietary composition of grazing animals. Factors that can be evaluated include the effect of administering clean feed for a chosen period at various times following deposition, changes in the proportion of contaminated feedstuffs in the diet and use of different feedstuffs.

- Administration of sorbents or boli.

- Soil treatments such as the addition of fertilisers.

- Change of the crop variety or crop species grown.

- Change in land use from agriculture to forestry.

Factors such as the timing of the implementation of an option or the duration of a given husbandry or farming practice can be changed by the user so that a range of possible scenarios can be considered.

Databases

A default database has been compiled for use in RODOS on a scale appropriate for providing advice to persons who make broad, policy decisions. This contains robust, representative data that can be applied generally to relatively large areas. To achieve this, cautious values have been chosen, where necessary, so that the radiological impact would not be significantly underestimated. The database is regularly under review to utilise the most recent, relevant data and to provide the necessary information for the extended capability of LCM, e.g. a more coherent capability for decontamination and the consideration of combinations of agricultural countermeasures, particularly soil treatments for different crops and soil types. The user has full access to the database to put in any more relevant data for the situation under consideration.

Robust dose reduction factors for decontamination in urban areas have been determined using an urban dose model. The effectiveness of a limited number of feasible decontamination techniques has been considered and the information in the database assumes an optimum implementation time that is consistent with the data chosen for the evaluation of the dose reduction.

A database on the effectiveness of the decontamination of agricultural land and other agricultural countermeasures in reducing activity concentrations in crops has been compiled from a review of available data, primarily from the Ukraine, Russia and Belarus following the Chernobyl accident, and the use of a dynamic foodchain model.

Not all of the measures implemented in the Former Soviet Union (FSU) will be effective in Western Europe and care is needed in the use of this database for wide application outside the FSU. Work is in progress to provide advice on data applicability and also data requirements for using RODOS on different spatial scales for all areas of LCMT.

Aquatic Countermeasures

The general approach taken for aquatic countermeasures in LCMA and the endpoints calculated are broadly the same to those for terrestrial countermeasures. The prototype module determines whether there is a need to implement restrictions on fish and drinking water at the source of their production. Simple countermeasures that can be applied to fish after they have been caught are considered, such as processing. More complex countermeasures that can be applied to the aquatic environment are being considered in close collaboration with the developers of the hydrological model chain.

3.3.5 Customisation of FDM and LCM

Significant resources have been used to adapt the food chain module to the various radioecological (e.g. climatological, agricultural etc.) conditions found within the different parts of Europe. This is required to make the food chain modules flexible enough to consider the animal feeds and human foodstuffs of importance in the countries in which RODOS will be implemented. The selection of such radioecological regions, with relatively uniform radioecological conditions, is predominantly determined by prevailing agricultural production regimes, growing periods of plants, harvesting times, feeding regimes for domestic animals, human consumption habits, etc.. Typically, a country is subdivided into 1 to 5 such radioecological regions. It is unlikely that finer subdivisions can be justified since the year-to-year variations, which are unpredictable, would be higher than the variations between such fine regions. Radioecological regions have been defined for Czech Republic Hungary, Poland, Romania, one part of Russia, Slovak Republic, and Ukraine.

Only a small number of animal feeds and foodstuffs which are produced nearly all over Europe are considered in all regions; this allows a comparison of the contamination of these standard products within the whole area under due consideration to be made. In addition, for each radioecological region the animal feeds and foodstuffs, which are important for the nutrition of the average population or individual groups, can be defined in the model. For this purpose, several plant models are available in the food chain module which can be adjusted by appropriate choice of model parameters to the conditions of individual crops. Similarly, region specific animal products can be defined by adapting the parameters of the model describing the transfer of radionuclides from fodder to animal products.

Default data are available for Central European conditions; they comprise 22 animal feeds (17 based on plants, 4 based on animal products and feeding water) and 35 foodstuffs (17 plant products, 17 animal products and drinking water). The relatively large number of products is due to the need to reflect properly the diversification of plant species in reality. Furthermore, some foodstuffs with small average consumption rates have to be included to cover the possibly high importance to critical groups, e.g., sheep or goat's milk.

Data collection on the use and effectiveness of countermeasures started in the middle of 1997 primarily in Central and Eastern Europe, but also in some EU countries. This will provide the possibility to extend the present data base for some agricultural countermeasures and to allow the application of LCM:FRODO over larger areas of Europe.

3.3.6 Modular structure

The design and development of an appropriate modular structure was one of the main tasks in the reporting period. The foodchain and countermeasure modules have been developed to be able to react in a very flexible way to the demands of the system: they can be applied in the automatic mode of RODOS where they produce a number of default results, as well as in the interactive mode where it is possible to specify very specific questions. For the latter purpose, input windows have been developed and will be further improved to enable the user to specify the calculation he wants to perform, e.g. which type of results he wants to get, which action is carried out and which intervention level is applied.

The modules of the RODOS system are being developed by a relatively large number of different institutes. In several cases there are equal or similar tasks to be fulfilled within different modules. There is, therefore, a need for consistency among the calculations within different modules. In order to fulfil this need, two actions have been taken:

- Libraries of subroutines have been created which are used within modules of different developers. This ensures the application of consistent methodologies within the system.

- A common data base has been created to avoid the existence of duplicated data sets.

3.3.7 References

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3.4 Hydrological modelling

3.4.1 Introduction

This report summarises the results of the joint efforts to implement a hydrological module within the RODOS decision-support system. This work was carried out under three different contracts within the fourth Framework Programme of DGXII in 1996 and1997. Generally, standard hydrological model sets have been developed within the third Framework Programme. The emphasis in this project period is on the extension of the hydrological model set to cover all possible temporal and spatial scales varying from the near-field short-term to the long-term far-field dispersion of radionuclides in aquatic systems. Together with SPA Typhoon (Russia) and IMMS CC (Ukraine), to whom some of the "RODOS-B" contract had been subcontracted, KEMA (the Netherlands) started work in 1996. At the outset, the most important task was the implementation of the hydrological module within the different prototypes of the RODOS system.

In 1997, customisation of the hydrological models was started: in Belarus, (at IPEP in Minsk), in Finland (at VTT and STUK), and in Slovakia (at NPPRI, "Vujett"). When the RODOS system is delivered to an emergency centre, the standard set of hydrological modules is provided, together with some specimen scenarios . Customisation and data collection is, however, required to adapt the hydrological models to the specific local circumstances. During the process of customisation, it became obvious that the implementation of this set of hydrological models for use in emergency circumstances required tools for the definition of lake , river ,and catchment properties, as well as selection filters to deal with large numbers of lakes, such as one finds in Finland. Some of these tools (catchment definitions) have been added to the RODOS system to support future customisation activities; other tools are under development (river and lake tools).

For special applications, a number of hydrological models are under development. A 2D groundwater model is being developed to describe the transfer of nuclides (especially with low adsorption capacity) from the soil to groundwater in the vicinity of a reactor site. A 2D lateral averaged river model is also being developed to predict the behaviour of fine suspended particles after the construction of dams to prevent further dispersion of nuclides.

At present, new models are being added to the current set of hydrological models. These models are meant for special applications involving near-range radionuclide dispersion. If the RODOS user wishes, he can apply these models for coastal areas, estuaries and deep lakes. The application of these models is of importance when it is necessary to identify contaminated areas so that countermeasures can be taken, or when the concentration differences in large aquatic systems are of importance with respect to, for example, drinking water production, or when knowledge of the radionuclide concentration near the water inlet of a water plant is of importance, as opposed to the mean lake water concentration.

In the RODOS system, the hydrological module has been integrated with its own interface, because of the large number of different hydrological models This interface enables the user to control the different hydrological models in the RODOS system. The suite consists of models with various spatial and temporal releases to govern the transfer of radionuclides in the different phases after an accidental release. The set of aquatic dispersion models developed in the period 1992-1996 was modified and implemented in the RODOS system in 1997, and is thus included in the subsequent releases, namely 2.2 (released in January 1997), 3.0 (released in August 1997), and 3.1 (to be released in January 1998). This set of linked aquatic models covers the transfer of radionuclides via processes such as run-off (RETRACE models), as well as in rivers (RIVTOX) and lakes (COASTOX and LAKECO). These models are described in detail elsewhere (Zheleznyak et al, 1996). To deal with the various scales and various aquatic systems, the hydrological models can be incorporated in the suite in accordance with the requirements of the RODOS system user . For direct releasesthe 2D model COASTOX, for example describes the near-site dispersion of radionuclides in the river, while the adjacent downstream transport of radionuclides is described by the 1D model RIVTOX. If necessary, the models can also be connected the other way around to model a plume of radionuclides flowing into a reservoir. In the earlier phase, before the integration of the hydrological module with its dedicated interface, a special dose model named H-DOSE was included in the suite. In the present release, the hydrological module is linked to the dose and food chain modules already present in the RODOS system. Using the dose and food chain modules, the doses via irrigation, drinking water consumption and fishery produce are calculated. The hydrological interface is user-friendly and has a high functionality: clear presentation of the calculated radionuclide levels by means of colourful 1D and 2D patterns gives an immediate impression of the real-time situation in the aquatic environment after an accidental release.

Table 3.4.1. The models of the hydrological module and their application in the current RODOS release 3.0.1

RODOS accident phase	Model applied	Customisation	Status in RODOS system development
Deposition in the catchment. Short term transfer	RETRACE-1 Runoff RIVTOX 1D River LAKECO Lake COASTOX 2D Reservoir	River Rhine catchment	Validated + Integrated
Direct release into water. Short term transfer	COASTOX 2D River COASTOX 2D Reservoir RIVTOX 1D River LAKECO Lake	River Rhine River Dniepr Vah/Dudvah River	Validated + Integrated
Medium and long-term transfer.	RETRACE-2 runoff RIVTOX 1D river LAKECO	River Rhine Finland (in progress)	Validated + Integrated
Special studies.	RIVMORPH 2D river THREETOX 3D, deep lakes, reservoirs, estuaries, coastal areas LATOX, (box model for stratified systems) lakes, coastal areas. VADZONE rapid soil-to-groundwater transfer SUSTOX 1D/2D groundwater model DELTA/HYDRO mountainous areas	Under development	Tested Tested, UNIX version Tested Under development Developed and tested Developed

The recently developed models for specific aquatic systems such as deep lakes and particular river shapes have yet to be integrated. These models were tested and customised in 1996 and 1997 and will be finally implemented in the hydrological module by the end of 1998 (RODOS release 4.0). However, these models must be considered as extensions to the set of models for use in special cases. The models in question are the groundwater model SUSTOX, the soil-to-groundwater model VADZONE, the 3D lake model for deep lakes, THREETOX, the box model for stratified water bodies, LATOX, and the 2D lateral averaged river model RIVMORPH. This report concentrates on the work done to customise the hydrological modules, which involved validation and application, as well as on the he work done to improve the flexibility of the hydrological models. In table 1, the various hydrological models and their applications are summarised.

3.4.2 Lake modelling: compartment models

Customisation in Finland

Adaptation of the LAKECO model, intensively tested on a wide range of lakes (Heling, 1997), is problematic if the number of lakes in the relevant area is unusually high. Although lack of flexibility is not a problem, the software structure does not allow for more than twenty to thirty lake-ecosystems in a given territory. The application of LAKECO for each individual lake ecosystem would be problematic, due to the vast set of input parameters required in such a region.

About 10% of the total area of Finland is covered by lakes and in some areas the figure can be as high as 25%. Finnish lakes have a relatively high humic status, low nutrient levels and are slightly acidic. The lakes are generally shallow, with a mean depth of about 7 metres. The large lakes have several basins, numerous islands and a long shoreline . Due to the latitude, seasonal variations in discharge and temperature are relatively large. Finnish lakes are dimictic and exhibit summer stratification and inverse stratification in winter. In natural lake water, outflow rates have a maximum value during the spring flood and a minimum value either in late winter or in late summer.

Precipitation varies from about 500 mm/year up to about 750 mm/year, with a mean annual precipitation of 650 mm/year. Evaporation decreases over the length of the country, from 300-400 mm/year in the south to 100-300 mm/year in the north. The quality of the catchment affects the run-off, which is lowest in the lake area of southern Finland, at 5-7 l/(s*km^2), and highest in north-eastern part of the country, where it is 12-13 l/(s*km^2). The north-east is the wettest area in Finland, with the highest snowfall rate and the lowest evaporation.

A prototype customised model, designed to simulate Finnish lakes on the basis of the key parameters which determine the transfer and behaviour of radionuclides in a limited number of lake ecosystems, has been developed. At a later stage, the customised model will be incorporate in the existing RODOS model suite.

The behaviour of radionuclides in a drainage area can be described by two main (key) parameters: land use (forest/peat, pasture and cultivated land) and gradient of the catchment area (steep, flat and gentle). The two key parameters governing the lake type are: nutrification level (oligotrophic, mesotrophic and eutrophic), and lake area (1, 100, and 1000 km^2).

Each of these key parameters controls a number of secondary parameters. The land use and topography determine the extent to which erosion of particles from the catchment to the lakes occurs. The sorption of nuclides to particles is determined by the land use; each land type has its own adsorption properties for the different radionuclides. Topography determines parameters such as the run-off rate and soil resuspension (wind effect).

The key parameters assumed to determine the turnover and transfer of radionuclides in a lake ecosystem are the hydrological turnover time and the sedimentation and resuspension rates. The suspended sediment load in the lake water affects the sedimentation rate. Lake size and nutrification affect these parameters greatly.

Lake nutrification also affects the biomass in the lake and the food-web type (Håkanson & Peters, 1996). Higher nutrification levels cause higher biomasses of different aquatic species, and a higher biomagnification factor between the species in the different trophic levels. The nutrient level also determines the food uptake rate of the different fish species, since lower nutrient levels result in lower biomasses of the prey organisms.

This approach can be applied on a grid area of the RODOS system after determination of the fraction of the different classification criteria. Each chain of key parameters causes an "event tree" of possibilities, depending on the occurrence of each type in the area. After determination of the various combinations, for each possible combination of parameters, the hydrological model predicts the radionuclide transfer. Finally, the dose assessment is performed by combining the different calculation endpoints in a defined grid area.

Altogether, many possible combinations exist for each area grid specification: lake area (3 classes) * topography of catchment (3 classes) * nutrient content of lake (3 classes). This type of modelling approach should predict aquatic consequences in quite a reliable way and at least gives a good estimation of the early effects. From the time-integrated values, the doses can be calculated by applying consumption rates and radionuclide-specific dose factors.

The core module prototype of the physical calculation model is already available for a PC environment, and applicability of the module has been tested to some extent on data in Finland. Clearly, given the simplification inherent in limiting the simulation to a small number of standard lakes, application of this core module needed careful validation (Suolanen, 1997).

The first step was the development of the lake and drainage models. This involved collecting hydrological and radiological data for six Finnish lakes with varying bathymetry, hydrology, and trophic status. To test the model, time-series of radiocaesium in fish was collected for the period 1986-1992. To validate the model predictions, independent data sets for eight other Finnish lakes and their catchments were made available. (Saxen et al, 1997).

Customisation for deep lakes

The customisation of lake models to make them suitable for the prediction of nuclide dispersion in deep lakes requires a special approach. Due to the stratification and mixing periods, dilution of large volumes cannot be assumed and a simple box model is not sufficient to deal with the complex mixing and stratification behaviour in these lakes. Therefore, the hydrological module has to be enhanced by the addition of two different models to deal with stratification. The multi-layered model LATOX can be regarded as a multi-layered box model and can be used to simulate medium and long-term dispersion (i.e. dispersion over a period of between ten days and several years) of nuclides in deep lakes. This model contains a submodel to predict the thermal and hydrological regime of a deep lake based on climatological data. A stand-alone version of the model has been developed and successfully tested using radiocaesium data for Lake Constance in Germany (see Figure 1) and Lake Bracciano in Italy. Validation tests on LATOX are also being carried out using data on Cs-137 dispersion in the Black Sea after the Chernobyl accident. LATOX will be implemented in the RODOS system in the near future (Maderich et al, 1997)

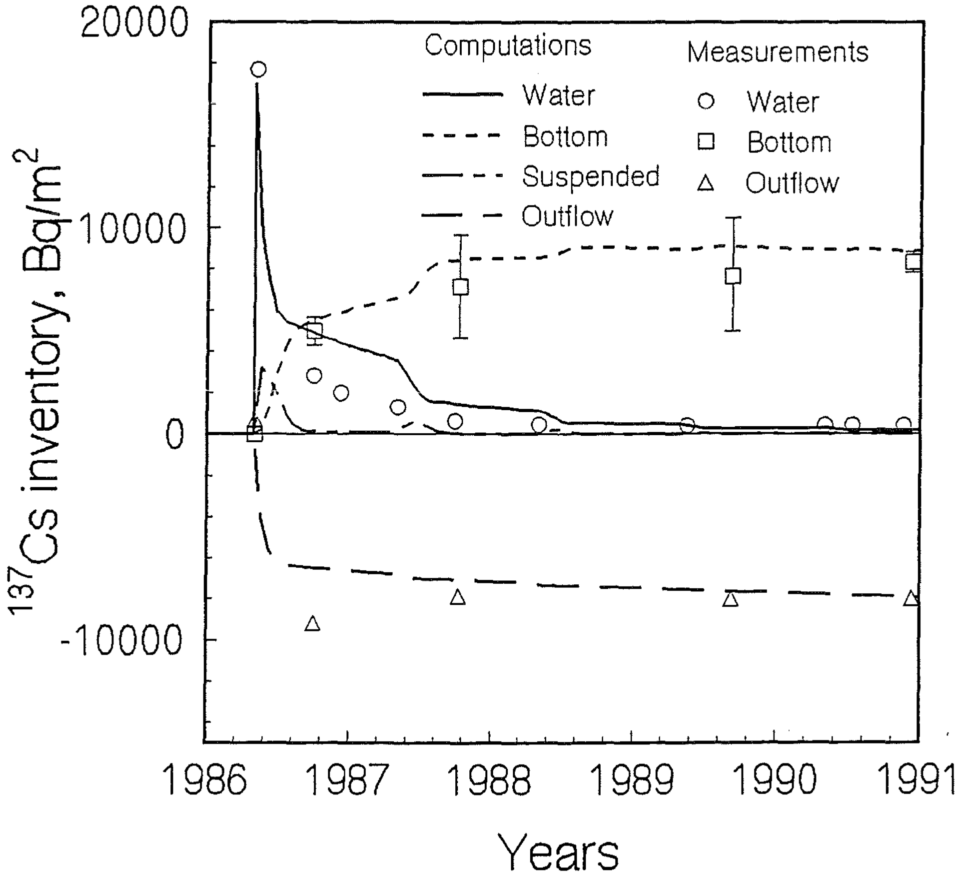

Figure 3.4.1. Comparison of model predictions and measurements for Lake Constance in Germany. Dispersion of Cs-137 in the epilimnion in the lake as predicted by LATOX.

For short-term dispersion modelling in stratified water bodies, THREETOX, a 3-D model for radionuclide dispersion, has been developed for application in situations involving deep stratified lakes. This model is also suitable for simulating short and medium-term radionuclide dispersion in nuclear power plant cooling ponds, estuaries and coastal stretches of sea. THREETOX (Margvelashvily et al, 1997) has been validated for various types of water body and for different radionuclides. Thus, validation has been carried out for radionuclide dispersion in a deep lake in Germany, in an estuary in Ukraine (Sr-90 in the Dnieper-Bug estuary), in a reservoir in Ukraine (Kiev Reservoir), and in the Kara Sea in the Arctic. So far, this model has been tested only in stand-alone form, but it will be attached to the hydrological module in due course.

3.4.3 River and reservoir modelling.

For modelling the transfer of radionuclides in fluvial systems and reservoirs, the hydrological module contains the 1D model RIVTOX and the 2D dispersion model COASTOX, developed by IPMMS, Ukraine. These models and their validation are described elsewhere (Popov et al, 1997; Gofman et al, 1996; Heling et al, 1997; Zhelaznyak et al, 1992). The tests conducted were intended both to validate the hydrodynamic and radiological submodels and to improve flexibility.

Validation tests with separate dispersion models were performed to check the reliability of the models. The combined predictive power of the the hydrological models in RODOS was also tested. This led to modifications or to the development of new models where necessary for application in relation to particular aquatic circumstances. This customisation work provided insight into the particular problems encountered when the models were applied to territories other than those for which the models were originallydeveloped. Examples of the work done to customise and validate RIVTOX in combination with COASTOX and with the run-off model RETRACE include the following:

- RIVTOX and COASTOX were used to model dispersion in the Slovakian Vah-Dudvah river system of nuclides discharged from the Bohunice power plant. This work was done by IPMMS, Ukraine, and NPPRI, Slovakia.

- RIVTOX was used in combination with RETRACE to model the rain flood event for the Ilia river in June 1988 (30-km zone of Chernobyl NPP). These tests were performed by SPA Typhoon, Russia, and IPMMS, Ukraine.

- RIVTOX was used in combination with RETRACE to model the flood events in December 1993 in Germany. These tests were also performed by SPA Typhoon, Russia, and IPMMS, Ukraine.

To enhance the RODOS model suite for use in relation to river systems, the 2D (laterally averaged) river model RIVMORPH (Andrijevskij et al, 1997) has been developed by IPEP, Belarus, to deal with specific complex river morphology. In the RODOS system, this model will be implemented for special applications involving the implementation of countermeasures, while RIVTOX and RETRACE are included in RODOS's basic emergency response model set.

For use in combination with the run-off model RETRACE to deal with flood events, RIVTOX has been enhanced by going over to numerical solution of the full Saint-Venant equation instead of relying on the existing simplified (high performance) "diffusive wave approximation" of the St. Venant equation. This was done because the original simplified set of equations was not adequate for rivers with dams and other waterworks, which play a critical role in high-discharge and flood events. The disadvantage of this method is that it requires more input parameters, such as detailed cross-sections of the river.

During the customisation of RIVTOX in Slovakia, it was found that the description of the sorption processes was not appropriate for modelling the first wave of nuclides following a discharge directly into the river-system. The radionuclide transport module of RIVTOX was accordingly analysed and expanded for simulation of the immediate post-accidental period on the basis of a two-step kinetic model to describe the water-sediment exchange.

A validation study of COASTOX has been performed using data on the Kralova reservoir in the Slovak Republic. The zone with the most contaminated bottom sediments in the reservoir was predicted successfully.

Customisation in Germany to deal with flood events

Generally, the most difficult and significant test for the validation of the combined models involves determining how accurately they can predict extreme flood events, such as the flooding which occurred along the River Rhine in the period December 1993 - January 1994. To customise the model suite for floods, RIVTOX and COASTOX were accordingly tested using data on this flood event. The results of the first stage of validation and the data used were briefly described by Popov (Popov et al, 1997). The latest results and some of the problems involved in this application are described below.

The main objective of the validation study was to compare the model suite results with the daily averaged measured discharges in four outlets on the River Rhine. Deviations between predictions and measurement (see Fig, 3.4.1) are due to differences in resolution of the used input data (elevation and channel net data). Data sets with higher resolution can solve this problem. Collection of compatible data sets is of crucial importance when combined models are adapted to river-catchment system, and can be considered as an main issue in data collection in general within RODOS.

As meteorological input data precipitation data for about 70 meteorological stations were provided by the German Meteorological Service. The air moisture was assumed to be constant for the whole validation period, during which the heaviest rainfall occurred. The air temperature was 5°C and the relative air humidity was 90%, which gives an air moisture deficit 0.873 hPa.

The calibration period selected was the first month of the flood event (to be precise, 1 - 29 December 1993); the following month (January 1994) will be tested at a later stage.

Measured data is available for four outlets on River Rhine. It should be noted that the location of the outlets makes it possible to consider some parts of the watershed separately, which is very useful for checking and calibrating the distributed model parameters. However, the software tool necessary for management of RIVTOX parameters is not yet available, so separate validation has been postponed. Thus, the main goal of the validation described was to demonstrate the capabilities of the model suite, to obtain reasonable agreement for all partial watersheds.

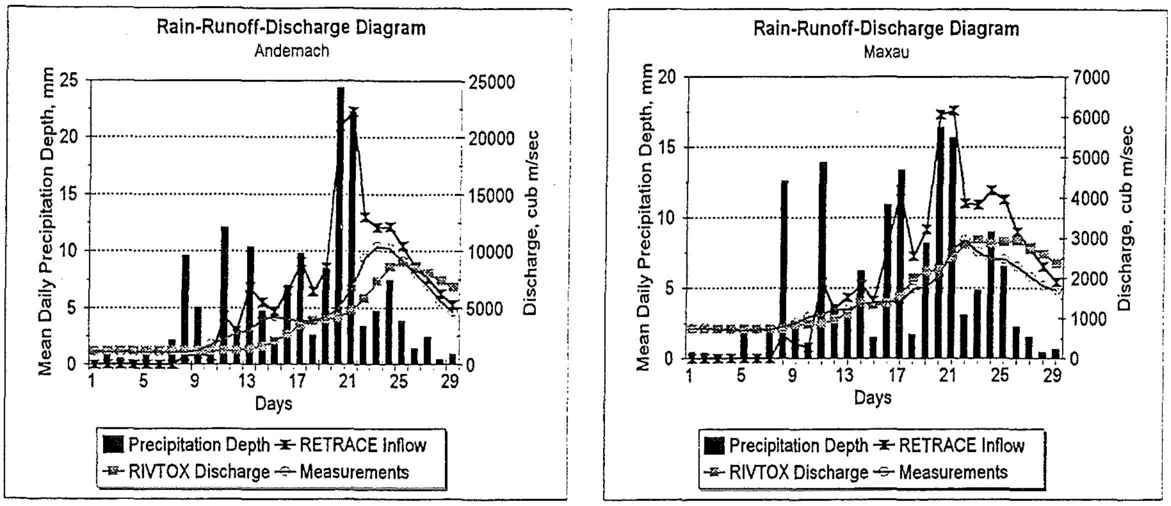

Figure 3.4.2 Results of a simulation of the flood event which occurred along the River Rhine in 1993, performed using the RIVTOX and RETRACE models in combination. Comparison of predicted and measured discharge data. "Precipitation Depth" is measured rainfall rate (left y-axis), "RETRACE inflow" is land-to-water discharge as predicted by RETRACE (right y-axis). "RIVTOX discharge" is discharge in the river as predicted by RIVTOX (right y-axis), and "Measurements" is the measured discharge rate in the river (right y-axis)

In Figure 3.4.2, the simulation results are compared with measured data for two outlets on the River Rhine, representing the smallest and the biggest of the four selected subbasin outlets. Although for this extreme flood situation there was reasonable agreement between the modelled and measured data, more validation tests should be performed, since the reasons for the disagreement are quite clear and it should therefore be possible to improve the simulation results.

The validation described showed that the RETRACE-2 - RIVTOX model suite is able to provide reasonable results even when simulating an event as challenging as extreme flooding along the River Rhine. Tools for the preparation of RIVTOX input parameters will be developed in the near future to support customisation in the different countries. The customisation tools for RETRACE have already been developed, while those for RIVTOX are currently under development.

Customisation of the models for rivers and reservoirs in Slovakia

RIVTOX and COASTOX have been used to model the River Dudvah-River Vah--Kralova Reservoir system in the Slovak Republic. On the basis of topo-hydrological data collected by NPPRI (Slovak Republic), the PC version of RIVTOX was used for the River Dudvah-River Vah system and the PC version of COASTOX was used for the Kralova Reservoir (Slavik et al, 1997). The model suite was validated on the basis of measured data on accidental releases of radioactive material to the hydrosphere from the Bohunice Nuclear Power Plant (NPP) in the Slovak Republic. The field data and data from laboratory experiments carried out by NPPRI was also used to assess the need for the RIVTOX model to be improved in order to enhance simulation of the immediate post-accidental period, on the basis of a two-step kinetic model for the description of water-sediment radionuclide exchange. The models produced an adequate reconstruction of the concentration in the aquatic system of historical releases of Cs-137. The scope for identifying practical hydraulic management techniques for reducing radionuclide concentrations in this aquatic system following an accidental release were analysed as well.

Customisation of the RIVTOX-COASTOX model for the above-mentioned systems demonstrated the applicability of the RODOS RIVTOX and COASTOX models to the most important rivers and reservoirs in the country. During the customisation work, it became apparent that the following site-specific data should be collected: 1. topographically modelled river-cross-sections (important for proper customisation) 2. sorption parameters related to the site-specific bottom sediment conditions and the suspended matter K_d, 3. a good estimation of the thickness of the top sediment layer in interaction with the water column, the total mass of the sediments and the total suspended matter load 4. detailed bathymetry maps of the reservoir.

Modelling of the long-term dispersion of nuclides in river systems.

For long-term predictions of radionuclide transfer in river catchments, RIVTOX and COASTOX are less applicable due to the model complexity and run-time. The WATOX model has accordingly been developed for use in situations where the user is interested in medium and long-term behaviour in catchments. With this model, a compartment approach is applied to rivers and reservoirs. A simplified run-off model will be added to WATOX to estimate the long-term transfer of nuclides from the catchment to the river system.

A UNIX version of the long-term river model WATOX has been developed from the existing PC version. The model has been modified to increase its flexibility, thereby making it more suitable for long-term projections (up to hundreds of years) involving different water systems. The model has been used to simulate the Rhine river basin. Details of the run-off component of WATOX are presented in the following section. IPMMS in the Ukraine developed the river catchment model, while SPA Typhoon was responsible for developing the long-term run-off model.

Customisation of the hydro-module on complex rivers

The problem of sediment transport in surface waters was given particular attention in an earlier report (Andrijevski et al, 1997). This problem arises because most radionuclides are adsorbed on and consequently transferred together with solid particles .

The earlier report focused particularly on the mass transfer of sediment particles and radioactive substances under the influence of the morphological characteristics of fluvial flows. The non-stationary 2-D model RIVMORPH (vertical, along the flow), which is generally used for research purposes, is based on the full system of non-stationary conservation equations. The model permits calculation of the vertical distribution of sedimentary matter and of radionuclide concentrations (taking into account adsorbed and dissolved radionuclides). RIVMORPH can be used for the evaluation of hydrological countermeasures such as dam building, bottom sediment removal and so forth. A full description of the RIVMORPH model is contained in an earlier report (Andrijevski et al, 1997).

Within the framework of the RODOS hydrological module, the model set will be extended by addition of the 2-D vertical model (RIVMORPH) for simulating the dispersion, deposition and removal of radioactive material in rivers with morphological peculiarities. RIVMORPH has been developed jointly by IMMS CC (Ukraine) and KEMA (The Netherlands). The model can be used for complicated parts of a river (such as vortex flows) and is therefore suitable for application in different situations from those in which COASTOX and RIVTOX are used (Heling R. et al, 1997). To make the customisation of this complex model type easier, a special selection tool (MORPHOLOGY) is under development. This tool will make it possible to determine on the basis of the water morphology and the completeness of the hydrological database whether RIVTOX, COASTOX or RIVMORPH is the most appropriate model to use.

It is important that this complex river model, the selection tool and its criteria are all validated.

Validation of RIVMORPH's description of mass transfer processes in the area near to the bottom of the transport flow has been performed using laboratory data on the dynamics of local changes in bottom relief and contamination data on the River Iput. The RIVMORPH validation studies were carried out with the assistance and direct involvement of IMMS CC (Ukraine) on the basis of published experimental data . Two components of the RIVMORPH model have been tested, the sediment transportcomponent and the radionuclide transportcomponent.

In Figure 5, the validation results for the mass transport flow model are presented. The test involved modelling the behaviour of sediment particles filling a trench in the river-bed. The flow pattern is from left to right.

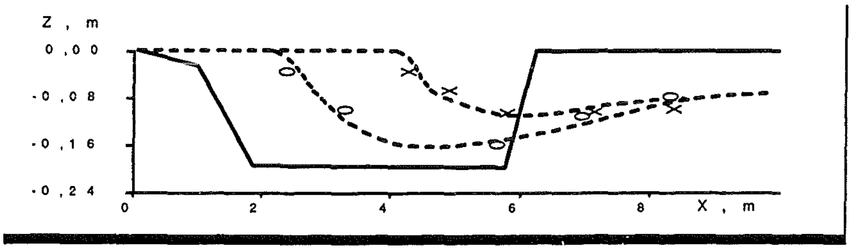

Figure 3.4.3. Time history of the river bed level under the test conditions. The solid line represents the initial condition, the dotted lines computed profiles after 7.5 and 15 hours respectively; the markers represent the measurements at 7.5 hours (0) and at 15 hours (x).

During the initial period, more intensive sedimentation of sand particles was observed. After 15 hours had elapsed, the sedimentation intensity had reduced significantly. The sedimentation of particles was mainly observed at the leading edge of the trench. The trailing edge of the trench was first eroded, then gradually filled by the settlement of sand particles.

To validate RIVMORPH's radionuclide component, a validation of the RIVMORPH code was carried out using experimental data on the radiological contamination of the River Iput near the village of Ycherpje in the Bryansk region. At this location, there is a natural trench of about 0.5 metres in the riverbed, where sediments are trapped.

The concentration of dissolved radiocaesium before the trench was 10.58 Bq/l; after the trench it was 7.7 Bq/l. The concentration of radioactivity in the silt after the trench was 930 Bq/kg. The predicted radiocaesium concentration matched the experimental data on the sediment bed at 27 hours. The concentration of silt radioactivity asymptotically converges from an initial value of zero, up to experimental value.

The classification of river morphology is of importance for the customisation of the hydrological models for use in Belarus. A tentative analysis of morphological peculiarities has been carried out to classify the key characteristics for rivers with respect to the accumulation of radionuclides. The classification is based on measured data on rivers contaminated following the Chernobyl accident. Plane critical formations are: bights, crooks, side formation, and locations of lateral inflow. Altitude stocktaking formations: reaches, and river bed formations. In addition, the definition of radioactive sites is important, especially in relation to small rivers.

The tests carried out to validate the description of mass transfer processes in the area near to the bottom of the transport flow showed that there was a good degree of agreement between the model predictions and the measured data. The tentative analysis and classification of morphological peculiarities in rivers resulted in a classification of river morphology. The initiation module MORPHOLOGY helps the user to customise RIVMORPH for those parts of the river system which are significant in relation to sedimentation, by making use of databases. The module suggests appropriate parameters for use in the customisation process.

Run-off and groundwater modelling.

The application and customisation of RODOS's hydrological models in the Ukraine and Russia demonstrated that certain new model functionalities are required to complete the hydrological model set included in the current RODOS release, 3.1. Ice break-up and snowmelt in the spring brought about sudden floods along the River Pripyat in the Ukraine, resulting in unusual discharges and causing the River Pripyat to break its banks near Chernobyl. Such events might increase the transfer of nuclides between the flood plains and the river and should therefore be modelled in order to enable reliable assessment to be made of floods which are extreme in terms of radionuclide transfer. .The existing run-off model RETRACE has accordingly been enhanced by the addition of a snowmelt model to predict the transfer of radionuclides from the contaminated flood plain to the river system. To assess the behaviour of nuclides close to the source after an accidental release, the groundwater model SUSTOX has been developed and tested. Another model that is under development, by SPA Typhoon, is the soil-to-groundwater model VADZONE. This model will be used for short-term predictions in the days following the deposition of nuclides. The background to the development of this additional soil model was the observation of rapid radionuclides transfer to the groundwater. Such transfer cannot be explained by the traditional methods, which assume a homogenous soil texture instead, one has to assume that the soil is not homogeneous, but contains macropores.

Customisation of RETRACE

The customisation of RODOS's run-off models is a relatively difficult task, especially the definition of the drainage system based on elevation and hydrological maps. To support future users of RODOS's hydrological models, a set of software tools has been added to the hydrological module

Particular attention was given to the development of special software tools for customising and preparing data for the RETRACE model. The following software tools for the preparation of watershed data were developed and implemented during the period under review:

- A tool with which to arrange the artificial drainage network for regions where no orographic data are available (this is very often the case with the watersheds of small rivers and creeks). This tool has both automatic and manual options; the latter enables the user to manage the run-off models for very plain or artificially drained territories.

- A tool with which to classify watersheds in order to define discharge-generating regions (DGR) on the basis of data on soil properties, elevation data and another available data; with this tool, the user can automatically split a watershed into hydrologically similar regions (DGRs).

- A tool with which to cut the part of the terrain on the basis of data on the delimiting curve; this tool enables the user to define any watershed on the basis of watershed division data.

- A tool with which to generate the watershed on the basis of artificial and natural orographic networks used in the RETRACE model.

- An on-line pop-up help tool for RETRACE software and for model parameters.

- A tool with which to map any points of interest such as outlets, towns, etc.; this feature makes the use of the RETRACE Display window easier.

To increase the flexibility of RETRACE further, the input modules of the software were improved so that meteorological input data could be used both in text format (as before) and in grid format, as is used in RoGIS. This improvement will provide greater software efficiency when the model software is customised. Furthermore, the model software has been improved in order to provide the run-off transfer in any number of lakes. This feature is especially important for regions with ponds used for fish farming.

Various snowmelt models were examined in order to select the most appropriate one for use with RETRACE.The models in question were those described by Donigian et al, 1982; Singh, 1995; Vinogradov, 1988 and WMO, 1989.

The conclusion was that, despite substantial differences in mathematical structure and calibration methods, the existing snowmelt models were relatively similar. The catchment area and the amount of input data are the main restrictions on the application of the models. This is particularly true where the physically based distributed models are concerned.

The most complex process is the transfer of melt-water in frozen soil, which is important in forests and steppe, but less important in mountainous catchments. The analysis of the models has shown that there are no clear criteria on which to select the the most appropriate model from the existing range. It was therefore concluded that the most suitable way to improve the RETRACE run-off model was to use the snowmelt submodel developed in the State Hydrological Institute in Russia (SHI snowmelt model, or SHIS model). This submodel has been developed as a continuation of the current rain run-off model included in RETRACE-2, and makes use of similar approaches and concepts to simulate run-off formation in watersheds. The additional advantage of this submodel is the application of general hydrometeorological input. It should be noted that the SHI snow-melt model is only a prototype, and several of its parameters need calibration.

The SHIS model makes use of two equations for the heat balance in the snow cover and in the top layer of soil. The heat fluxes are approximated by the empirical relations derived from Newton's Law on heat fluxes. In other words, the SHIS model uses a temperature-based method. The empirical relations are used as heat parameters (specific heat, heat conductivity) for the frozen soil and for the snow cover comprising the water. This system of equations allows approximate analytical solution when daily averaged parameters are used. The water produced by the melting of snow is used in the run-off submodel of RETRACE-2. The snow-melt module has been implemented in RETRACE in a standaloneform. Furthermore, it is assumed in the snow-melt module that when the snowmelts, only dissolved radionuclides are transferred.

Long term runoff modelling

For the long-term modelling of run-off transfer from land to river, the hydrological suite will use a simpler approach than that used in the RETRACE models. SPA Typhoon is currently developing RETRACE-3 for such applications. This model will be linked to WATOX, the long-term river transport model under development by IPMMS, Ukraine. RETRACE-3 will be based upon a combination of the conceptual catchment transfer models described by Shukla (1993) and Monte (1996). The long-term river dispersion model WATOX has a simplified river network structure. The main differences between the Shukla and Monte models and RETRACE-3 is, that RETRACE-3 should deal with distributed hydrological and radiological properties.

From the literature search performed by Typhoon on existing run-off models, it was clear that such models could be divided into two distinct sets:hydrological models and numerical models. The hydrological method, used for example in theHSPF model (Donigian et al, 1982), tended to be popular in the period when model runs were limited by computer capacity. Such models typically require watersheds to be divided manually and assume that subcatchments are homogenous in terms of hydrology and contamination. In the numerical method, the catchment is subdivided into small regular grid squares, within each of which homogenous conditions are assumed. RETRACE–1 and RETRACE-2 are based on this approach. As indicated, most of the models examined are based on one of the two aforementioned approaches. The most remarkable conclusion of the study was that the best calculation results could be expected when both methods were combined. RETRACE-2 combines these two methods, and its use therefore demands expert judgement and a wide range of input data. It has accordingly been decided that RETRACE-3 will be a modified version of the RETRACE-2 run-off model, adapted for making long-term predictions.

Customisation of the groundwater model SUSTOX

For modelling subsurface contamination, a stand-alone version of SUSTOX has been developed for use in a UNIX environment (version 1.1). It includes 1-D (vertical), 2-D (vertical-longitudinal), and 3-D transient models of moisture movement through unsaturated-saturated porous media and pollutant transport in soil and groundwater. The description of the contaminated subsurface environment formulated in these models is founded on governing equations for conservation of water mass and species mass. Liquid transport through soil occurs in response to pressure gradients and gravitational body forces, in accordance with Darcy's flow equations. Species transport through the subsurface environment occurs by diffusion, dispersion, advection and radioactive decay. Adsorption or exchange reactions between the solute and the soil matrix are considered to be instantaneous and are described by a linear equilibrium isotherm. Successful tests have been performed, in which SUSTOX was used to model the downward transport of Sr-90 under the shelter of the Chernobyl Power Plant. In Figure %, an example of this prediction is shown (Kivva, S., 1997).

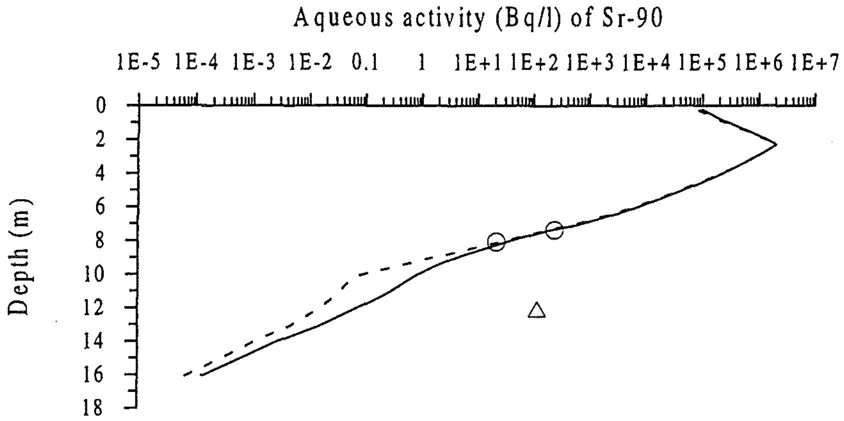

Figure 3.4.5. Example of a prediction of the downward transfer of Sr-90 under the Chernobyl shelter. Comparison of predicted and measured activity-depth profiles of ^{90}Sr in the aqueous phase in 1995. Profiles were obtained for two different sources of leakage in the shelter (——) source 1 and (- - -) source 2. Δ and O denote mean values of radionuclide activity detected in two different wells corresponding with the source locations.

Customisation on mountainous areas.

Demokritos, Greece, has developed the DELTA/HYDRO model. This model is intended to be a physically based distributed model, describing most of the hydrological processes taking place in natural watersheds. This model is in the development phase, and will be used to evaluate the transfer of soluble nuclides in river catchments of complex topography.

The model incorporates the physical characteristics of the watershed through a subdivision of the area of interest into triangular areal unit elements, created by the DELTA/GAIA model, on the basis of digital elevation maps. All significant hydrological parameters such as ground slope, hydraulic conductivity, roughness coefficient, initial soil moisture content etc are assumed to be uniform within each triangular ground surface element but may vary from one surface element to another.

The model automatically computes the geometric characteristics of the topography under consideration, whereas the hydrological parameters are set by the user as single values in each homogeneous area of the watershed.

The key feature of the model, as it has been extensively reported in (Catsaros et al, 1997), is the accurate description of the overland flow trajectories towards the deepest slope direction, ending at the domain outer boundaries, local minima of altitude or feeding channels.

Furthermore, the simulated network of channels is automatically redistributed, to create independent river systems. The criterion characterising an independent river system is an outlet common to all its individual channel flows. Each river system is therefore formed by one main river having numerous tributaries and in each tributary junction, the river network is formed in such a way that a given river gains water from no more than one tributary. The numeration of the various tributaries follows the logic of gravity, from upstream to downstream in the principal river of the system. Each river of the system is formed by a succession of reaches; each reach receives water from its upstream reach and by a succession of run-off overland flow cascades contributing to the lateral inflow.

The various physical processes are modelled with efficient methods able to handle the complexity of the physical phenomena; more precisely, the overland flow routing is performed using kinematic approximation where the flux and the velocity are functions of the flow depth. During rainfall episodes, the ponding time is computed for each ground surface element; ponding may occur in different surfaces during different time steps, leading to a variable run-off source area which is time- and location-dependent. The various modules of the model are currently under testing. The model is expected to be integrated into the final RODOS version PV4.0 in July 1998.

Customisation of the hydro-module on soil-to-groundwater transfer.

The modelling of soil-to-groundwater transfer, as performed by SUSTOX, is only of importance when soil contamination levels are significant. Normally, the transfer of nuclides is extremely low in comparison with other aquatic pathways. However, observations in certain areas of Ukraine, Belarus and Russia have demonstrated unexpectedly quick transfer to the groundwater level. This remarkable effect was discovered after the Chernobyl accident (Karasev, 1988; Freeze, 1993). Similar phenomena involving chemicals have been investigated in detail. It was found that quick transfer takes place through biological macropores in clay soils with shallow groundwater (lower than 2.5 metres). The rainfall intensity must be sufficient to saturate the soil surface.

The concept of fast filtration through the vadose zone has been modelled in the VADZONE program. This model relies on the numeric solution of the one-dimensional Richards equation. The processes of filtration and evapo-transpiration are taken into account. Where rainfall is heavy, both the level of soil moisture and the proportion of the precipitation which cannot be filtered by the soil are calculated. This proportion of the precipitation can be transported via macropores to the groundwater. The conductivity of macropores is calculated from their concentration and size using empirical relations from (Smettem, 1985). The proportion of the precipitation, which is not absorbed by the soil matrix and is not transported by the macropores is the input for the surface run-off. Therefore, VADZONE can be used to refine the hydrological models included in RODOS.

The input parameters for the VADZONE model are the texture, porosity and saturated hydraulic conductivity of the soil and a leaf area index for use in the calculation of transpiration. The meteorological parameters used are six-hour data on the temperature and air humidity near to the surface and the amount of rainfall.

Calculations of soil moisture in the vadose zone using the archive of meteorological data permit the reconstruction of a moisture profile, given information about radionuclide deposition, without any additional measurements and, hence, enable conclusions to be drawn quickly regarding the possibility of fast radionuclide run-off to the groundwater. If the conditions for macropore flux are met, according to field data, several per cent of the sorbed radionuclides can get into the groundwater during the first two weeks after deposition . In view of the fact that these specific conditions must be met, the VADZONE model will be incorporated in the hydrological module of RODOS only in the early phase. Integration of the model in RODOS should be completed by December 1998.

Improvements of the RODOS hydrological module: Uncertainty Analysis and Data Assimilation

In the current RODOS release, 3.1, the hydrological module transfers the model output for fish, drinking water and irrigation water to the countermeasure and dose modules. The uncertainties in this output are not presently known; but in the future release of the hydrological models, a Monte Carlo uncertainty analysis will be significant part of the hydrological module. Various forms of uncertainty can be distinguished in the hydrological module, the main ones being uncertainty in the model input parameters and uncertainty resulting from error propagation throughout the whole model suite. An assessment of the uncertainty in each of the individual models can be made on the basis of experience with the models. A method is presently under development, which should reduce uncertainty in the hydrological flows by using monitoring data and rainfall forecast data to correct the assumed hydrological budgets. Uncertainty will be further reduced using a data assimilation method, whereby incoming radiological data will be used to tune the river dispersion parameters. The first step in the implementation of this method will be to incorporate it in the river model RIVTOX. Further special hydrological countermeasures will be implemented in the hydrological module by using the reduction factor approach to estimate the effect of the chemical treatment of lake systems to reduce biological uptake. Although these factors will be derived from complex countermeasure models, the RODOS system will give rough estimates of the possible concentration reduction effect. More detailed studies of the effect of chemical treatment could be carried out by decision-makers, using other model systems specially developed for the purpose. In the next development phase, feasible physical countermeasures such as dam building and flow control will be implemented in the system.

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3.5 Decision Support, Data assimilation and Uncertainty Handling within RODOS

RODOS acknowledges four levels of decision support (see Table 3.5.1). It is possible to relate these levels to the ASY-CSY-ESY and GSY structure of RODOS: the GSY and ASY modules provide support at levels 0 and 1, the CSY modules provide support at level 2 and the ESY modules support at level 3 (see Figure 3.5.1). However, this identification of level 3 decision support – i.e. prescriptive decision support (1) – with the ESY modules of RODOS is a little too simplistic. The decision makers and their advisors need to make judgements in evaluation and the support of these judgement is provided by level 3 modules. But they also need to address the uncertainty in all the information provided by RODOS. This means that uncertainty handling and data assimilation must permeate all levels.

Table 3.5.1: Levels of decision support for off-site emergency management. Support at higher levels includes that provided at lower levels.

Level 0:	Acquisition, checking and presentation of radiological data, directly or with minimal analysis, and of geographic and demographic information.
Level 1:	Analysis and prediction of the current and future radiological situation based upon monitoring and meteorological data and models.
Level 2:	Simulation of potential countermeasures, e.g. sheltering, evacuation, issue of iodine tablets, food bans, and relocation; determination of their feasibility and quantification of their benefits and disadvantages.
Level 3:	Evaluation and ranking of alternative countermeasure strategies in the face of uncertainty by balancing their respective benefits and disadvantages.

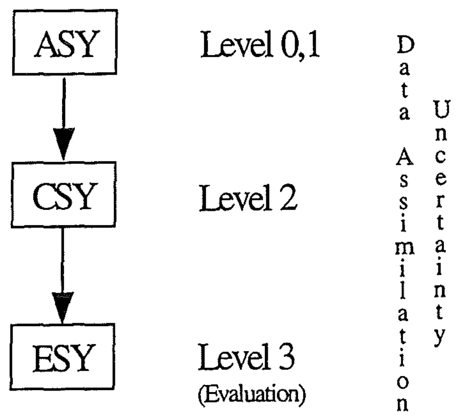


Figure 3.5.1: Levels of decision support ad their relation to ASY, CSY and ESY subsystems

Note that reference is made to 'uncertainty handling and data assimilation' together. They are intimately connected. To understand the import of data, one needs to understand the relative uncertainty in the current predictions relative to the current data. Equally to understand the uncertainty in a prediction from a model, one needs to have an understanding of the quality of the data and judgement on which it is built. Some of this understanding is built using Monte Carlo analyses and comparative studies *before* an accident to gain an intuition for the predictive quality of the models generally (2). During the course of the accident, data assimilation and model checking techniques may be used both to improve the predictions, where possible, and to warn the user when the models seem to be departing seriously from the real situation. Within the design of RODOS, methods are being developed based upon a variety of techniques from belief nets to krigging to assimilate many types of data including:

- plant and engineering data – including expert judgement – suggesting the strength and composition of the source term;
- meteorological data;
- on-site stack and periphery monitoring data, off-site fixed and mobile monitoring data;
- demographic data concerning the groups liable to be exposed;.
- agricultural, economic and land use data;
- hydrological data concerning both flow rates, depths, etc. and contamination;
- data on compliance with and effectiveness of countermeasures

The over-riding goal is to build a *coherent* system (3) in which the output of any single analysis at one decision point not only supports the decision to be made then but also provides prior information to analyses designed to support subsequent decisions. Moreover, the principles underpinning choice at one time should be compatible with those used at other times. To do otherwise invites inconsistency and risks confusing the decision makers. For example, the intent is to ensure that not only are plant and engineering data analysed to predict the source term in the very early stages of the threat, but if the release occurs, those data (and subsequent plant data) are also made in combination with sparse monitoring data collected in order to predict the contamination spread by the plume. Later after the plume has passed, methods are being developed to move smoothly from the predictions of ground contamination coming from atmospheric dispersion-deposition models to interpolations in the growing set of ground monitoring measurements. The analysis within RODOS will continually balance what has been learnt from past data with the information inherent in incoming data.

Designing decision support coherence into RODOS is not solely related to the relationship between uncertainty handling and data assimilation. The methodology embodied into the evaluation modules which form the ESY must also cohere with the representation of uncertainty so that they help the decision makers balance the various risks of different strategies in terms of a variety of soft and hard criteria. Bayesian methodology is being used as a general framework (see Figure 3.5.2). Uncertainties are encoded through probabilities, which model relations and dependencies between the decision makers' and their advisors' beliefs and uncertainties in the light of the predictions made by their models. As data arrive, applications of Bayes' Theorem in the analysis of the model prescribe how the beliefs should be updated. Bayesian updating provides the decision makers with guidance on the import of data and how they should be assimilated into their beliefs. Note that the Bayesian methodology separates issues of (scientific) knowledge from the value judgements needed to make a decision, the latter being modelled with multi-attribute utility models (MAUT). Thus in Figure 3.5.2, the left hand side can be thought of as providing support to the scientific advisors, whereas the right hand side supports the decision makers in articulating value judgements to determine a course of action.

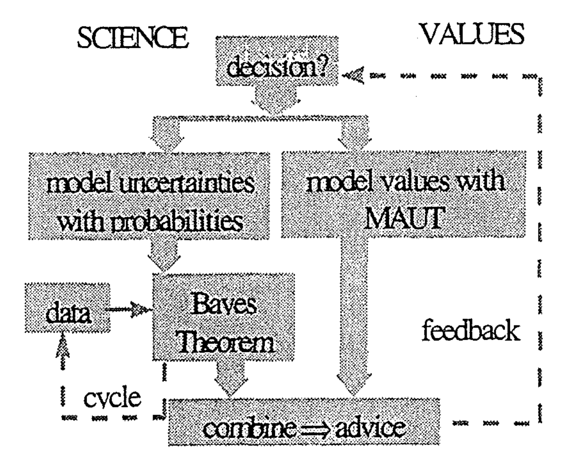


Figure 3.5.2: The Bayesian Methodology

In practice, the approach is somewhat more pragmatic than the above description might suggest. Approximations are used for the means and variances, rather than the full distribution, and linear utility functions are used rather than the more complex forms that might be justified in these circumstances; but the aim is to move towards a fully coherent Bayesian approach in later releases of RODOS. Note also that the development of some of these modules is necessarily only just being undertaken, since they are based upon deterministic modules with the ASY and CSY, which have only just been fully integrated into RODOS.

3.5.1 RODOS_STM, a source term module

In the early stages of an accident at a nuclear power plant, very little information will be available about the magnitude and characteristics of the release of radioactivity to the environment. This information, subsequently called the source term, will be the first input to a decision support system to assist in the implementation of the appropriate emergency response. Of more immediate concern to the emergency response team and the incident controller is an estimate of the likely release of radioactivity before it actually occurs. This should be based on the status of the plant and take account of the way in which the plant is likely to behave, either passively, or as a result of operator actions.

A source term module, RODOS_STM, has been developed which uses plant data to determine the likely source term characteristics and their probability. RODOS_STM employs a Bayesian belief network to calculate the conditional probability of different source term categories based upon plant status. A belief network is a graphical representation of probabilistic reasoning. It is composed of nodes, indicating observations and events, and arcs, indicating dependencies between the nodes. The one underpinning RODOS_STM is built upon the understanding of a reactor's behaviour developed during a probabilistic safety analysis. In short, RODOS_STM uses the information in a PSA to guide the early thinking on the risk when a release threatens. In the network there are essentially two types of node: those representing the (unknown) state of a part of the plant and those representing observations. Examples of the former are:

- a loss of integrity of one of the barriers to the release of radioactivity (primary circuit, auxiliary circuits, reactor building).

- the availability of safeguard systems (emergency core cooling system, reactor building spray system, reactor building fan coolers).

- the availability of condensers or ventilation systems.

An example of the latter is:

- data from plant instrumentation (core exit temperature, water level in the pressure vessel or steam generator, radiation levels in the Reactor/Auxiliary Building or steam lines, pressure in the Reactor Building).

The end-point of the network is the source term to the environment which is represented by three nodes on the network depending on the dominant release route:

- Primary circuit source term. The source term from the reactor building as a result of releases from the main primary circuit.

- Secondary circuit source term. The source term from the secondary circuit as a result of : (a) normal tube leakage or (b) enhanced tube leakage .

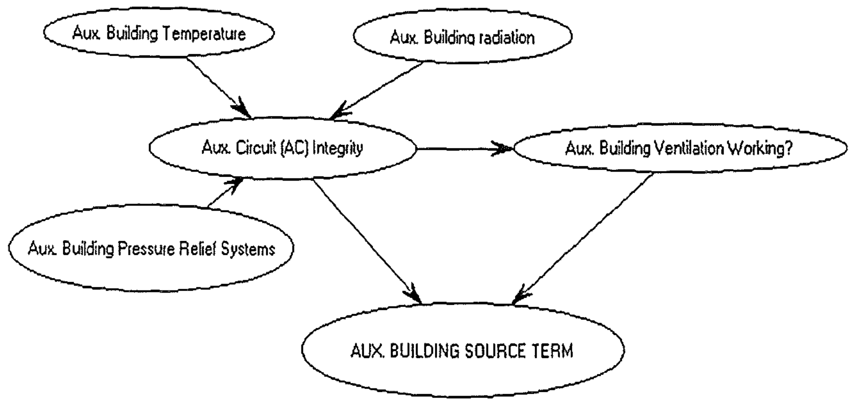


Figure 3.5.3: Illustration of part of the belief net showing some of the plant status factors which determine the auxiliary circuit source term.

- Auxiliary building source term. The source term from the auxiliary building as a result of leaks from auxiliary systems.

Figure 3.5.3 shows part of the belief net relating to the determination of the auxiliary circuit source term. Considering all three release pathways, the complete belief network has 42 nodes, each representing a plant indicator. Within each node a number of states (possible conditions) are defined, ranging from 2 to 25.

Although the main RODOS system is being built on a UNIX platform, RODOS_STM has been developed on a PC using the DXPRESS belief net shell (4). This designed choice has been made so that the system is able to capture plant data easily (Figure 3.5.4). It can, in principle,

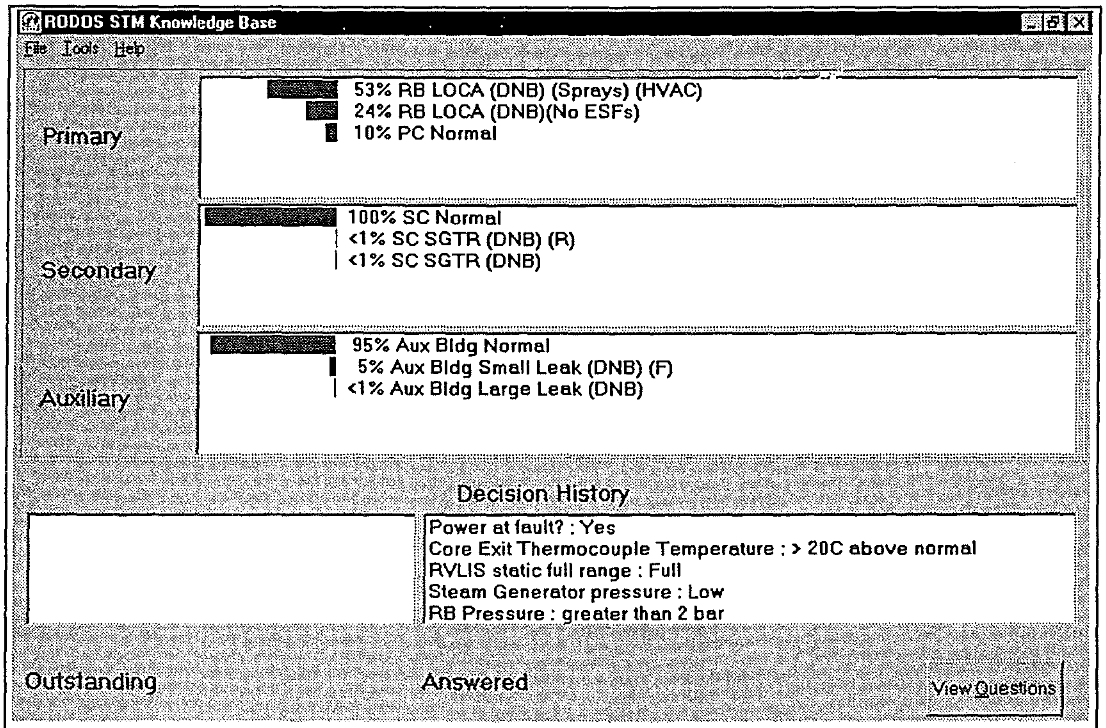


Figure 3.5.4: Output of RODOS_STM after a hypothetical series of plant status data. The data is suggesting a LOCA accident.

be linked to the Site Operating Instructions, which are often provided on a PC implemented manual in the control room.. The output from RODOS_STM is linked to the main RODOS system via a simple file. For further details, see Smedley *et al* (5).

One of the future tasks within the project is to combine the methodology underpinning RODOS_STM with the deterministic methodology involved in STEPS (see Chap. 3.9)so that it may predict how the threat will evolve over time.

3.5.2 Real-time estimation and prediction of the source term during a release

Two pieces of work are approaching the issue of estimating the source term from stack, on-site and near site monitoring data. Firstly, a bootstrap estimation methodology is being used to estimate the source term from site periphery gamma dose rate monitors (6, 7). The method is based on the conversion of measured dose rates to the source term, i.e. airborne radioactivity release rate, taking into account real meteorological data and location of the measure points. The bootstrap method provides an estimate of the mean value of source term and a confidence interval for it. Gamma dose rates from an inner ring of 'fence' monitors are used. The 24 values are measured and compared statistically with dose rates for a 1 Bq/s release under a variety of different atmospheric conditions which have been (pre)calculated using a Gaussian-puff dispersion model. Data which characterise the location of the detectors, source of release (dimensions of a reactor building, sensible heat) and meteorological conditions (wind direction, wind speed, stability class) were taken into account in these calculations. The ratio between measured dose rates and predicted dose rates is used via bootstrap methods to give the estimate of the source term.

The source term estimated by this methodology is an integral value. The isotopic composition of release is unknown during an accident and can be assumed only on the base of computational analysis. The results obtained on the base of sampling, e.g. post-accident sampling systems, are useful but these results are generally available much later than the data from the on-line environmental monitoring systems. Therefore, the (pre)calculated characteristics of isotopic composition of release are needed for a dose projection. Totally 54 sequences of the accidents and 46 corresponding isotopic compositions were evaluated for VVER 440/213 reactors for LOCA and containment by-pass releases. These sequences correspond essentially to the source term categories used in RODOS_STM, thus allowing the methods to be linked within a model chain in the RODOS system.

The second strand of development on source term estimation and prediction is under development and uses standard least-squares techniques to near-site gamma dose rate monitors. There are a number of constraints on its use. Firstly, it requires a number of simultaneous gamma dose measurements taken perpendicular to the main advection direction, and this implies that the positioning of early warning monitors may require some modification. Secondly, the quality of measurement from gamma detectors suffers seriously from contamination due to fallout (a problem common to all methods which use gamma detector data). However, it is thought that this will become a serious problem only for long duration releases. The least squares fitting is based upon the use of an atmospheric dispersion model, currently ATSTEP or RIMPUFF.

Currently the method is implemented in a Windows NT prototype. It is being ported into the RODOS UNIX environment and will include nuclide specific source term estimation based on:

- stack monitoring and an interface to the source term categories of RODOS_STM;
- weighing the fitted source term by the relative cloud composition given by in-situ gamma spectrometry measurements;

- the in-situ gamma spectrometry measurements based upon the semi-infinite cloud approximation and the inversion of a "home made" atmospheric dispersion model (using a sigma parametrisation developed at SCK•CEN).

A first version of this method has been validated against real-time Ar 41 emissions from the gas-cooled graphite-moderated BR1 reactor at SCK•CEN Mol and gives promising results (8).

Not only will a module be developed for use within RODOS, but investigations based upon the PC version will be made to identify reasonable dispositions of monitors around the plant and to identify the quality of prediction which may be expected on the basis of the quality and number of data likely to be available in the event of an actual emergency.

A sensitivity study has shown that the optimal location of gamma detectors should be at a distance of between 0.5 and 1.0 km. There should be a detector at least every 15 degrees around the advection direction to ensure not too high uncertainties (9)

3.5.3 Data assimilation within atmospheric dispersion models

The next stage in the decision support process requires that the predictions of atmospheric dispersion models are updated in the light of early monitoring measurements. This can be done either by using the measurements to estimate the source term and then running the dispersion model with the better estimated source term or more directly by using the measurement to update parameters (including those relating to the source term) within the dispersion model itself.

Within the project a prototype BayesRIMPUFF has been developed. This is a modification of the RIMPUFF module, which uses novel dynamic belief net methodology to update predicted concentrations, deposition and dose rates in the light of monitoring data. The theory of the method has been described extensively elsewhere (10, 11). Moreover, the approximations and algorithms have been compared against more exact but much more time-consuming methods and shown to be satisfactory (12). The current prototype software is only applicable to single nuclide releases under a single layer wind-field. Further developments are directed towards dealing with:

- the more detailed wind-fields and other meteorology provided by the PAD pre-processor within RODOS;

- multiple nuclide releases;

- gamma dose rate monitoring and integrated air concentration data in addition to the instantaneous air concentration currently developed.

One of the strengths of BayesRIMPUFF is that the model naturally accepts the output of RODOS_STM and can deal with monitoring data from stack, periphery, near site and distant monitoring. Thus, it naturally provides an ASY model chain which combines all the methodology described immediately above.

RIMPUFF is a near range atmospheric dispersion model. As noted above it is being linked in RODOS to MATCH, a long range model. A version of MATCH already exists which uses the adjoint method to assimilate monitoring data. These methods are fully compatible with the Kalman filtering and dynamic belief net approaches used in BayesRIMPUFF. Thus, the Bayesian approach should be extended to long-range modelling shortly.

3.5.4 Data assimilation with hydrological pathways

The spread of contamination is not solely via the atmosphere: hydrological pathways are important too. The suite of hydrological pathway models within RODOS has been described above. One of the next steps in the project is to develop and integrate suitable data assimilation techniques into these. For the RIVTOX module for river flows, this is a natural way of doing this. Rivers flow with time and the dispersion is essentially unidirectional. A simple statistical updating module is currently under development to update the predictions of contamination downstream from the points at which monitoring measurements have been taken.

However, for lake and ground water runoff models, the issues are more complex since the dispersion is far from unidirectional with time. An initial examination of the numerical solutions of dynamic systems models used within these modules suggests that Kalman filtering techniques might enable a Bayesian approach to be tractable. But much further work is needed.

3.5.5 Methods for interpolating in databases of ground monitoring measurements for the intermediate and later phases

Once engineering actions have stopped the release and the plume has passed, estimates of the contamination and uncertainty bounds upon these must be built more upon databases of monitoring data and less upon model based predictions. Currently ways of achieving this are being investigated using spatial statistics and techniques such as krigging. One important feature that must be achieved in any system for doing this is that the predictions based upon atmospheric dispersion and deposition models must move *smoothly* to those based solely upon monitoring data. Otherwise (apparent?) inconsistency may arise in the advice given to the public and this may lead to a loss of public confidence. Indeed, the decision makers themselves may reject the forecasts made by the system. Fortunately, the methods intended for use are based upon weighted averages and usually exhibit such smoothness of transition.

Currently a module is under development to interpolate in ground contamination data (13). The model is 'primed' with deposition data from the atmospheric dispersion models (see upper part of Figure 3.5.5). As the number of ground contamination measurements increase with time, the weight placed upon them with the model increases so that with sufficient data collected the weight placed upon the atmospheric dispersion model's predictions will diminish to (effectively) zero.

Across the project a number of groups are experimenting with a variety of similar spatial interpolation and krigging methods, both with the intention of developing modules and, perhaps more importantly, to gain an understanding of the quality and errors inherent in using such methods.

3.5.6 Uncertainty and data assimilation with the food dose module

A crucial task of RODOS is to predict the radiation exposure of the population during and after an accidental release of radionuclides to the environment. The transfer of radionuclides through the food-chain into foodstuffs is modelled in the Food Chain Modules and the resulting radiation exposure is calculated in the Dose Modules: see lower part of Figure 3.5.5. The improvement of the model predictions by assimilation of measurements is one of the main tasks for the project in the current framework program of RODOS. This assimilation of measurements is performed in two separate so called 'Monitoring Modules', the Deposition Monitoring Module (DeMM) and the Dose Monitoring Module (DoMM).

The DeMM is designed to update the predictions for deposition to plants and soil, which are calculated in the deposition module. Input to the DeMM are predictions from the atmospheric dispersion modules - mainly activity concentrations in air and wet deposited activity - and predictions from the deposition module, e.g. deposition to soil and various kinds of plants. Furthermore, measurements from online radiological monitoring networks, e.g. gamma dose rates, air concentrations, rain intensities etc., and from measurement campaigns like activities of soil samples, plant samples and results of in situ gamma spectrometry are input to the DeMM. These measurement data are stored in the RODOS online database by the operating subsystem OSY and can be accessed there via the Database Manager of RODOS. Some of the measurements can be compared directly with model predictions, some other have to be processed to give comparable values:

- Gamma dose rate measurements over different kinds of surfaces (e.g. lawn)

  → calculation of ground contamination from measured dose rate, nuclide spectrum, type of surface;

- In situ gamma spectrometry over different kinds of surfaces

  → contributions of different nuclides to total dose rate (nuclide spectrum), calculation of ground contamination

- Activity concentrations in samples of soil and plants

  → calculation of originally deposited activity on plant surfaces

The DoMM is designed to update the predictions of the food chain module and the dose module. These results are mainly activity concentrations in feed-stuffs and foodstuffs and all kinds of external and internal doses and dose rates. Besides these model predictions various kinds of measurements are input to the DoMM, e.g. activity concentrations in feed- and foodstuffs, whole body measurements, personal dosimeters, and stationary dose rate measurements.

The measurements are recorded, stored and provided to other modules by the RODOS Database Manager. As in the DoMM some of these measurements have to be processed before they can be compared with the model predictions:

- activity concentrations in feedstuffs

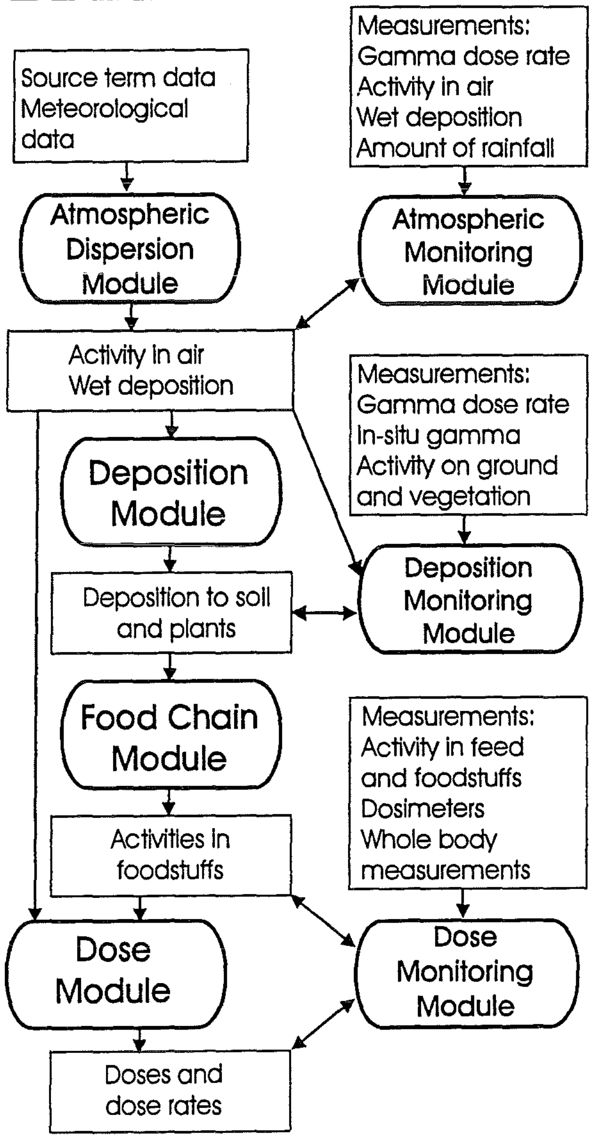


Figure 3.5.5:The conceptual structure and interactions of the deposition, food-chain and dose modules

→ direct comparison with predicted concentrations in feedstuffs

- activity concentrations in foodstuffs

    → direct comparison with predicted concentrations in foodstuffs

- whole body measurements

    → comparison with sum of activity intake by inhalation and ingestion

- personal dosimeters

    → comparison with sum of all doses

- stationary dose rate measurements

    → direct comparison with predicted external doses from cloud and ground

The general methodology for data assimilation in these modules has been developed in several steps. First, the methodology of data assimilation in the German decision support system PARK was reviewed (14). As the PARK concept of data assimilation is not fully compatible with that in RODOS, new algorithms and methods have been developed and are being validated against PARK. A test scenario has been developed for this comparison. This test scenario contains simulated results of atmospheric dispersion calculations, e.g. air activity concentrations, wet deposited activity, etc., on a regular grid and also simulated measurements of gamma dose rate measurements off the grid (15). The next step was to identify some key parameters of the model calculations such as wet deposited activity and harvest time. Based on a detailed sensitivity and uncertainty analysis these key parameters were identified and uncertainty bounds for each of them were defined. This analysis is based on a Monte Carlo method (including correlation information).

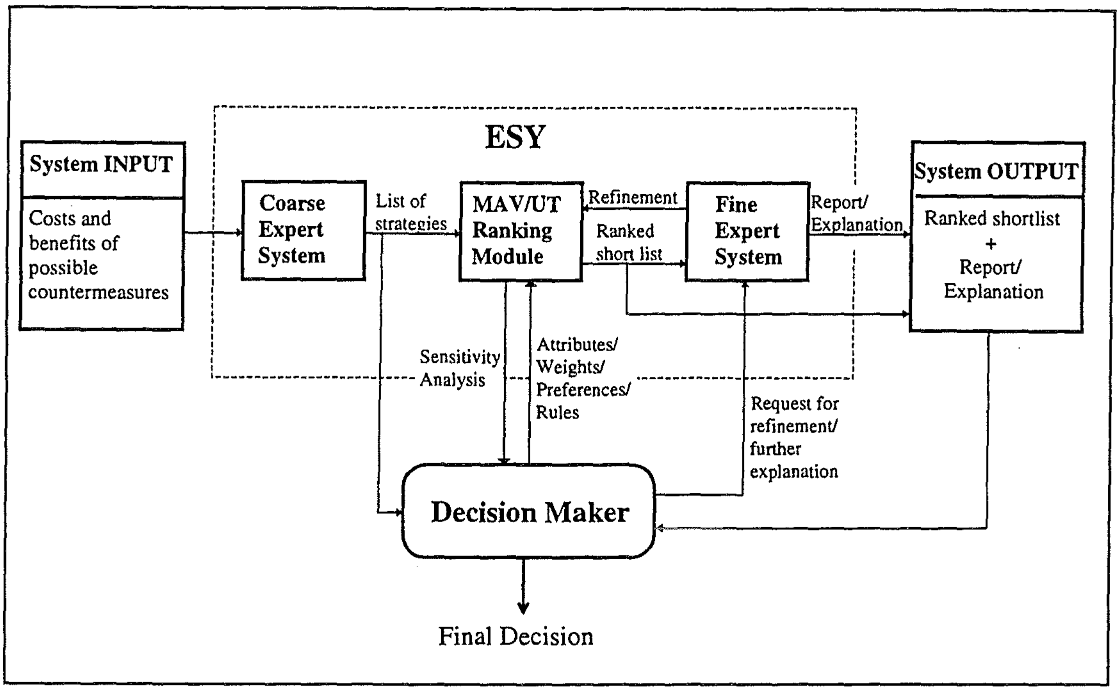
Based on this preparatory work a Bayesian hierarchical model for data assimilation in the deposition module has been developed. This allows for the combination of information from any kind of source like predictions from model calculations, direct measurements from

Figure 3.5.6: The conceptual structure of the ESY module.

monitoring stations or expert judgement. Other advantages are that such a model can be easily adapted for other parts of the model calculation in FDM, and it allows for a smooth transition from pure model predictions to data measurements when more and more data becomes available. Simplifying assumptions were made to derive linear approximations of the formulae of the deposition model and – as a first step – a spatial Bayes model for a fixed point in time was developed, which is able to update the predictions from the atmospheric dispersion modules on ground contamination with gamma dose rate measurement data (13).

3.5.7 Development of the evaluation subsystem modules (ESY)

The task of an ESY module is to help the decision makers choose between different countermeasure strategies in the light of their likely success against a number of criteria. Issues that should be considered during this stage include feasibility, resources required, public acceptability, and social, psychological and political implications in addition to the amelioration of health effects. Discussion of attributes which have been used or proposed for evaluating countermeasures may be found, *inter alia*, in French (16), French, Halls and Ranyard (17) and French, Harrison and Ranyard (18). Whereas ASY and CSY modules may implement different models during the course of an accident depending on time, location and



context, the ESY may be based upon the same software modules with the attribute trees and weights changing over time.

The ESY will have the form of Figure 3.5.6. It is split into three further subsystems:

- a coarse expert system (CES) filter which rejects any strategies which are logically infeasible or do not satisfy some given constraints;

- a multi-attribute value and utility theory (MAV/UT) ranking module which takes the remaining list of strategies and ranks them according to their effectiveness against the attributes;

- a fine expert system filter (FES) which takes the top 10-15 strategies and produces a report detailing the pros and cons of each.

An ESY module has as input the costs and benefits of possible countermeasures which were identified and quantified by an appropriate CSY module. Thus, the consequences of applying countermeasures such as the issue of iodine tablets, sheltering, evacuation, temporary and permanent relocation, food bans, decontamination measures and changes in the agriculture to contaminated areas need to be calculated. In considering the links between ESY and the earlier ASY-CSY model chains it is useful to distinguish two modes of use of the RODOS system[1]. Note that there is risk of a terminological confusion with the automatic and interactive modes of operation of RODOS. Here the discussion concerns a mode of activity and use of RODOS in the decision support process, not a mode of operating the RODOS system

In the *exploratory* mode, the analysts (perhaps without the decision makers being immediately available) will run one or more ASY-CSY chains against one or more scenarios

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[1] Note that there is risk of a terminological confusion with the automatic and interactive modes of operation of RODOS. Here the discussion concerns a mode of activity and use of RODOS in the decision support process, not a mode of operating the RODOS system

(i.e. sets of source term, meteorological conditions, etc.) to size or scope the issues and to get a feel for the scale of the emergency and the potential need for and effectiveness of various countermeasures in the particular context of the accident. In short, they will explore what is happening, what may happen and what steps might be taken to mitigate the effects. In the *decision* mode, the analysts *and* the decision makers will actually be seeking to make one or more decisions. Thus they will run (ASY)-CSY-ESY chains. The ASY is in parentheses because that part of the chain may have been run under exploratory mode and simply picked up from the database. Exploratory analyses may be run using the automatic or interactive operating modes of RODOS. Decision analyses may be only be run in interactive mode.

These modes of analysis both match how RODOS is extended to be used and also reflect the computation that will be required. In exploratory mode the analysts are likely to calculate many quantities to gain a feel for the accident: in decision mode the calculations will focus on just those attributes which may be needed in the evaluation of alternative strategies. Thus the CSY is 'different' in the range of its calculations when run in exploratory and decision modes.

Within the ESY, the CES discards all strategies that do not follow some 'coarse' feasibility rules or other constraints related to their acceptability. By decreasing the number of strategies the computational time needed to evaluate them by later ESY modules is considerably reduced. This is vital because the number of portfolios of countermeasures can grow exponentially. For instance in a supporting analysis for early phase measures (sheltering, issuing of iodine tablet and evacuation) which may be implemented in 17 distinct emergency planing areas, there are potentially 2^{51} countermeasure strategies. The current CES module, which is built upon constraint satisfaction methods, reduces those worthy of further consideration to under 1000 in about 95% of tests. Detailed description of the prototype CES module, which is based upon constraint satisfaction techniques, may be found in Papamichail and French (19).

The countermeasure strategies which satisfy the constraints of the CES are passed to the MAV/UT module. Currently two such modules are being developed: HERESY and M-Crit. Both operate interactively through graphical interfaces to communicate with a variety of DMs who may possess qualitatively different skills and perspectives. They rank the countermeasure strategies and produce a short list. Intuitive justifications for choices and underlying uncertainties inherent in the predictions will also be provided via the FES. Thus the system will support decision makers in modifying rules, weights and preferences and other model parameters as well as in understanding the consequences of each change. The FES will generate reports which will give a detailed commentary on each proposed countermeasure strategy, explaining its strengths and weaknesses.

The MAV/UT ranking module HERESY makes heavy use of interactive sensitivity analysis to confirm that the strategies in the final ranked list are worthy of careful consideration. To provide such sensitivity analysis, strong assumptions have to be made about the form of the decision makers preferences. The M-Crit module takes a different approach. It makes weaker assumptions, but in doing so can offer much less sensitivity analysis. Comparisons are underway to evaluate the judgemental demands that each place on the decision maker relative to the support that they provide.

There is considerable complexity in the interactions with the decision makers:

- They may not be convinced by the output of the MAV/UT ranking module and/or feel that there are some issues which need further explanation and clarification.

• Initial preferences, weights, attributes and rules will be encoded into the system. However, RODOS is designed to support decision making throughout all phases of a nuclear accident. Each phase has its own requirements and different types of decisions have to be taken each time. Thus there will be a need to adjust these parameters in an exploratory and informative manner.

• In a nuclear emergency, there will be a variety of decision makers with qualitatively different skills and perspectives such as plant managers and senior politicians, along with their advisers – but there may be no decision analyst available to explain the output of the model. The users may perceive decision theory as a black box and may not understand how information is elicited.

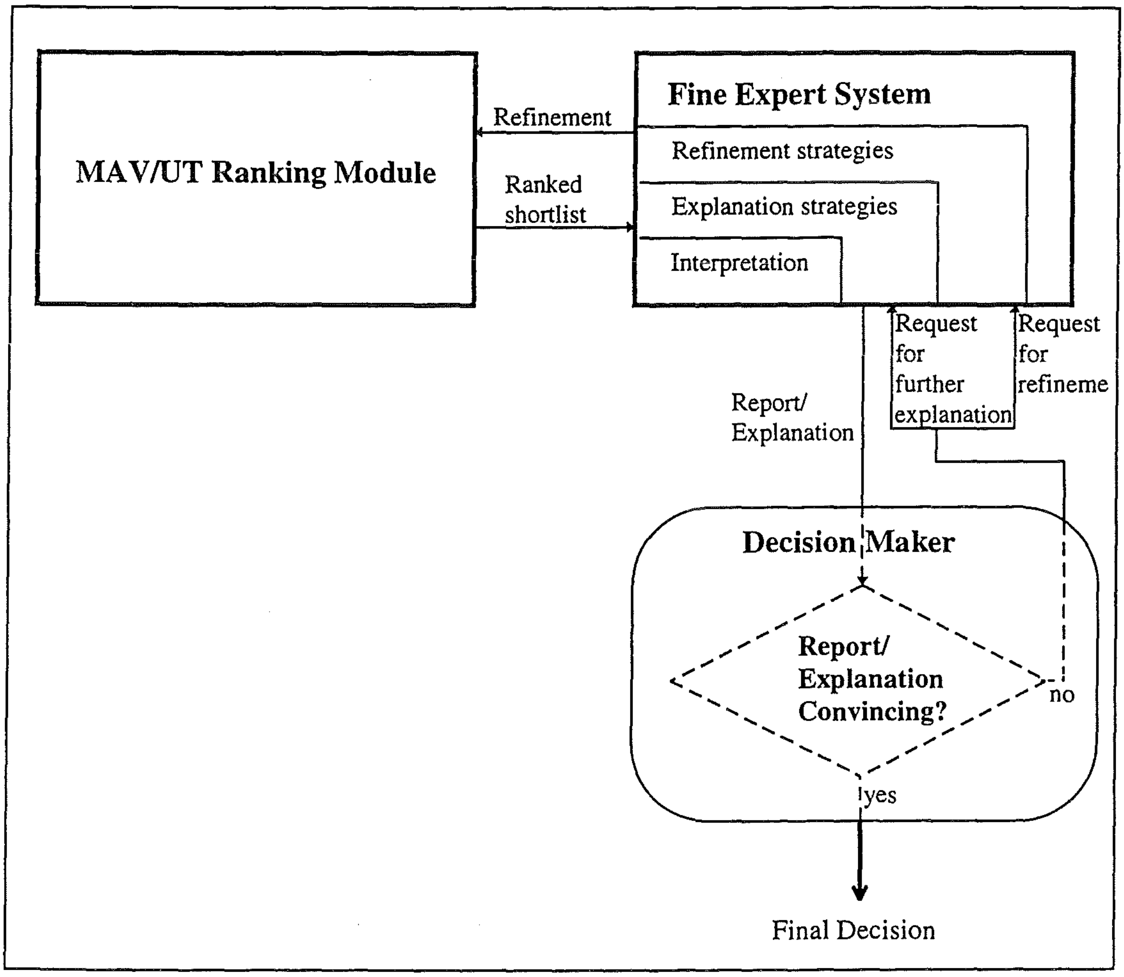

Figure 3.5.7: The fine expert system.

The FES addresses some of these issues; the remaining ones will need the skills of the analysts to facilitate a solution though communicating the issues clearly and succinctly. The design of the FES is influenced by interpretative value analysis described in (Klein, 1994). This framework uses knowledge-based methods and heuristics to describe value-systems. It increases the transparency of multi-attribute theories by embedding them in a framework for explaining and refining value-based choices. The FES (see Figure 3.5.7) consists of:

- interpretation which will analyse and interpret the model;

- explanation strategies which will provide the user with sufficient insight into the system's operation by giving a critique of each strategy and justifying choices;

- refinement strategies which will assist the user in identifying faulty parameters and correcting them.

The FES takes as input the ranked short list of the top 10-15 strategies. The small number of strategies allows a full set of explanations to be developed. If the decision makers find the explanation convincing then they are ready to take a final decision. If not, they can either request further explanation from the fine expert system or refine the model.

3.5.8 The needs of the decision makers

In order to test and develop the ESY, a programme of workshops is being held with potential decision makers across a number of European countries. To date, five have been completed and three further are being organised. Actually one of the remaining three has been held, but the results are still being analysed. In each workshop the emergency managers who would be responsible for the countermeasures are presented with an hypothetical accident scenario in their own region of responsibility. The five workshops held and analysed to date have focused on early phase decision making. Uncertainty on the timing of any release and shifting wind direction meant that there was considerable uncertainty as to the size of the population at risk. The RODOS system was used to simulate the accident and outcomes, with and without possible protective actions. Thus, support at levels 0, 1 and 2 was provided. The intention was to interrupt the exercises at appropriate points and reflect upon the level 3 support required and the attributes that would concern them in evaluating the different strategies. Several observations may be drawn, although it is, of course, a moot point whether the observations should be attributed to the use of RODOS or the workshop format which did not parallel faithfully the current emergency management procedures in any of the countries.

- The decision makers generally found level 0,1 and 2 support very useful. Indeed, simply the interactive level 0 support of using a geographic information system was novel and thought to be valuable in itself. 'What-if' analyses, which are possible with level 1 and 2 support were used extensively.

- The advent of decision support systems such as RODOS, with their potential to support more detailed analyses and 'what-if' simulations than before, mean that the emergency management structures in some countries or organisations might need revision to allow more interaction between technical experts and decision makers.

- The introduction of uncertainty into an exercise was very discomforting to the decision makers. None found the expression of this uncertainty in terms of probabilities useful. Generally, they adopted the heuristic of assuming that all the area at risk would be exposed: i.e. they effectively assumed a much larger and broader plume than formed by any release.

- Issues relating to the equity of treatment of different sub-populations were of considerable concern. Was it right to evacuate rural regions when it was quite infeasible to evacuate a highly populated urban region which was equally at risk in terms of individual dose?

- No group has been able to articulate a complete and explicit set of criteria for early phase decisions. This is not to imply irrationality or lack of careful consideration upon their part; just that they did not find it natural to think in terms of the multi-attribute models currently planned within RODOS and which have seemed of considerable value in medium and longer term decision making.

- Generally, no group felt in need of level 3 support. They felt able to make the decisions required of them without detailed modelling and exploration of their value judgements.

The last two points suggest perhaps that either the provision of level 3 support in the early phase is unnecessary or that the design of such support within RODOS is inappropriate. We are currently evaluating the evidence in this respect. However, we would point to two further possibilities. Firstly, the provision of a DSS to help them was so novel in itself that the decision makers were not sufficiently 'acclimatised' to realise the benefits of level 3 support. There is a considerable body of evidence that *consistency* in decision making is of vital importance if public confidence is to be maintained. Within decision support systems, it is level 3 support which 'polices' consistency. Thus there may be reasons for national authorities to 'impose' level 3 support on the local emergency managers. Secondly, some of the difficulty may lie in conventional approaches to multi-attribute modelling. Essentially standard methodology holds that *all* outcomes should be described against the *same* attributes or dimensions. Only then, it is argued, is it possible to compare outcomes consistently. When decisions are made under the threat of a major release, however, it is difficult to model the decision makers' judgements in this manner. The context after an accident is so different from the context after one has threatened, but been averted, that different sets of attributes are needed to represent the decision makers' judgements. The decision makers are aware that their decisions will be discussed with hindsight very differently in the event that there is no release to the event that there is one. Currently, event conditional attribute modelling is being tested as a means of representing this *anticipated regret* phenomenon (French, Ranyard and Harrison, 1997). Finally, the issue of uncertainty and the decision makers reluctance to consider it explicitly remains a significant issue. That major uncertainties will exist in the early phase of an accident is beyond doubt. It seems a natural and ethical requirement, therefore, to design RODOS to present these uncertainties clearly to the decision makers. Our problem remains how to do this.

3.5.9 Validation

The project team has an obligation, both moral and contractual, to ensure that the RODOS system is fit for the purpose of supporting the emergency management. 'Validation' is used to mean this process of checking fitness for purpose in the broadest of senses. It is not an easy task. Indeed, arguably it is an ill-defined one. Moreover, in a project undertaken by many institutions in many countries, there are special difficulties. Note that validation of decision support is distinct from software verification of decision support systems. Verification checks whether a system calculates and presents accurately what it was designed to do. Validation does more than that: it checks that it does something useful. A validated system is necessarily a verified one; but the converse is not necessarily true.

The aim is to support emergency management decision making, so in validating RODOS the following questions are relevant:

- What outputs from RODOS *do* the decision makers want?
- What outputs from RODOS *should* the decision makers want?
- Do the decision makers understand the outputs?

- Do the outputs actually help the decision makers?
- Are we making cultural/organisational assumptions inappropriate to some users?
- How accurate are the predictions, allowing for all forms of error?
- How sensitive are the outputs to variations in the incoming data?
- How timely is the support?
- Is it possible to obtain the data?

The exercises in the previous sections are helping address the first four bullet points. Other studies are being undertaken to test the individual data assimilation algorithms on specific data sets and to compare their performance against more exact algorithms which do not need to run in real-time.

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3.6 Training and exercises

3.6.1 Training courses for users of the RODOS system

The aim of courses for RODOS users is to introduce and aquaint the participants with the functionality of the system, the user interface, data input, the available results and their representations. Upon successful completion, the participants shall be able to run the system by themselves with the help of the user guide and the training material provided with each course.

The first „Training course for German speaking future users of the decision support system“ was held at Forschungszentrum Karlsruhe, Institute of Neutron Physics and Reactor Techniques (FZK/INR) in February 1997. Key elements were two training blocks of one day duration each for the operation of RODOS for emergency management applications (analysing and countermeasures subsystems ASY and CSY). The training blocks were framed by two half days of introduction and demonstrations also of system components exceeding the scope of the course.

3.6.2 Training courses in radiological protection and emergency response using RODOS as a training tool

The use of the RODOS system as a didactic tool for training and education in radiological protection and emergency management is one of the objectives of the RODOS project. For this task field RODOS is well suited because it offers information relevant for the evaluation of both the radiological situation and the consequences of possible countermeasures throughout all phases of a nuclear accident, and because it´s system architecture makes the implementation of scenarios relatively easy. These properties allow to use RODOS for a broad spectrum of training purposes with respect to learning aims and target groups and facilitate the adaptation, testing and optimisation of individual training scenarios.

To demontrate the usefulness of RODOS for training and education applications, two computer based training courses for decision support for off-site emergency management are developed, one for the early phase and one for the later phases of a nuclear accident. The courses are concerned with the estimation and evaluation of the off-site radiological situation following a nuclear accident and how this can be managed through the timely and effective introduction of appropriate countermeasures; whereby, the early phase course focusses on the emergency actions sheltering, evacuation, distribution of stable iodine, and the later phase course on the countermeasures relocation and agricultural countermeasures including decontamination and waste management. Particular attention is given to accidents in LWRs involving the release of radioactive material to the atmoshpere, although the principles addressed are applicable to other types of nuclear accidents.

The general intention is to convey principles of radiation protection and off-site emergency response as well as to demonstrate the functionality and applicability of the RODOS system. There are three basic design objectives:

- The transfer of knowledge should be selective and praxis oriented.
- The participants should actively exercise as much as possible by themselves.
- A demonstration of the role and usefulness of RODOS as a decision aiding and training tool should be intervoven with the course.

To meet the objectives, a syllabus for the lectures is used to provide a means of control for the topics covered therein. Practical sessions are designed in which the participants can address the topics covered in the lectures and collect and consolidate experience through the evaluation of a variety of accident scenarios. During these sessions, RODOS is used as a tool to provide the technical input for the problems considered. However, RODOS is operated by experienced course staff, so that no computer skills are required from the participants. The hardware and manpower available for this mode of operation limits the maximum number of participants to thirty.

The development of the *early phase* course was finished in 1996, and the course was included in the European Radiation Protection Education and Training (ERPET) activity of the European Commission. It was held for the first time in April 1996 at the Fortbildungszentrum für Technik und Umwelt (FTU) at FZK under the name "Computer-Based Training Course on Off-Site Emergency Response to Nuclear Accidents"(1), and was repeated with minor modifications in November 1997 at FTU under the new name "Computer based training course: Decision support for off-site emergency management in the early phase of a nuclear accident". From discussions with the participants and from the "Questionnaire for the Follow-Up Evaluation of European Training Courses" it could be deduced that both courses were well received by most of the participants.

The above early phase course was designed mainly for participants from member states of the EU with the additional intention to create a corresponding separate course for participants from East European countries. As a first step in this direction it was decided to adapt the original course for participants from the former Soviet Union and to held this course first at the Federal Environmental Emergency Response Centre (FEERC), Scientific Production Association „Typhoon", Obninsk. The activities for creation of the course comprise the translation of the lectures of the original course and the adaptation of the computer based software into Russian, the development of computer based exercises specific to local conditions, and the preparation of material which covers aspects of emergency preparedness and management in Russia.

The "Computer based training course: Decision support for off-site emergency management in the *later phases* of a nuclear accident" is currently being developed. Work until now consisted of the definition of the target group and of the preparation of a first complete draft of the lecture syllabus and a list of proposed lectures. This material is currently undergoing an independent review to ensure the consistency of the syllabus and the coherence and relative weights of the different lectures.

3.6.3 Application of the RODOS software package in decision conference settings

In order to study and improve the applicability of the decision support system RODOS in general and it's evaluation subsystem ESY in particular, a programme of workshops called " decision conferences" is being organised with decision makers and technical experts responsible for emergency management. Main objectives of these conferences are:

- identification and study of criteria, attributes and their weights which describe the decision makers` thinking in evaluating countermeasure stragegies;
- determiniation of firstly what information technical experts are looking for and what information is desired by decision makers, and secondly, of how the RODOS software package can optimally be developed and applied to satisfy such needs.

Three separate activities are undertaken in this area for the early, intermediate and later phases of an accident; activities on the first two phases have already started.

3.6.3.1 Decisions in the early phase of an accident

Four meetings with different sets of participants have been organised in Finland. In the first three meetings no uncertainties or threat phase were considered, that means, everything was assumed to happen as described in the given scenario. The theme in the fourth meeting was the inclusion of uncertainties. All information was calculated by the RODOS software.

The first and the second meeting were held with experts involved in emergency management from the organizing institution only. In the first meeting the formalities a of decision conference were not followed, rather, the aim was to evaluate the attitudes to value-focused thinking, to test and explore the meeting methods for the oncoming events, and to study through discussions on values which the decisions on early protective actions are based.

In the second meeting the procedures of a decision conference were followed more closely. The primary aim was to structure the hierarchy of attributes and set weights on them without elicitating any probabilities. In addition, some particular research tasks were prepared for discussion in the meeting, for instance, "is it feasible to recommend different kind of countermeasures to different subgroups of the population", or,"which one would be a more appropriate measure: radiation dose, reduction in life expectancy or number of cancer cases caused by radiation". Furthermore it was studied whether it could be avoided that the decision makers immediately anchor to the internationally recommend intervention levels: an alternative procedure would be first to define attributes, trade-offs and then, secondly, to set intervention levels applicable in the given situation, and afterwards to compare the assessed values with international intervention levels.

The third meeting was held with experts involved in emergency management, representatives from the Finnish nuclear power plants, and a social-psychologist expert. The meeting was started by giving the value tree and values elicited in the second meeting. Then the hierarchy of attributes was restructured, the values of the attributes were revised and, finally, personal trade-offs were derived.

The fourth meeting was similar compared to the third meeting but this time uncertainties were the main issue: How could probabilities be handled and how could they be used in the analysis. The uncertainty to be considered was the release fraction distribution for a given containment event tree branch and the estimated uncertainty in values of model predictions (it was known that a release will happen).

Although the results of the meetings are not yet analysed, some findings however can already be mentioned. Lot of information was prepared in advance for the meeting but less than expected were needed to make the decisions on the protective actions considered. Only a few times some additional information was requested to be calculated during the meeting with RODOS. Once it was recognised that no deterministic effects would be observed the information considered was the number of radiation induced cancer cases with and without actions and the costs of the actions. It was especially desired to get the number of thyroid cancer in children, because thyroid cancer could easily be seen later in the statistics. The number of leukaemia cases was also requested.

It was told to the attendees that a RODOS prototype version was used for the meetings and suggestions for improvement of the system would be put forward. For example, almost all calculations were performed based on a 4km x 4km grid size which proved to be too robust considering for instance demographic data bases and close to the NPP areas. Also because of administrative practices in Finland it was desired to define all early phase protective actions based on a selection of municipalities. This kind of area definition was not possible with the used version of RODOS.

3.6.3.2 Decisions in the intermediate phase of an accident

The structure and work plan for a decision conference in the Netherlands on the intermediate phase of an accident has been elaborated and discussed between Dutch organisations. The conference will take place in spring 1998; about 10 members of the Netherlands' emergency organisations in addition to observers will attend the meeting. Part of the participants have a bio-medical background. RODOS will supply information to be presented to the participants. Special subjects to be discussed during the conference will be:

- where and when/ foodban and control on agricultural products and drinking water supplies;
- decontamination and waste;
- relocation.

3.6.4 Development of a guideline for the preparation, organisation and evaluation of emergency exercises

The quality and usefulness of a decision support system such as RODOS has to be tested during emergency exercises which simulate as closely as possible the reality of a crisis situation. The aim of the envisaged guideline is to help in the preparation of such exercises. It will describe, according to the type of exercise, the different tasks and means and gives recommendations for the preparation of the scenarios. In comparison to a similar guideline already published (IAEA Recommendation Guide N°73, 1987), the present one is aimed to be more practical, taking advantage of the experience gained since 10 years on the preparation of exercices in different countries.

3.6.5 Scenario development

A RODOS scenario for training and education purposes consists of source terms, meteorological data, data about the initial radiological situations etc. which are specifically taylored to the corresponding applications. For the training courses and decision conferences already carried out with RODOS, existing source terms (e.g. from the German Risk Study Phase A and B and from the International Nuclear Emergency Exercise INEX 1), sets of emergency action parameters and specially developed meteorological scenarios were included in the RODOS data bases; this development will continue routinely as RODOS is used for new applications.

Moreover, in order to improve the applicability of the RODOS system for training and education in particular in Eastern European countries, two major activities are undertaken with respect to scenario development, which are described below.

1. **Elaboration of data on the Chernobyl accident to make them suitable for post-Chernobyl scenarios in RODOS:** As a basis for future training courses and exercises, data on the Chernobyl accident are collected and elaborated for generating post-CHernoby scenarios in RODOS. The collection of data distinguishes the territory of Ukraine and Belarus inside and outside the 30 km zone. The required data are ground and foodstuff contamination, information about early countermeasures, traffic net, population distribution, and doses rates. The data exchange is via RIF format.

2. **Construction of a set of typical source terms for NPPs of the WWER type for use in RODOS:** For applying RODOS to sites of nuclear power plants in Eastern European countries, typical source terms for WWR-440 and WWR-1000 type NPPs in a data format suitable for RODOS are being derived. As a first step in assembling a set of source terms for WWR-440 NPPs, accident sequences were investigated. This survey resulted in the suggestion of a subset of sequences for the calculation of source terms for .inclusion in training scenarios. Furthermore, preliminary source terms (released activities and the release heights) are available for four scenarios for design basis accidents.

3.6.6 Reference

1. Steinhauer: "Computer-Based Training Course on Off-Site Emergency Response to Nuclear Accidents" held April 1996 at FZK/FTU", Report RODOS(WG7)-TN(96)-01.

3.7 The RODOS polling and data exchange system

3.7.1 Background and objectives

The radiological consequences of the Chernobyl accident highlighted the need to establish or enhance the national radioactivity monitoring and information systems for emergency situations in most European countries. Based on the experience gained from existing bi- and multilateral data exchanges the European Commission (EC) has made provision for and is continuing to develop technical systems to exchange information of common interest.

Interfaces between these EC information systems and RODOS are being developed to provide RODOS users with access to international real-time data on-line.

Currently the EC foresees in two international information exchange systems:

- ECURIE (European Community Urgent Radiological Information Exchange), the official EC system, by which encoded information is exchanged in case of nuclear emergencies. The system is tested by means of regular exercises, to which the fifteen EU Member States and Switzerland participate.

- EURDEP (European Union Radiological Data Exchange Platform), a technical feasibility study, in which fifteen European countries (AT, CZ, DE, DK, ES, FI, GB, GR, IE, LU, NL, NO, PT, RO, SE) exchange every week gamma dose rate measurements, using mainly public email (SMTP). The system will be further extended with the participation of BE, CH, FR, HU, PL AND SK from early 1998 onwards .

The incoming messages of the ECURIE information exchange system are automatically recognised and uploaded into real-time databases at the JRC/EI (Joint Research Institute-Ispra, Environment Institute). Due to partial data transfer by email the EURDEP system still needs manual upload to manage the radiological information.

Within the RODOS project, a RODOS polling and data exchange system has been established. Further developments of the interfaces to the real-time databases are foreseen. Its main objectives are:

- to agree on procedures for establishing data exchange between RODOS participants and the JRC/EI

- to maintain regular data exchange using various communication means

- to regularly report on the outcome of the communication exercises

3.7.2 Polling and exchange concepts

Based on experience gained from the existing networks for radiological data exchange (ECURIE, EURDEP) at the JRC/EI different concepts for the RODOS information transfer were discussed. The liberalisation of the telecommunication markets on the one hand and modern technologies and innovations, which are provided by the computer industries and software companies, on the other, led to the development of a data exchange system, which fits with resources and needs of the RODOS contractors.

The ECURIE system is based on telex communication whereas EURDEP currently uses mainly public email for the transfer of the data. In both network the information need to be decoded into special formats: the CIS (Convention Information Structure) format for ECU-

RIE and the EURDEP format for the exchange of the EURDEP information. The frequencies of the data exchanges for ECURIE are two international exercises per year and a regular weekly data transfer for EURDEP.

The RODOS participants in the various countries should not be limited to a special format or only one communication channel. On the other hand the TCP/IP based computer communication is now widely used (e.g. Internet) and the TCP/IP protocol is a part of the RODOS system server by default. The most used information exchange utilities like file transfer, mailing system and web applications are based on the TCP/IP communication. A RODOS data exchange system based on the TCP/IP protocol fits into the RODOS philosophy for an "open system" with the design client/server applications. Furthermore the RODOS system includes a Real-time Data Format Converter. The data interpreter guarantees that a conversion of the information can be done. Where it is needed and a common format like CIS or EURDEP for the international data exchange is becoming obsolete.

Therefore the TCP/IP file transfer for the polling and data exchange tasks has been chosen as the concept for the international RODOS data exchange system. Email as a 'receipt acknowledgement' message will be sent in response to a successful information transfer.

3.7.3 The JRC/EI data exchange system using TCP/IP (FTP)

In order to set-up and maintain regular data exchange between the RODOS participants, file transfer procedures have been implemented at the JRC/EI. The software packages implement a callable interface to the ftp utility on the JRC/EI RODOS server (HP/Unix version 9.05), which is based on the ftp specification in RFC 959.

The Polling and Data Exchange Participants

The current RODOS data exchange set-up (status of December 1997) procedures polls four RODOS contractor computers (FZK-Germany, GSF-Germany, RISØ-Denmark, NCSR-Greece) in EU countries and four RODOS contractors (NRIRR-Hungary, IAE-Poland, IAP-Romania, TYPHOON-Russia) in eastern Europe.

Furthermore, NRPI, Czech Republic and STUK, Finland are transferring their information to the RODOS system at JRC/EI, Italy. The Bundesamt für Strahlenschutz (BfS) in Germany is also included into the RODOS polling and data transfer system. BfS provides information from the radiological German network IMIS, which is stored at the JRC/EI and forwarded to FZK and GSF, Germany.

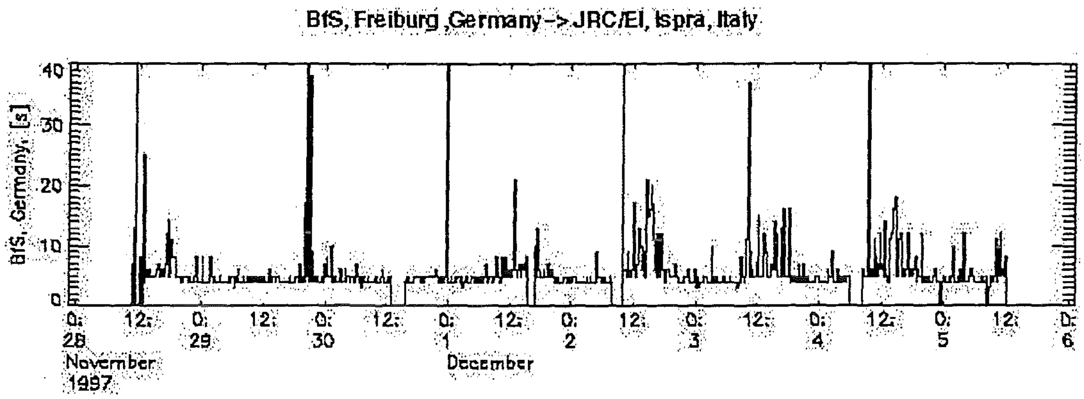
When the RODOS polling system detects information in the specified directory at the RODOS contact point server the data transfer procedure is triggered. For example if the data is transferred from GSF the RODOS polling and data exchange system gets this data and subsequently removes the file from the GSF server. Access and data handling is monitored and reported by the system. The information is stored in the directories of the JRC/EI RODOS server and, if requested, forwarded to other members of the RODOS project.

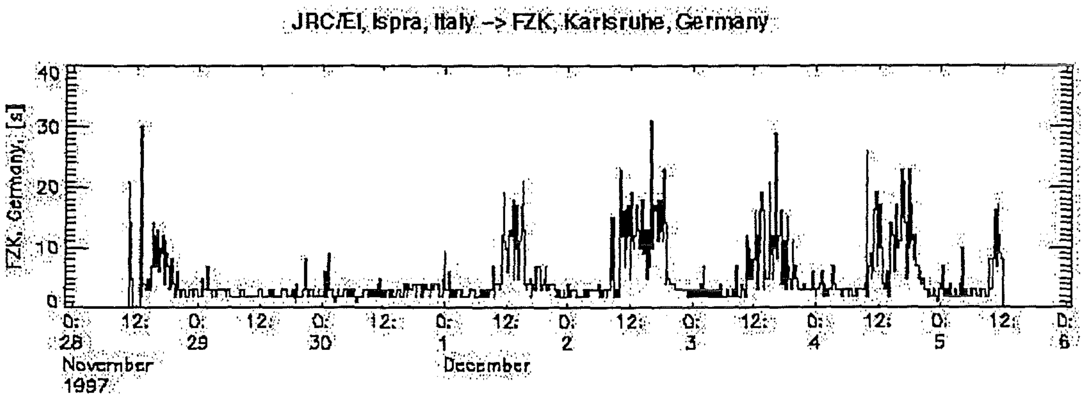
Acknowledgement by Email

An automatically generated email acknowledgement message is shown below. The message has been generated after the successful transfer of the German IMIS information from BfS via JRC/EI to FZK.

The Polling and Data Exchange Monitoring System

For every participant of the RODOS data exchange system and for every activity (polling and data transfer) the JRC/EI system monitors and stores the access and exchange results in log-files. The data transfer can be seen in figures below and is indicated by a pointer.





As part of the monitoring system the visualisation routines are started every five minutes after the execution of the polling and transfer procedures. The visualisation routines generate a graph of the access and transfer times for every RODOS data exchange participant and display the images on the RODOS web-pages of the JRC/EI-REM web-server (http://java.ei.jrc.it/rodos/com/rodos_mon.html).

This set-up enables all participants of the RODOS data exchange system to access the communication status. The graphs for the access and transfer times from/to FZK and BfS above, show, that the normal polling times are less than 20 seconds and depend on the time of day (higher access times can be seen during working hours). Data transfer times are normally less than 60 seconds. In general the polling and access times to RODOS participants are normally up to a factor 2 higher than to RODOS participants in the EU member states.

Further Developments

The current RODOS polling and data exchange system is based on TCP/IP (Internet) communication and shows a practical solution for transferring information frequently between the different members of the RODOS project. In addition, the possibilities to visualise not only the results of the communication, but also the information itself can be performed using web technologies.

The security and reliability of the data transfer could be improved by using dedicated lines (ISDN, point-to-point connection) instead of the public Internet. Furthermore, a user-friendly and intelligent RODOS communication system could be developed by using web-agent technology.

A future scenario for the web-agent based RODOS data exchange system could contain:

- TCP/IP based communication
- Message routing
- Applet communication through web-browser
  (Netscape Navigator, Internet Explorer, etc)
- Persistent socket connection with time-out
- Support of stand-alone applications and applets
- Secure connection with Agent Name and Password
- In-build FTP Clients

3.7.4 Conclusions

Based on experiences gained from ECURIE and EURDEP, the RODOS network system, based on the TCP/IP utilities of the RODOS servers and the communication channels of the public Internet has been established. The procedures include an acknowledgement via email and a monitoring visualisation published on the web-server of the REM group.

The reliability and security of the data exchange between participants in the RODOS project will be further investigated. To avoid uncertainties of data transmission through the public Internet a router network could be installed. In this case, a communication/routing gateway would be established at JRC/EI. The RODOS contractors will then be able to connect directly to the router via ISDN (digital) or modem (analog).

3.7.5 References

1. M. De Cort, H. Leeb, G. de Vries, L. Breitenbach, W. Weiss "International Exchange of Radiological Information in the Event of a nuclear Accident - Future Perspectives", Proc. 1st International Conf. of the European Commission, Belarus, Russian Federation and Ukraine on the Radiological Consequences of the Chernobyl Accident, Minsk, Belarus, 18-22 March 1996, EUR 16544, 1996, p. 1159-1169

2. M. De Cort, G. de Vries, L. Breitenbach, G. Dubois "EURDEP: a System for Radiological Data Exchange in Europe", Proc. 6th Topical Meeting on Emergency Preparedness and Response, San Francisco CA, April 22-25, 1997

3. M. De Cort, G. de Vries, L. Breitenbach "Real-time Monitoring of the Environmental Radioactivity in Routine and Emergency Conditions: The EC Radiological Information

Exchange System: Present Status and Future Developments" Poster ETEX Symp. On Long-Range Atmospheric Transport, Model Verification and Emergency Response, Vienna 13-16 May, 1997

4. M. De Cort, G. de Vries, L. Breitenbach, G. Fraser and S. Vadé, "International exchange of radiological information in emergency conditions" Proceedings of the IRPA regional symposium, Prague, 8-12 September 1997 (in print).

3.8 The European database

In previous work at the IPSN (Bonnefous et. al., 1990) a database was established of population and agricultural production data referenced to an equal-area grid. The database was provided with text-based and graphical query interfaces. The grid was implemented to provide a common spatial framework for heterogeneous data so that these data could be easily used as input into models developed for the RODOS system.

The present work extends the former European database design to use Geographical Information Systems and Relational Database technologies. The term GIS is applied variably to a range of functions, data and organisational components which collectively aid the capture, storage, analysis and visualisation of spatially referenced data. The uniqueness of GIS as distinct from other information systems arises from the geo-referencing of its data (that is, data have a geographical location). This offers a range of new techniques for the analysis and visualisation of that data. Importantly, in the context of the present requirements, spatial referencing provides a basis for integrating heterogeneous data.

The thematic aspects needed for the models in the decision support system have been defined and the subsequent search for pan-European data-sets has been started and will continue until the end of the RODOS contract.

3.8.1 Background and Objectives

The previous European database, based on Paradox and Microstation software, stored data referenced to an equal area grid. The grid was constructed by partitioning the European Union by lines of longitude at a constant spacing of 1.5 degrees and lines of latitude spacing calculated to maintain an area of 10,000 km2 for each cell across the surface of the grid. Further sub-divisions were made by dividing each side of these large cells into 10 equal parts. The finer grid cells were originally maintained for areas which were estimated to be "more critical" which could be potential sources of pollution or for "very non-homogeneous meshes" such as coastal areas. Cells were labelled according to the method described in "Evolution of a European Database" (1). These labels provided a key to records in the database on agricultural production for Europe.

Formerly the term EUROGRID, was used to refer to "the whole set of data and packages" (packages here refers to database management software and to software for browsing the European database). However in this document, EUROGRID is used to refer only to the reference grid. The data about themes of interest to the RODOS project, are referred to collectively as the RODOS GIS data.

The RODOS GIS design was based on the following objectives. Firstly, and of primary importance, users of the RODOS GIS must be able to gain easy physical access to data of interest to the RODOS modelling activities. Additionally, they must be able to browse and query all the data that have potential relevance. The browsing system must be easy to use and intuitive. The system must give clear information about the quality of the data, that is, its fitness for use within the context of the RODOS requirements. This will include not only information on the source and processing history but also on the detailed thematic content of the data. The system must provide an accessible means for extracting the data from the database in a convenient format. Finally, the system must be both flexible and extensible. Flexible, to accommodate future changes in RODOS users' requirements; extensible, to facilitate the increasing expansion of the database without any significant re-structuring. In summary, therefore, the system must be convenient for both its users and its administrators.

RODOS data are highly heterogeneous. They are characterised by having varying spatial data type (both raster and vector) and varying data format (including Arc/Info, Arcview, several ASCII formats, and general raster image formats e.g., band interleaved and band sequential), varying extent (from full coverage of the European continent down to only a few tens of kilometres), various scale (from 1:25M down to 1:1M) and resolution (10,000 km2 to 100 km2 for Eurogrid data) and varying thematic content (including land-use, soils zones, elevation, hydrology and demography) (Figure 3.8.1 (a)).

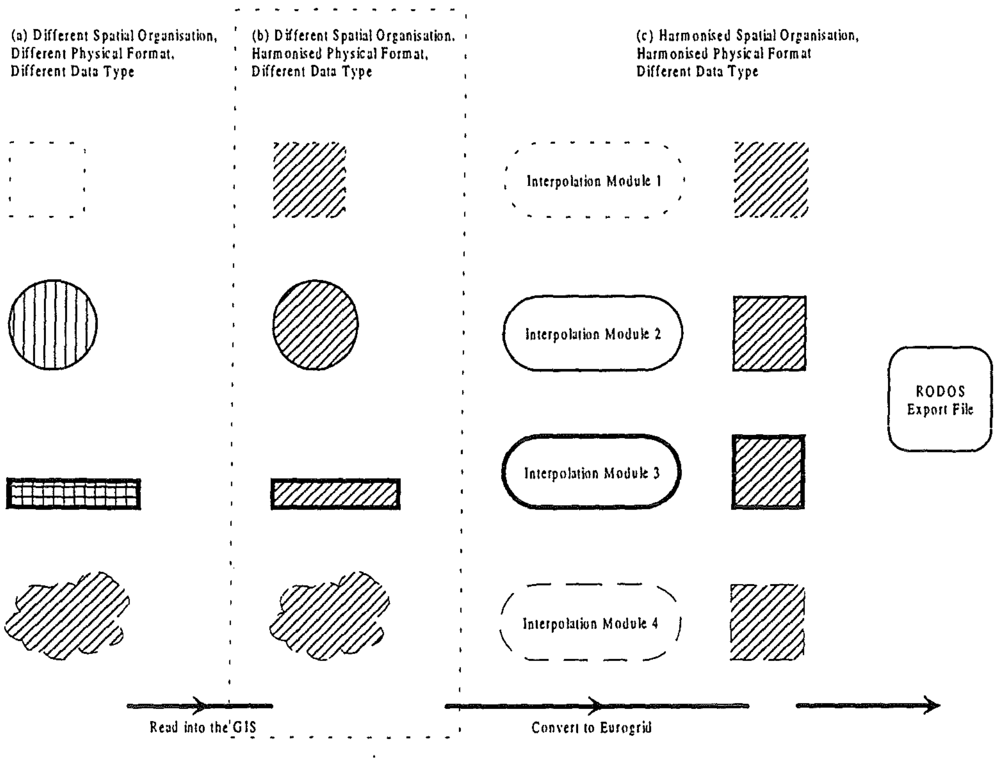


Figure 3.8.1. The various stages of GIS data harmonisation leading to data export. Data undergo physical format conversion for input into the database. Harmonisation of the spatial structure into a RODOS-compatible format is performed as an output operation.

RODOS modellers must be able to select for their use any of these disparate datasets. Several approaches to structuring these data are possible. At one extreme, they are assembled in their respective native formats. Processing into a format for input to the RODOS models is performed at the last stage. Users are at liberty to browse these datasets as files on a file-system. At the other extreme, these data would be processed into an immediately digestible form by the data administrators who would take responsibility for deciding which information was most important to the users and which should be discarded as a necessary consequence of the processing. This latter case describes the previous RODOS approach (1).

The approach described here is a hybrid of these extremes. Data, unlike previously, will not be automatically re-structured to suit RODOS requirements but will be held usually in their native format. A coherent interface to these heterogeneous data will, however, be presented to the user.

A major distinction between the system described here and the former one is that data in the EUROGRID format, rather than being held as source data in the database, is functionally separated from the database itself (except where those data are supplied to the JRC in EUROGRID format). 'Eurogridded' data are not a primary format but represent a significant degrading of data through spatial averaging. It is the intention here to employ conversion software on primary GIS data. The Eurogrid-compatible data thus become a product derived from the RODOS GIS database, not a primary storage format (Figure 3.8.1c). It is the intention to develop a flexible database, in that it can support many activities or applications. To aid this, a distinction is held between the data, the meta-data and the applications. The conversion of primary data to Eurogrid format provides a first example of a RODOS application.

3.8.2 Methods

GIS data are stored in a file-system on a Windows NT server. The file-system accommodates the diverse file structures of existing data and organises these data in a way which supports easy administration (see (2) for a detailed description of this file-system structure).

Data are placed on this system usually in the format in which they were received by the data centre. Various reformatting has been performed to make these data readable (Figure 3.8.1b). For example, much Arc/Info data arrive in an 'export' format and must be converted for use using the Arc/Info system. All data from the existing Eurogrid database were received as ASCII data and reformatted to a normalised relational table in Oracle (3). The original Eurogrid regular reference grid was generated using a 'C' program from latitude and longitude coordinates taken from the publication of Bonnefous (1) and converted to an Arcview polygon Shapefile. Grid cell labels were stored as an Oracle table, referenced to the grid polygons via a key field. Details of the reformatting of various other datasets depends on the specific format in which those data are received

An Oracle database was designed to hold information about these data. Because this database contains 'data about data' it is termed a 'meta-database' (the term 'catalogue' will be used synonymously). The catalogue describes the main characteristics of a GIS dataset. Entity Relationship Modelling was applied to identify those entities which are important to users of this system. The resulting entity relationship model was then converted by automatic means using the S-Designer software, into a physical model which was then implemented in the Oracle Relational Database Management System. The relationship between components of the GIS database are shown schematically in Figure 3.8.2.

Data conversion software was written in Avenue, the Arcview customisation language. Conversion requires the calculation of values for each Eurogrid zone based on the values of the contributing zones from the input data, for example population data based on EC commune boundaries. The process has been termed areal interpolation (4).

The method is different depending on the nature of the input values. To date, two scenarios have been considered both used a sample of population data referenced to EC commune boundaries. One deals with population density and the other with count data.

In this example, the EC commune boundaries represent source zones while Eurogrid cells represent target zones t. Source-target zones st are created by the intersection of source zones with target zones. Y_s, Y_t and Y_{st} represent values for source, target and source-target zones respectively while As, At and Ast represent the areas of source, target and source-target zones.

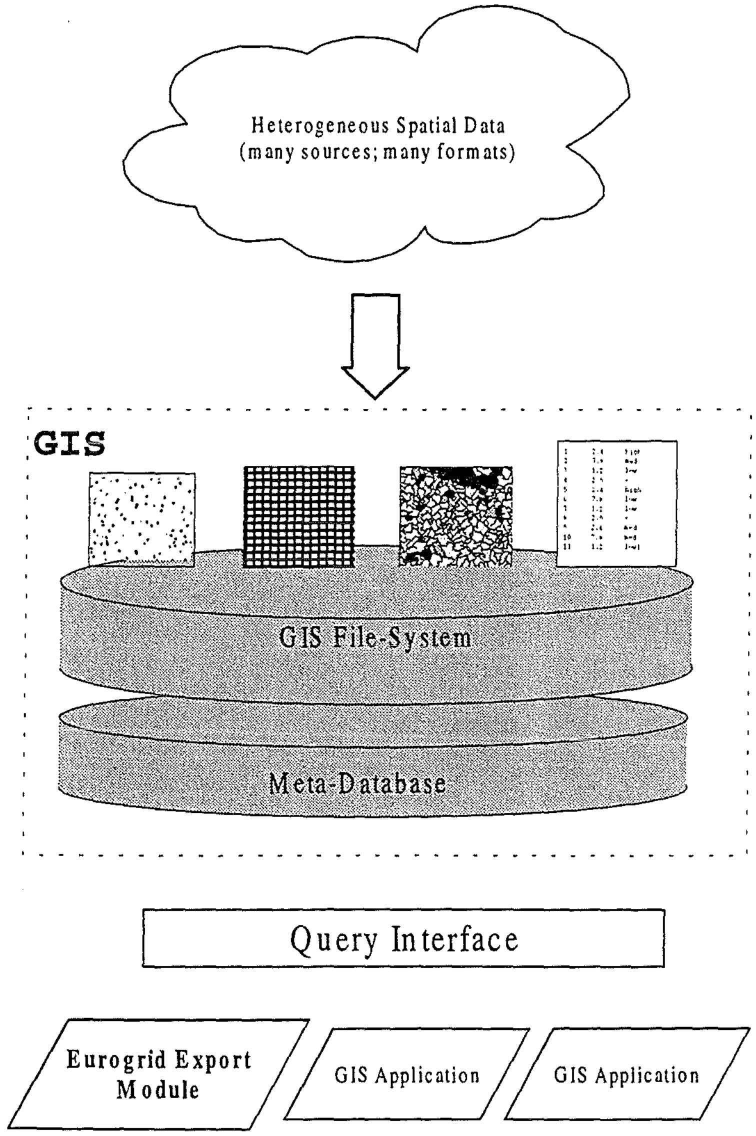


Figure 3.8.2. The RODOS GIS database structure. Heterogeneous data are organised in a file-system. Application access is via a query interface to a meta-database which describes the characteristics and location of these data.

The conversion to Eurogrid requires the calculation of Y_t.

For count data, this is simply:

$$Y_t = \text{sum}(Y_{st})$$

for all values of Y_{st} for a given target zone Y_t.

where

$$Y_{st} = (A_{st} / A_s) . Y_s$$

For density data,

$$Y_t = \text{sum} ((A_{st} / A_t) . Y_{st})$$

again for all values of Y_{st} for a given target zone Y_t.

where

$$Y_{st} = Y_s$$

Here, a uniform distribution of source value over the source zone is assumed.

3.8.3 The REM RODOS GIS database

The File-System

The file-system design is described in full in the RODOS work package (2). In brief, data were divided into 'internal' and 'external'. Internal datasets, for example, those supplied from the existing Eurogrid database, are characterised thus because they have undergone substantial processing within the RODOS project or previously. The original source of measured data is usually not from RODOS, but these data have been substantially re-structured so as to be considered as 'owned' by the RODOS project. Official clarification on this point is always sought from the original dataset provider. The crucial characteristic of internal data is that it embodies substantial work effort by RODOS project members and therefore represents an 'original source' of this work.

Conversely, external datasets are held on the file-system in more-or-less unadulterated form. Re-formatting is sometimes applied but this relates only to the physical form of the data to make them convenient to read by existing software. Removal of these data would waste little effort of RODOS project members and may in fact occur frequently as data are updated from the supplier. If these data are substantially restructured, then they will be moved to the 'internal' directory.

Provision was made in the file-system for all foreseen types of ancillary data such as reports, reference documents, other reference geo-datasets, attribute files etc. These were held in 'library' directories at a level in the file-system equivalent to their scope of relevance. Again, refer to RODOS work package for details (2).

Existing spatial data formats include Arc/Info coverage format (ESRI, 5), Arcview Shapefiles (ESRI) and various image formats. A number of data from the previous version of the Eurogrid database are held as Oracle tables which contain their reference key to the Eurogrid. Other formats may be included in the future.

The Meta-Database

The entity relationship model describing the primary entities of the GIS meta-database are shown in 3.8.3.

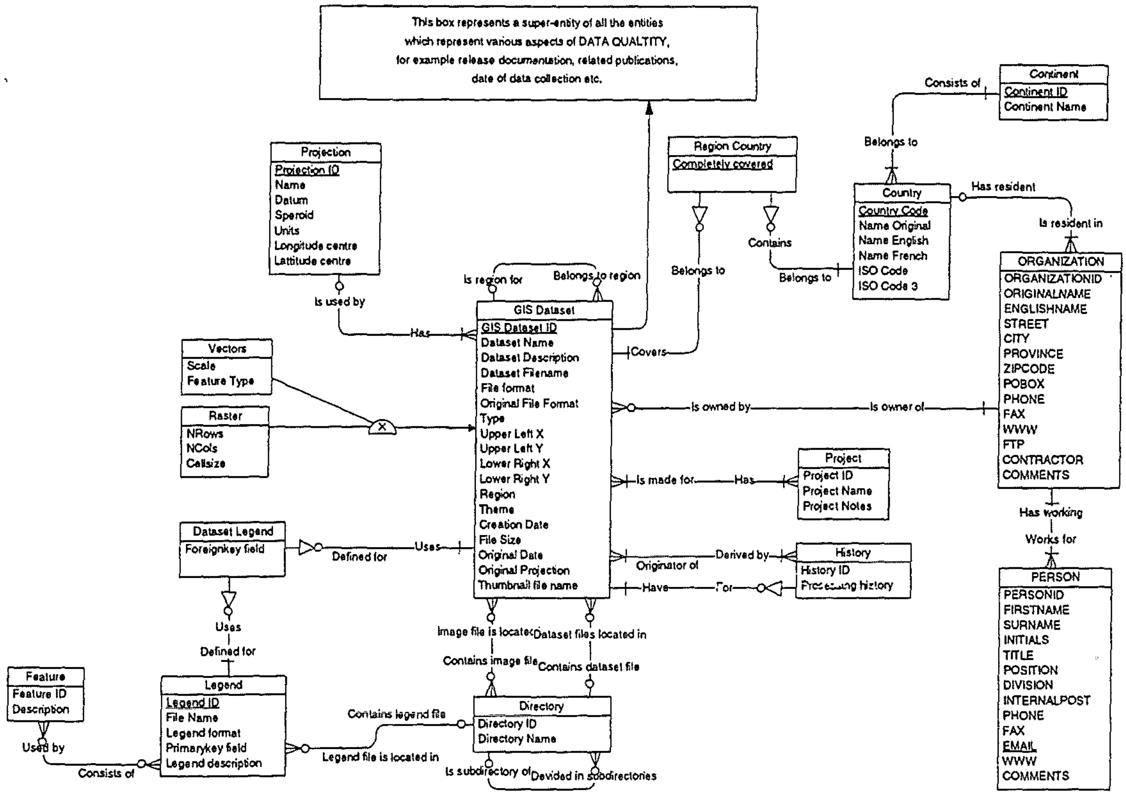


Figure 3.8.3. Entity Relationship Diagram. This shows the major entities in the GIS meta-database.

A GIS (6) Dataset is either a Raster or a Vector. It can be held in a Directory which is a recursive structure consisting of many sub-directories. A GIS Dataset has a Projection which determines the coordinates in which it is stored. A GIS Dataset can belong to a region which is a special type of GIS Dataset consisting only of rectangular coordinates which geographically just contain the GIS Dataset. A GIS Dataset must contain (partially or fully) one or more of Country and conversely, a Country belongs to (or is contained within, partially or fully) one or more GIS Datasets. A GIS Dataset is made for (this could also be interpreted as belongs to) one or more Projects. It also has a History (which has associated information such as processing method) which consists of GIS Datasets from which it was derived or to which it contributes. GIS Dataset uses one or more of Legend and Legend is defined for one or more GIS Dataset. A Legend can be comprised of one or more Features. Finally, a GIS Dataset has a set of data Quality information.

The attributes and related entities of a GIS dataset fall approximately into 4 categories: those that describe the general characteristics of the data file (e.g., name, brief description of theme, location in the file-system, file format), the spatial nature (e.g., bounding coordinates, spatial data structure, projection and gross geographical location such as region, country or continent), quality information (e.g., origin, derivation, sample date) and thematic content. For a fuller description see RODOS publication (2). For a description of the current contents of the RODOS GIS, RODOS publication RODOS 1997a(7).

Determination of the database thematic aspects

The contents of the European data base, with respect to the thematic aspects needed for the models in RODOS, were determined and described (8). This document describes the data the models need and is the guideline to complete the study of the contents of the database and the subsequent search for data. The themes described in this report are, with respect to their priority:

Primary

- land-use
- elevation
- soil + chemical properties
- population
- agricultural production

Secondary

- housing
- economic data
- Rivers and lakes
- lake foodweb
- trophic status and chemical conditions of lakes
- production of fish and drinking water

Ancillary

- coastline/political
- country names
- power stations
- climate
- conservation
- commune boundaries of the EU
- ecological zones

3.8.4 Discussion

The current requirements of RODOS are for data in the Eurogrid format. RODOS analysis modules are thereby provided with a consistent format on which to operate. Converting various GIS to this format will result in the loss of information. The loss of information is not considered critical because often the small scale at which RODOS models operate render this tolerable. The crucial question is at what point will this loss of information qualitatively affect a decision based on the RODOS system. In other words, at what point will data degradation through conversion resutl in an erroneous decision? In order to answer this question, quantitative data must be gathered about the error both inherent in the source data and that generated by the conversion (9). Secondly, it must be determined at which point error in the input data critically affects the outcome of the models.

An advantage of the system presented here, over the previous system, is that data are stored in their most primitive form available. The decision as to the fitness of a particular dataset for the task in hand is left to the user. Also, if these data are required in an alternative format to the Eurogrid, then the source data are available on which to apply the new conversion routines.

The development of a file-system to hold heterogeneous data is an interim solution. It has a number of major draw-backs. Different datasets may have disparate underlying models and representations. Historically, most GIS software has been designed to use proprietary data formats and much of the work of a GIS practitioner has been taken up in converting between these different representations in order to combine data for analysis. The Open GIS Consortium (10)are leading the way to a solution to this problem but this work is still not reflected in the available data. A primary function of the meta-database is to provide a logical and coherent interface to the heterogeneous data. Users will use this meta-database as a first access point. Once the required data has been selected, as the result of a logical or spatial query, other application software will retrieve these data and present them in a form useful to RODOS users. These applications will use information in the meta-database to determine how to process these data. If changes are made to the datasets or the file-system (such as new data added), then the catalogue will be updated. Thus users and software applications will be immediately aware of such changes. The general principle is one of *encapsulation* whereby the physical structure of the database is hidden from the outside. Users simply need to know useful information such as the theme of a dataset and its geographical extent, after which the data can be extracted in a useful form.

Current Challenges and Future Prospects

Additional functions for interpolating area based data to the Eurogrid spatial framework will be required. These will be implemented as new data types are encountered. For example, ordinal data (e.g., "small", "medium", "large" or "low density", "medium density", "high density") will require a new approach. If a target zone is a combination of "small", "medium", and "large" source zones then it might be tempting to assign to the target zone the value of the majority source zone (the one that contributes most area to the target zone). However, if the function mapping the original values to these classes is not linear then a majority assignment makes little sense. Preferably we could map these classes back to their numeric equivalents before interpolating and then define new classes in the output data.

Additionally, depending on the purpose to which the data is put, a certain value (e.g. "high") might be of disproportionate significance. Therefore, an alternative scheme might be to assign this value to a target zone if it occurs in any quantity in the contributing source zones. Similar arguments apply to nominal data (e.g., "forest", "non-forest" and "water") which are characterised by having no intrinsic order. Again the assignment of such a value to a target zone might depend on an arbitrary value (or significance) placed on each class according to the use to which this data is put.

For the purposes of the RODOS decision support system, data will often be required over a region that stretches beyond the extent of a single dataset for a given theme. In such a case, it will be incumbent on the information system to merge together data fragments into one coherent coverage. If the themes are of interval scale data, i.e., a continuous value , then a mapping function might be required to bring adjoining datasets to the same unit of measurement. Where there is an over-lap, either a decision would have to be made as to which dataset was of superior quality and would therefore take precedence (alternatively, the output could be calculated as a function of the two inputs). Occasionally, two adjoining datasets will be of the ordinal or nominal types (e.g., classifications of some kind) and will be of the same basic theme but will use different classification systems. Harmonisation of the classification may be impossible without reference to more primitive data or may require expert knowledge within the particular thematic domain.

An additional but related task is that of evaluating the fitness of existing data for use within RODOS. Data quality in terms of spatial and attribute accuracy is one consideration, but perhaps a more immediate one is that of matching the specific requirements of RODOS modellers with the available data. Usually, data will have been acquired from an external source and will have been originally collected for a purpose other than that of the RODOS project. Inevitably the accuracy, scale or thematic content will not ideally suit the needs of RODOS. Therefore, it is now necessary to re-evaluate the data requirements of the project with respect to the available data.

Areas Requiring Further Research and Development

Interpolating disparate data to a common spatial framework is a common operation in most analyses of area spatial data and is an existing requirement of the RODOS system. The interpolation algorithms described here have all assumed uniformity of distribution of source data within a given zone. The accuracy of the interpolation could be significantly improved by challenging these assumptions and by using prior knowledge or expectations of the underlying distribution of source data with respect to contextual information provided by other datasets (11)

Future Possibilities

Future development opportunities for the RODOS GIS database include a WWW interface to the RODOS database at the JRC which might additionally provide a spatial query interface as well as a textual (or logical) one to improve the accessibility and circulation of RODOS GIS data.

3.8.5 References

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3.9 Source term estimation based on in-plant information

3.9.1 Objectives

In the event of an accident in a nuclear power reactor, the authorities should be in position to implement the counter-measures necessary to protect the surrounding population and the environment from radiological consequences of any releases. The means may be complex and require a few hours to set in place; however, the rate of development of such accidents in light water reactors is relatively slow with, in general, no significant releases occurring before a several hours into the accident.

It is, therefore, necessary to monitor the progression of the accident as soon as it is detected by the plant operator in order to forecast the future behaviour of the reactor so as to be able to recommend to the relevant authorities the implementation of counter-measures within a time compatible with that needed to protect the population.

One of the most important input data for the analysis of consequences of severe accidents in a nuclear reactor is the **Source Term** ; there is the quantity, timing and characteristics of radioactive material released to the environment in an accident.

The aim of the STEPS (Source Term Estimation based on Plant Status) is precisely to monitor the progression of an accident, to forecast the future behaviour of the reactor and to estimate the ongoing and the potential releases, i.e. the Source Term, on the basis of data regularly transmitted by the operator of the nuclear power plant concerning the state of the installation. Thus, the consequences of these releases for the environment and population may be calculated with the other modules of RODOS system.

An important and difficult objective is that the STEPS software should be applicable for every type of light water reactor operating in the European Union. So, the operator could choose and/or introduce the data and physical models adapted to the of reactor of interest.

Moreover, this software is not intended to be a safety assessment code which are not designed for use in emergencies but rather a computer package comprising simplified models for use for specifically emergency preparedness.

It is important for the user, in these situations, to be guided in the output of STEPS but to retain responsibility for the evaluation.

To achieve the main objective defined above, a **methodology** and sub-objectives with corresponding **work packages** have been defined.

Concerning the **methodology**, it is spaced on the adaptation of the SESAME methodology, SESAME being the operating system used in the IPSN crisis centre to assess the source term in case of an accident in a French pressurized water reactor.

The principle of the SESAME methodology, which is deterministic, is based on the concept of defence in depth. The SESAME methodology comprises:

- diagnosing the state of the barriers considered in the defence in depth concept using the data transmitted by the plant. To do so, the relevant parameters for the assessment of each barrier are presented in an adapted manner, compared with thresholds or values calculated for typical accident scenarios. Besides, the data transmitted by the plant are used to assess in a quantitative manner, important characteristics of the accident scenario using simplified physical models. An An example of an important characteristic is the size of the break in the case of loss of coolant accident. Finally, by using these characteristics as intermediate parameters, the fission product releases are estimated.

- prognoses of the future state of these barriers. This prognosis is mainly done on the basis of the evolution of parameters measured on the plant and assessments done for the diagnosis phase. An example of a prognosis is the estimation of the delay before core uncovery.

- assessing the source term which corresponds to the present and estimated future state of the barriers and also to the estimated future state of these barriers.

This methodology has to be adapted toaccommodate the diversity of LWR designs to Europe. Besides, an important point of this methodology is the use of expert judgement, i.e. it is considered that the users of the STEPS system are experts in nuclear safety and engineering and have a good understanding of severe accident phenomenology.

Concerning the definition of the **work-packages** and of their sub-objectives, they correspond to the barriers of the defence in depth concept (i.e. containment, primary system, fuel work-packages or STEPS system modules), and to additional workpackages related to the data acquisition, the system validation and finalization.

So defined, each workpackage has its own sub-objective : a consistent module to be integrated in the overall STEPS system (the first four work-packages), the integration, validation and finalization of the system for the last two.

3.9.2 Structure and content of the STEPS code package

Quality assurance programme

The quality assurance programme of the project is now in application and covers the whole STEPS project ; it explains the organisation of the project, defines the steps of work to be done, describes the provisions made to ensure the quality for each of these steps, defines the quality assurance documentation to be established, the reports to be written and gives indications about the expected content of these reports.

Two important points of the quality assurance plan are:

- the several progress and technical meetings which enable discussions between the contractors,

- the process which led to the final approval by IPSN (as coordinator of the project) of the documents and software. This process includes preliminary review by IPSN of draft versions of the documents (or software), technical discussions on particular points, presentation of the modified draft versions and discussion on this basis during the progress meetings, and finally approval.

3.9.3 Description of the interface between the source term code and the existing RODOS system

This document provides a description of the possibilities for input of a source term into RODOS/RESY-PV3.0 together with the resulting data requirements for the interface between STEPS and RODOS.

Particular attention has been attached to the list of the nuclides to be considered and to the way to combine or not groups of nuclides. Different possibilities of source term input modes have been considered (see Table 3.9.1).

(1) Fraction released for the nuclide groups Noble Gases, Iodine, Aerosols*.
(2) Fraction released for the nuclide groups Noble Gases, Iodine, Alkaline metals, Tellurium and Selenium, Alkaline earths, Ruthenium group (incl. Ru, Rh. Mo. Tc), Lanthanides (incl. Y, La, Zr, Nb, Ce, Pr, Np, Pu, Am, Cm).
(3) Released activity for the nuclide group Noble Gases and for the nuclides I-131 (as representative for the iodine group) and Cs-137 (as representative for the aerosol group).
(4) Released activity for the nuclide groups Noble Gases, Iodine, Aerosols*.
(5) Released activity for each nuclides individually.

* "Aerosols" means here fission products released to the atmosphere as solid or liquid suspensions in air via a carrier (e.g. CsI, NaOH etc.)

Table 3.9.1 : Source term input modes

Another important point also treated is the connection of STEPS (source term) prognosis period and RODOS prognosis (radiological situation) period. The way that this is implemented is represented in Figure 3.9.1 below.

This figure shows that there is independence between the three following periodicities :

- the periodicity of data transmission between the plant and the STEPS system,

- the periodicity of the source term assessment by the expert using the STEPS system,

- the periodicity of the assessment of source term consequences with the RODOS system.

The forms of data transmission between the codes are also outlined in the document. An open choice is given between several possibilities.

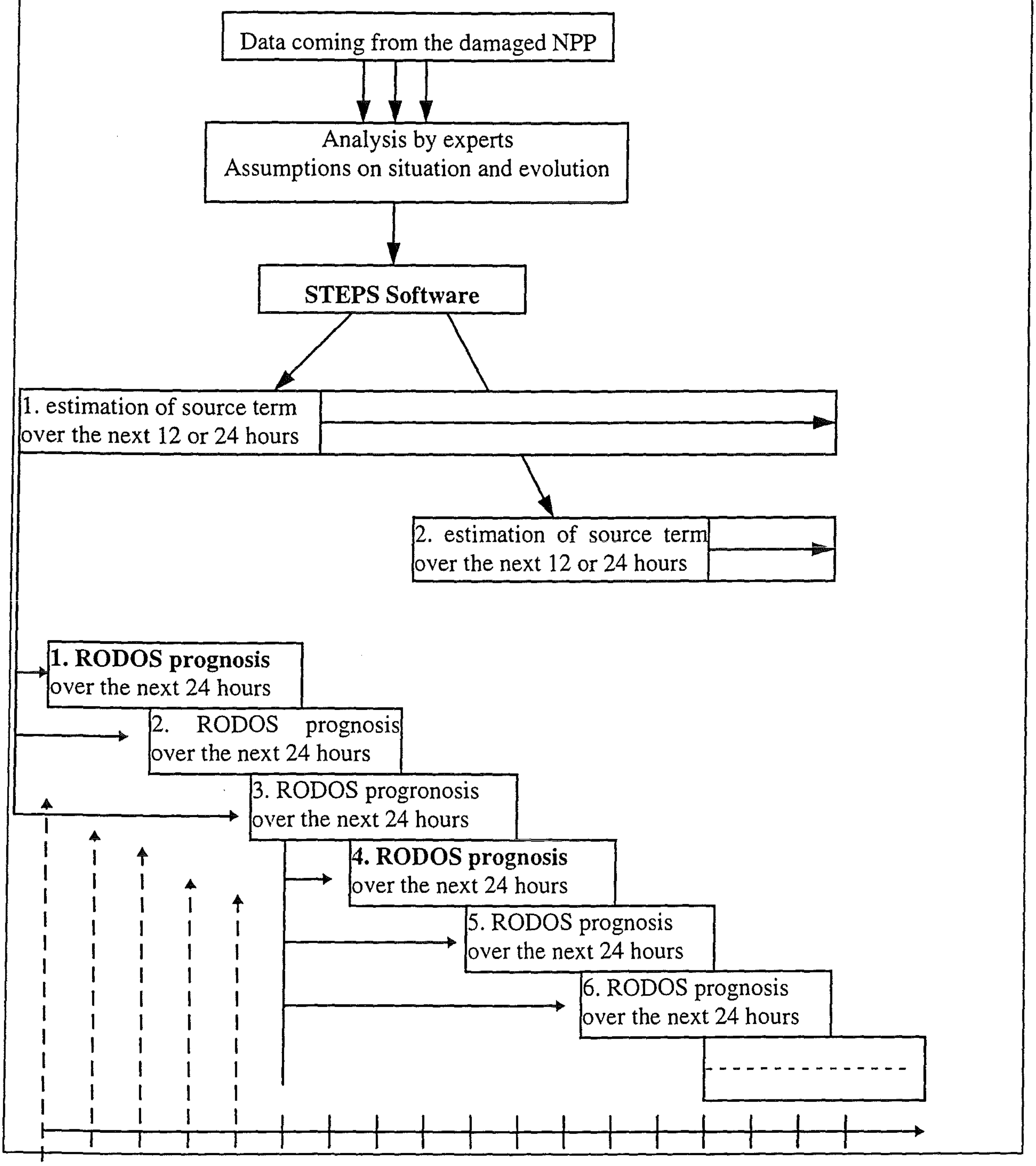
Software Development Plan (SDP)

This document presents, in a synthetic form, the software development procedure of the STEPS project. It describes the methodology and the means to be implemented to develop and install the software which makes up the STEPS system.

The main steps of the software development are outlined and concern :

- the requirement analysis and system specification,
- the architectural design of the system,
- the detailed design,
- the implementation (coding),
- the unitary tests,
- the functional validation phase,
- the global code verification and description.

Figure 3.9.1 : RODOS prognosis of radiological situation and source term input from STEPS



Also defined in the SDP are the software documentation, the configuration management including the development platform, the management of modifications and the archiving of the software elements.

Technical specifications of the containment module

In substance, the technical specification combines:

- Condensed technical knowledge items bearing upon physical models, constitutive equations, basic assumptions, validity and uncertainty considerations ;

- Recommended methods and code design features : model-embodying guidelines; logical flowcharts including event trees; I/O tables, parametric data etc.;

- Supportive items, including explanatory texts, diagrams and figures.

The main difficulty in drawing up the technical specification of the containment module have been to define an approach which can, at the same time, be :

- as generic as possible - with simplified models adapted to the majority of the LWRs in the European Union,

- but still analytical - with a source term calculated on the basis of information coming from the damaged unit and representing the essential physical parameters of this unit.

This difficulty has led to :

- the definition of STEPS containment classes. Each containment class is defined by the design of the containment itself (including links to surrounding buildings) and the availability of specific engineering features,

- assignment of each LWR to a specific STEPS containment class,

- the notion of « expanded SESAME box model », each STEPS containment class being properly represented by a succession of adapted box models,

- the choice of an analytical approach to describe the phenomena inside each box of the chain,

- the proposal of the determination of models' parameters using parametric equations rather than smoothing the results of existing reference studies.

Figure 3.9.2 shows the generic box model of the containment module with the corresponding basic equations.

In this figure, for each containment unit (i) with the volumetric concentration of nuclide's i at time t $C_i(t)$, a balance is done between :

- the containment activity source rate,

$S_i(t)$ for unit 0 (based on the activity rate expected to flow out of the primary system)

or $f_{i-1 \to i}\ F_{i-1 \to i}$ for other units where $F_{i-1 \to i}$ represents the leak term of unit (i-1) and $f_{i-1 \to i}$ the fraction of this leak term to unit i

- the *depletion term*, $DC_i(t)$ which describes the deposition mechanisms depleting the airborne activity in the unit i,

- the escape fraction term of unit i, $E_i(t) = F_i(t)\ f'_{i \to i+1}$ where $f'_{i \to i+1}$ represents direct releases fraction of leak term.

Determination of the direct or indirect releases requires appropriate rate equations (see Figure 3.9.2) considering the building volumes $V^{(i)}$, the volume outflow rate $Q^{(i)}$ and the filter efficiency $\eta^{(i)}$.

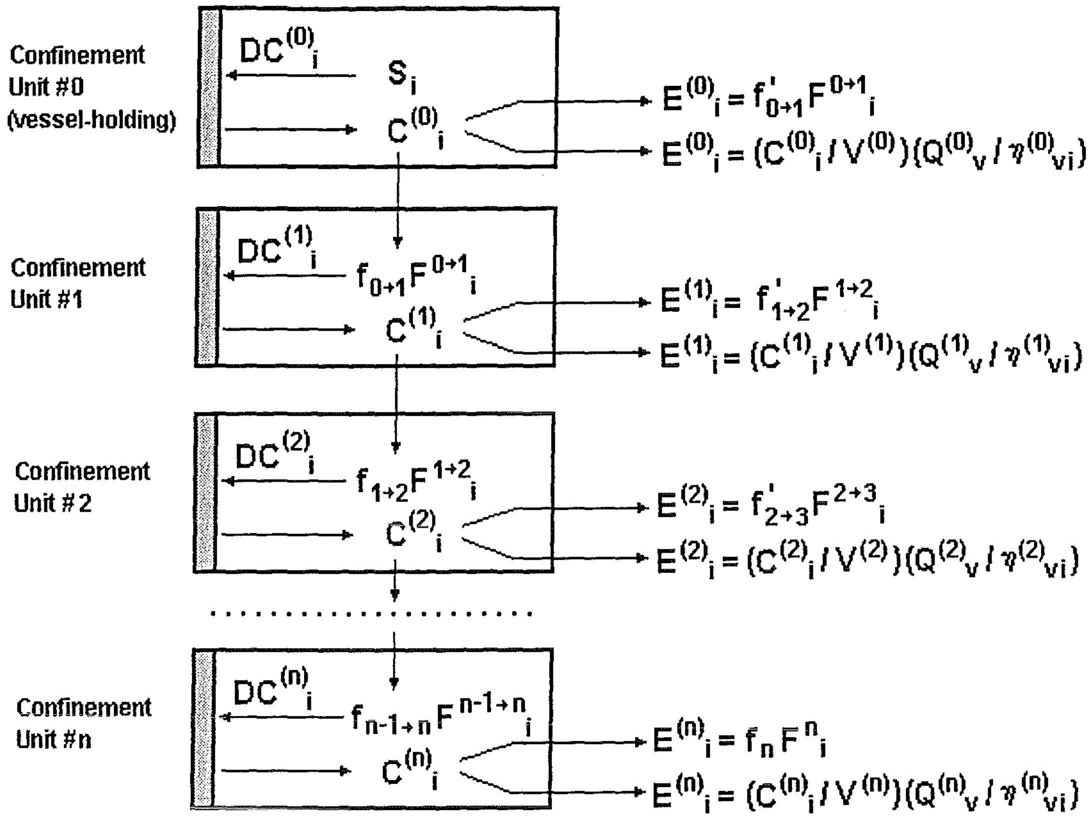


Figure 3.9.2 : STEPS box model for the containment module

Preliminary considerations have led to a box model with two units for usual PWR design (main containment building and auxiliary buildings), a box model with a single unit for the VVER 230 design and a box model with four units for the BWR design (dry well, wet well, containment building and auxiliary buildings).

Development of the physical models of the containment module

The development of the physical models of the containment module have been undertaken in assistance with the technical specifications. Particular attention has been attached to the determination of the depletion term of the differential equation describing the aerosols behaviour in the containment :

$$\frac{dC_i(t)}{dt} = \frac{R_i(t)}{V} - \sum_d \Lambda_{d,i} C_i(t) - \frac{Q(t)}{V} C_i(t)$$

where, according to the technical specification:

- $C_i(t)$ [Bq/m^3] is nuclide's i volumetric concentration at time t [s],
- $R_i(t)$ [Bq/s] is the containment box activity inflow rate in the nuclide i;
- V [m^3] is the containment box free volume;
- Q(t) [m^3/s] is the containment box volumetric outflow rate carrying the nuclide i;

- $\Lambda_{d,i}$ [s^{-1}] are exponential depletion constants and their sum in the right-hand side of the equation extends over all depletion mechanisms.

It has been stressed that this equation does not refer to a single nuclide i - as suggested in the technical specifications - but to an aerosol which carries specified nuclide groups (e.g. volatility groups). The index, i, refers therefore to a group, not to a nuclide. Although the equation is very similar to the original one, the interpretation has changed considerably.

The explicit finite difference form of this equation can be written in the following form :

$$C_t+\Delta t=C_t+R_t*\frac{\Delta t}{V}-(1-\frac{1}{DF(P,t,\Delta t)})*C_t-C_t*\frac{Q_t}{V}*\Delta_t$$

using the decontamination factors DF as defined in reference studies.

This depletion term can be thus assessed using uncertainty distributions for the decontamination factors and the decontamination coefficients as functions of time. Such distributions have been developed with the help of Monte Carlo analyses for aerosol removal by natural processes in reactor containment, aerosol removal by containment sprays and decontamination by BWR steam suppression pools and are available.

Development of the software of the containment module

A first version of the containment module software package has already been developed in accordance with the technical specifications and subsequent discussions. The software manual is ready and a set of disks for the containmnent module will be available at the end of 1997.

Technical specification of the primary system module

Different points of view have been examined in the technical specification of the primary system module. They can be expressed as follows:

- What are the important parameters characterising the reactor system and the accidents to be considered taking into account the diversity of LWRs in Europe?
- What should the primary system module calculate, determine or estimate and what phase of accident progression?
- What are the limits of the SESAME adaptation?
- What are the links between the primary system and other modules?

As a compromise, a list of the main requirements for the primary system module is given in the technical specifications with a distinction between diagnosis and prognosis modes. Specified as physical models for the primary system module are:

- for the transient state of reactor, the representation of blowdown of primary system, flow through breaks, and core uncovery,
- for the transient state of secondary system, the representation of steam generators and connected systems,

- for the activity and fission products transport to the containment, the representation of fission product behaviour in the primary system and mass transport to the containment by homogeneous flow of coolant and aerosols.

Accidents specified are mainly LOCA and SGTR with a possible extension to other accidents in the software validation phase.

Development of the physical models of the primary system module

The development of the physical models of the primary system module has been undertaken on the basis of the technical specification.

The physical models concern the assessment of :

- the size break in the case of loss of coolant accident and steam generator tube rupture. For the extension of the SESAME approach to BWRs, reflection is needed to find another solution than using the pressurizer level evolution to assess the break size,
- the delay before core uncovery and the kinetics of water level variations in the core region using mass and energy balances in the case of loss of coolant accidents,
- the fission products transfer from the fuel to the containment in case of core degradation,
- -the fission products releases into the environment in case of steam generator tube rupture using mass, energy and activity balances.

The choice of a five element representation of the primary system has been judged necessary rather than the more simplified representation used in the SESAME physical models.

Technical specification of the fuel module

The main objectives assigned to the fuel module are that it should consider the following physical phenomena taking into account the plant characteristics :

- core activity inventories,
- coolant activity inventory,
- gap inventory,
- decay heat production,
- water level variations in the core region (in relationship with the primary system module),
- fuel overheating and melting,
- cladding rupture,
- control rod degradation.

Reference studies for the different items above are listed in the technical specification. They will form the basis of the development of the physical models.

Besides, the technical specification defines the list of plant and accident specific input data of the module, and the expected output.

STEPS system definition and integration

The architectural design of the STEPS system defiens the general constraints for the system development, and indicates the structure, functionalities, modules and resources of the system.

The corresponding document (draft version) is organised in four parts :

- the first presents the system, its environment and the functionalities and the constraints for its design,
- the second details the functional needs,
- the third proposes a technical architecture,
- the last examines how the needs are covered and justifies the choices made.

The following diagram represents, in a synthetic form, the choice done for the system architecture with a DELPHI environment for the physical models and library of utilities design, Oracle as data base management system for the design of the relational data base.

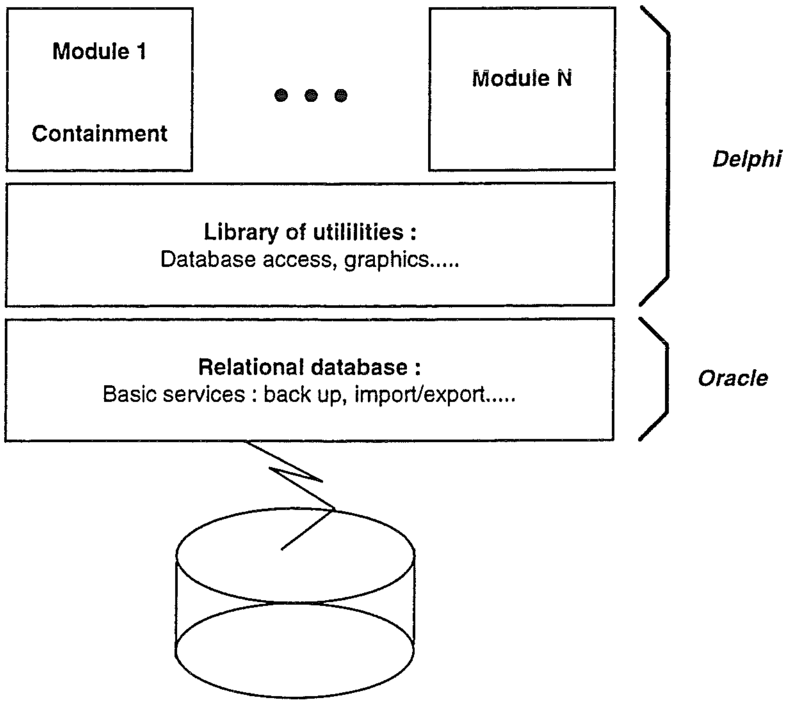


Figure 3.9.3 : architecture of the STEPS system

These choices arose from several considerations and, particularly, from analyses of the correlations between the needs and several possible solutions.

The following table indicates an analysis of these correlations.

Needs/Solution	Recovery of SESAME applications	Software architecture	Development tools	Relational data base
PC environment	X	X	X	X
Ergonomics	X		X	
Modularity	X	X		
Portability		X	X	X
Data standardization		X		X
RODOS adaptation	X			
Speed and cost of the development	X		X	

Table 3.9.4 : matrix of the correlations between needs and solutions

The functional decomposition of the STEPS system leads to the global tree function shown in Figure 3.9.4. In this figure, the representation of the system is made in the sense of the module decomposition usual for the STEPS participants, it is however obvious that, in certain cases, several functionalities tailored for the purpose of task definition are to be combined to constitute comprehensive STEPS system.

Besides, the draft of the technical specifications of the STEPS system includes the following items :

- system environment : description of the limits of the system itself and its links with its environment,
- management and organisation rules : management of the system development, conditions of use and definition of the users of the system,
- information treated by the system : preliminary organisation of internal information and of information exchanged,
- more detailed description of the functionalities of the system in relationship with :
- the physical models developed (or to be developed) in the framework the four STEPS modules (i.e. containment, primary system, fuel and data acquisition modules),
- user interface definition.
- so that the tailored description of Figure 3.9.4 is more transparent for the user of the system.
- preliminary static and dynamic design of the system,
- malfunction treatment.

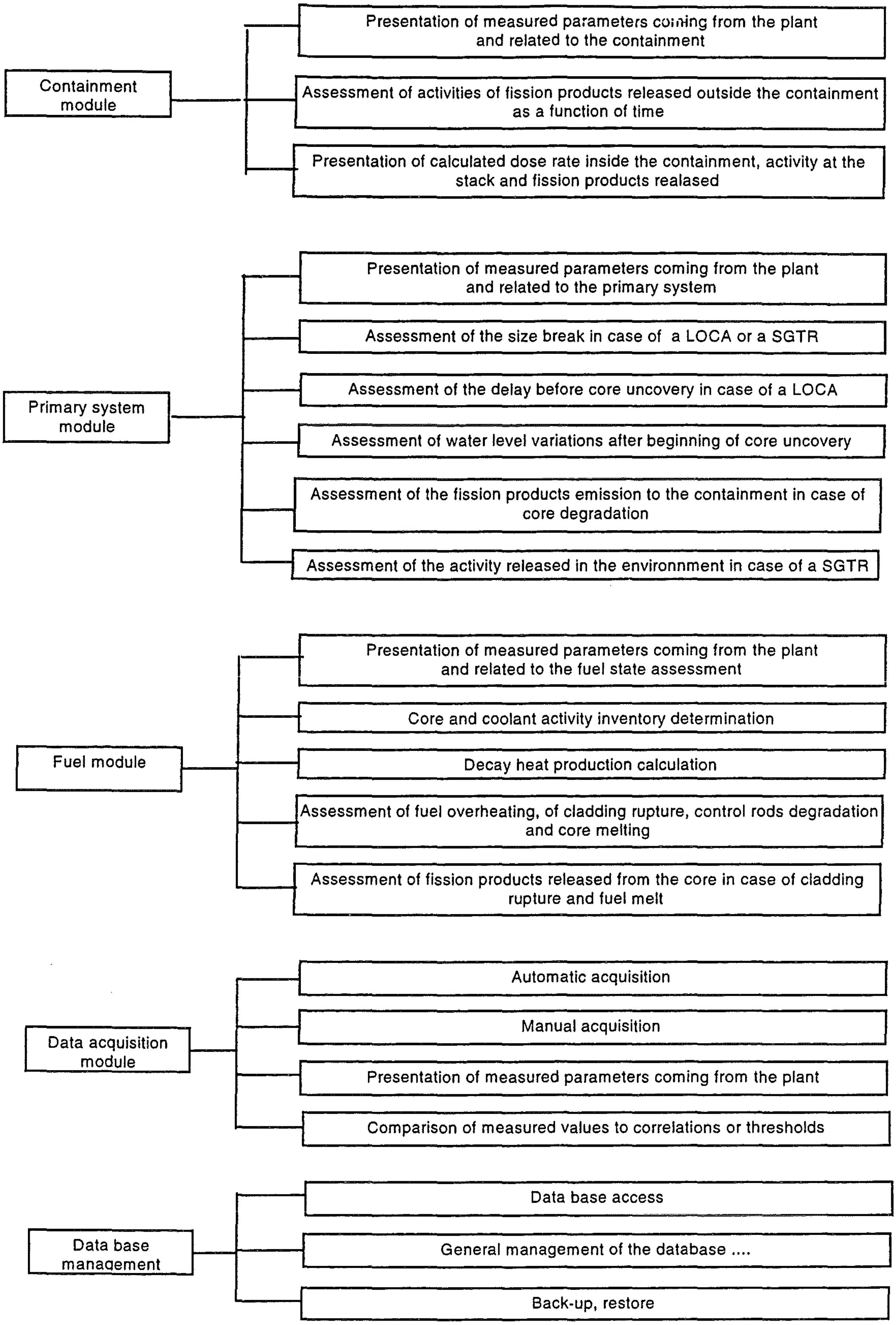


Figure 3.9.4 : Functional diagram of the STEPS system

3.9.4 References

The list of documents written in the framework of the STEPS project is given in the following:

1. Chaumont; Quality assurance programme for the project FI4P -CT96 - 0048; RODOS(WG10) - TN(97)01 final
2. Chaumont; Minutes of the meeting held in Fontenay -aux Roses, France on the 22nd of January, 1997; RODOS(WG10) - MN(97)01
3. Chaumont; Minutes of the meeting held in Fontenay aux Roses, France on the 29th of January, 1997; RODOS(WG10) - MN(97)02
4. Ph. Schmuck; Software development procedure for the STEPS project; RODOS(WG10) - TN(97)02
5. Steinhauer, J. Ehrhardt ; Description of interface between the Source Term Code and RODOS ; RODOS(WG10) - TN(97)03
6. Chaumont; Minutes of the meeting held in Karlsruhe, Germany on the 14th of March; RODOS(WG10) - MN(97)03
7. Dan V. Vamanu; STEPS - Source Term Estimation based on Plant Status. The CONTAINMENT Module technical Specification; RODOS(WG10) - TN(97)04
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12. Chaumont; Minutes of the meeting held in Karlsuhe on the 1st of October, 1997; RODOS(WG10) - MN(97)05
13. Chaumont; Minutes of the technical meeting held in Karlsuhe on the 24th of October, 1997; RODOS(WG10) - MN(97)06
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18. Technical specifications of the STEPS fuel module - draft; RODOS(WG10) - TN(97)14
19. User and installation manual of the containment module software (draft version); RODOS(WG10) - TN(97)15

3.10 ETHOS implementation in Belarus

3.10.1 Abstract-Introduction

ETHOS is a pilot research project supported by the radiation protection research programme of the European Commission (DG XII). The project has initiated an alternative approach of the rehabilitation of living conditions in the contaminated territories of the CIS in the post-accident context of Chernobyl.

It is a three year project which started at the beginning of 1996 and is implemented in the Republic of Belarus. The ETHOS project involves an interdisciplinary team of European researchers including disciplines such as: radiological protection, economy, agronomy, safety, co-operation and social trust management, social risk management, sociology and psychology. On the Belarus side the ETHOS project involves as a scientific partner the Ministry of Emergencies of Belarus. It also involves the different levels of relevant local administration of the implementation site.

The ETHOS project is based on a strong involvement of the local population in the rehabilitation process. Its main goal is to create the conditions for the inhabitants of contaminated territories to reconstruct their global quality of life. This reconstruction deals with all the day-to-day aspects that have been affected or threatened by the contamination. The project is aiming at the creation of a dynamic of rebuilding acceptable living conditions. Radiological security is developed in the ETHOS project as part of a general improvement of the quality of life.

One characteristic of the ETHOS approach is to address jointly the social and the technical dimensions of the post-accident situation in an attempt to avoid the difficulties resulting from making on the one hand the risk assessment and risk management a technical problem for the experts and on the other hand the public acceptability an insoluble communication problem in a context of distrust.

This report presents the main features of the methodological approach of the ETHOS project. It also presents how it is implemented in the village of Olmany in the district of Stolyn (Brest region) since March 1996 as well as its first achievements.

3.10.2 Background

The improvement of living conditions in territories contaminated by the Chernobyl nuclear accident, and the re-establishment of radiological safe living conditions for the population still face many obstacles. Experience built up over the last 10 years in Belarus, Ukraine and Russia, combined with the collaborative research between the EU and the CIS, have highlighted specific features and problems raised by the continuous presence of human settlements on a contaminated territory. A post-accidental crisis without return to normality (1) was reported from the IAEA project (1990). Further European surveys undertaken within the EC/CIS Collaboration Programme on the Evaluation of the Consequences of the Chernobyl Accident (1991-1995) have provided an extensive assessment (qualitative and quantitative, (2)) of the social and psychological effects of the accident on liquidators, relocated populations and inhabitants of contaminated territories. The main features of the living conditions in the contaminated territories can be described as follows.

The investigations carried out in Ukraine, Belarus and Russia have revealed strong social disturbance and stress phenomena within the population of the contaminated regions. A climate of widespread anxiety is observable among the population. This anxiety focuses on the effects of the Chernobyl accident, notably the effects of the remaining contamination on the health of those surveyed, and their families. A particular focus is the health of children. Anxiety is manifest in interviews, where multiple references are made to various somatic effects reported by the population that are generally attributed to the Chernobyl disaster.

Environmental contamination is a basic concern for most of the inhabitants of the contaminated regions. The contamination is perceived as omnipresent but invisible and hardly localisable and measurable. Surveys have demonstrated that this fear was, in psychiatric or psychoanalytical terms, not akin to a phobic syndrome. Those questioned expressed their fears and their anxiety, but never in the form of unreasonable fear, or uncontrollable anxiety. This fear was always underpinned by a rational approach to the situation and based on personal observations. The radiation protection concept of intervention levels has been rejected by the population as soon as the emergency phase of the accident ended. Risk levels in coherence with normal situation standards was a strong claim of the inhabitants of the contaminated territories. All post-accidental laws passed in 1991 in the concerned CIS countries, therefore, refer to the limit of 1mSv/year (see above mentioned surveys). Later on, the various attempts to regulate the situation by the means of intervention levels have also failed.

As a consequence of the long term contamination it is observed that inhabitants of the contaminated territories experience an overall depreciation of all types of values (social, economic, aesthetic, symbolic, ethical, political, etc.). In the eyes of the population, their quality of life seems strongly and irreversibly affected. In most cases those questioned speak about their lives "before and after the Chernobyl accident". It seems that for them as they put it: "nothing will be the same again". A study performed in Belarus shows that very few people experience a kind of "return to normality" based on the belief that immunisation against contamination is possible which is a kind of risk denial.

Another feature of the post-accident situation is the lack of trust of the population in the scientific, medical, and political authorities. Extensive anxiety is observed as a result of the distrust experienced by individuals facing a highly complex post-accident situation. Inhabitants of the contaminated regions feel insecure and deprived of means to avoid radiological hazards experienced as all-pervasive in their day-to-day life. Studies highlight the sense of disarray experienced by the population, and a general feeling of loss of control of the situation. This loss of personal confidence appears to be related to the disappearance of a climate of social trust.

3.10.3 A necessary involvement of the population in the risk management

In the post-accident context of Chernobyl, the initial strategy implemented since 1991 by the national authorities of the concerned independent countries of the former USSR (Ukraine, Belarus, Russia) was to organise a large process of relocation of the population according to the level of contamination of each territory (zoning process). Different approaches have been proposed and implemented since 1993 in order to cope with the local situation of the contaminated territories, notably the so-called "social consequences" of the accident. Approaches to the social dimension of the post-accident situation aim at resolution of the post-accident crisis and at the rehabilitation of a "normal situation". They can roughly be divided in two approaches:

The first (introduced in 1987 shortly after the accident (3)) emerges from the idea that, given the objective level of risk in most contaminated areas (considered as negligible by many experts[1]), worrying about the radiological risk is a kind of psychic pathology (radiophobia) which requires some psychological or psychiatric support in order to restore a normal situation. The other approach is based on the idea that the only way to resolve the social crisis is to develop a risk communication strategy in order to fill the existing gap in terms of risk perception between the experts and the public. These two approaches are now invalidated by the available research or are encountering many difficulties given the characteristics of the Chernobyl post-accident situation.

[1] About 80% inhabitants of the contaminated zone in Belarus are living on a territory which level of ground contamination (Cesium) is less than 185 KBq/m2.

Research has indicated that stress and social disturbance result from the confrontation with the contamination rather than from any kind of psychological pathology. Psychological therapies are, therefore, not relevant. The real issue at stake is to investigate to what extent inhabitants of contaminated territories can rebuild their security and restore their own quality of life.

As a consequence of social distrust (4), the population no longer believes that authorities and experts are able to manage the situation. Inhabitants of the contaminated territories confronted with the contamination have no way to deal directly with the radiological risk and to regain control of their protection. Risk communication can hardly be efficient when trust is lacking. In such a context, experts appearing to minimise the risk are perceived by the population as denying the risk which re-enforces mistrust and anxiety.

Although some 80% of the inhabitants of the contaminated territories in Belarus are living in an area where the level of contamination is low in the eyes of experts (less than 185 KBq/m^2 of ^{137}Cs), for several reasons the remaining radiological risk is not considered as negligible by the population. The view is that it should be managed to reduce it to a level as low as reasonably achievable as recommended by international guidance. The first reason is that an average level of ground contamination can lead to significant internal contamination, notably for children as a result of complex radioecological and agricultural process of re-concentration. The second reason is grounded on the ethical principle of precaution given the uncertainty of the long term consequences of this unknown situation that affects the life of people in a contaminated environment. As an interviewed local representative put it: "One should never consider as normal giving a baby a feeding bottle of contaminated milk". Living in contaminated territories implies, therefore, the prevention of risk or at least a precautionary attitude toward the possible unknown future consequences of low chronic internal contamination.

According to the Chernobyl post-accidental law of 1991, the most contaminated territories (over 555 KBq/m^2 of ^{137}Cs, annual dose in excess of 5 mSv) were subject to compulsory relocation. But most of the remaining contaminated territories were subject to voluntary relocation (from 185 to 555 KBq/m^2, annual dose ranging from 1 to 5 mSv) or not relocated (from 37 to 185 KBq/m^2, annual dose under 1 mSv). As a consequence, many people are still living in the territories defined as contaminated. In Belarus for example 2.4 million people are living in the such circumstances.

Experts cannot guarantee to the population of a contaminated area that there is no risk (however low their estimation of risk is). The population cannot be forced to live in a contaminated territory and nor can this be decided by experts; this is a political decision. In a context of social distrust, the role of experts in advising the population is severely constrained. The decision making process must, therefore, involve the population confronted with the risk in order to increase their accountability (5). The responsibility of such a decision has to be shouldered by all individuals concerned. The involvement of the population in the decision making process is, therefore, needed both for ethical and political reasons (to improve acceptability and accountability of the stakeholders).

Economic constraints also call for the direct involvement of the population in the decision making process and for a more decentralised approach to risk management. An important emerging aspect of post-accident management is the increasing role of cost constraints. This results from the recession encountered by the CIS economies and is also linked to the gradual decline of the Chernobyl issue in the political process.

Prescriptive centralised programmes of countermeasures face many obstacles: they do not cope with local features, they are rejected by local stakeholders, are inefficient and expensive in the long term. Centralised approaches for post-accidental risk management, although necessary in the early phase, are not appropriate for the long term, and are not sustainable.

Local authorities are inevitably confronted with progressive decreasing external or national support for the management of radiological quality and safety -- although national and international solidarity arrangements remain essential for sustainable life on the contaminated territories.

Most of the choices must be contextualised at the local level and should involve local populations if they are to be acceptable, coherent and efficient. Individuals and local communities in the contaminated territories should, therefore, be actively involved in improving the coherence and the efficiency of the risk management process.

3.10.4 The ETHOS project

The ETHOS project has initiated an alternative approach to the post-accident rehabilitation. One characteristic of this new approach is to address jointly the social and the technical dimensions of the post-accident situation in an attempt to avoid the difficulties resulting from making, on the one hand, the risk assessment and risk management a technical problem for the experts and, on the other hand, the public acceptability an insoluble communication problem in a context of distrust.

The ETHOS project is based on the strong involvement of the local population into the rehabilitation process. Its main goal is to create the conditions for the inhabitants of contaminated territories to reconstruct their global quality of life. This reconstruction deals with all the day-to-day aspects that have been affected or threatened by the contamination, that is health, especially of their children, food, security at home, professional life, social life, environmental quality, leisure, the economic value of produce and goods, future and that of their children, individual and collective identity and culture.

In order to avoid the social dynamic of loss and restriction that is observed when focusing on risk reduction, the ETHOS project is aimed more at rebuilding acceptable living conditions. Radiological security is developed as part of a general improvement of the quality of life. As many social factors can affect progress in radiological safety[2], the quality of living conditions in the affected territories must be taken into account comprehensively if sustainable and solid progress is to be achieved.

ETHOS is a three year project initiated in the Republic of Belarus at the beginning of 1996. The ETHOS project involves an interdisciplinary team of European researchers from the following institutions: the Centre d'étude sur l'Evaluation de la Protection dans le domaine Nucléaire - CEPN (radiological protection, economics), the Institut National d'Agronomie de Paris-Grignon - INAPG (agronomy, management), the Compiègne University of Technology (safety, social trust) and Mutadis Consultants (social risk management, sociology) who is ensuring the scientific co-ordination of the project. On the Belarus side, the ETHOS project involves as a scientific partner the Ministry of Emergencies of Belarus. It also involves relevant local administrations.

A first mission in Belarus was organised in April 1996 in order to determine a site of implementation given that the selection had to be based on the voluntary commitment of the local authorities. A total of 6 districts in the contaminated territories from the south of Belarus were visited, and the broad outlines of the project were explained to the local authorities. After discussions and negotiations with different authorities, the candidate village of Olmany in the district of Stolyn (Brest region) was selected.

The village of Olmany (1265 people) is linked to a kholkoze of roughly 1800 hectares. The main production of the kholkoze is milk, wheat and meat. Tradition is still very deeply rooted in the social organisation, and the population, contrary to other districts more affected by previous relocation

[2] The economic recession has for example led to a decrease of the radiological protection.

policies, has a large proportion of young people (369 less than 17 years old). The village of Olmany is characterised by a quasi-absence of evacuated people in spite of having a ground contamination ranging from 37 to 555 KBq/m^2. The active involvement of the population is at the very heart of the ETHOS approach; consequently, the existence of social networks, including families with children was of primary importance in selecting the site for the implementation. Problematic contamination levels of privately produced food appear to be a real concern for both the population (notably the mothers) and the local authorities. Despite an on-going political debate on the opportunity to relocate the population of the village, there is a strong opposition from most of the people.

A co-operation framework was signed in July 1996 between the European research teams and the CIS partners of the project at three administrative levels: the Chernobyl Ministry of Belarus, the District of Stolyn and the Village of Olmany (Kolkhoze). A series of 8 missions in the field took place from March 1996 to October 1997, allowing the creation of 7 working groups involving the local population.

3.10.5 The ETHOS approach

The first stage of the ETHOS approach was to establish relations and trust between the population and the researchers. This process is driven by strong ethical principles which underpin the co-operation between the European team of researchers and the local population. The first addresses the usual question of the local population when meeting foreign experts: "Do you think we can live here with our children ? Are there any risks for our health ? Should we leave this territory or stay here ?". This type of questions relates to the lack of trust between the population and the experts. It was decided to adopt the position of answering that the task of the research team was not to take decisions for those confronted with the risk but to help those having decided to stay in the village to re-establish their security and quality of life. This answer led to questions from the population like: "What would you personally do yourself ? Would you come and live here with your children ?" which were answered by each participant on the basis of his personal feeling toward the situation.

The second main ethical principle relates to the responsibility of the research team towards improvement of the local situation. As a result of the numerous Chernobyl post-accident international surveys, the population of the contaminated territories has a general feeling of "being treated as guinea-pigs" by the scientists "without any kind of benefit in return". This makes it necessary for the ETHOS team to commit itself to improve, as far as possible, the real local situation within the duration of the project. An extensive list of some 50 criteria of success was set up by the research team and discussed with the partners at the local, regional and national levels in Belarus (including four main headings: radiological safety culture, quality of life in the village, self government of the local population, co-operation and social trust). The above principle was put into practice throughout the project; any research that would not lead directly to potential improvement was avoided.

The second stage of the ETHOS approach was a process of collective learning and assessment of the local situation. Local working groups were created with volunteers and researchers with limited tasks aiming at a concrete improvement of the quality of life and including a radiological dimension (for example: to provide children with clean milk). Each working group progressively involves the different actors that have an interest in the task (stakeholders) at different levels. This includes the population itself, the administrative framework at local, regional and national levels but also different networks such as public health, agriculture and farm produce industries, retail business, etc.

The relevant aspects of the radiological situation are assessed by local measurements, managed directly by the population. Every member in the groups participates in the collection of information. Existing information is also checked according to European scientific standards. This process makes possible for both the population and the ETHOS team to draw a common picture of the situation and to validate each piece of information. It was noted when discussing with participants of the groups at the end of this second stage that their general appraisal of the situation has shifted from an average feeling of "dark grey" to a more contrasted evaluation ranging from some very dark to much clearer views of the situation.

This second stage is a collective learning process involving both the ETHOS researchers and the population. The research team does not make its own assessment to be communicated subsequently to the population. The primary goal is the creation of a context in which the radiological appraisal makes sense for the local actors as regards concrete improvement achievable with available resources

The third stage of the ETHOS approach is a process of reconstruction and improvement. The creation of reliable common pictures of the radiological situation makes it possible for the local people to reassess and reconstruct aspects of life which have been threatened or deteriorated: food, safety notably at home, social and economic relations, relation with nature, leisure, their the future, individual and collective identity, etc. They can reassess what is still good (but was wrongly considered as deteriorated). They also have to reconstruct affected aspects of life in developing, for example, new techniques to grow "clean" vegetables or to produce clean milk and meat, new economic activities coping with the radiological context and in creating new safe leisure activities for children.

The participants are discovering significant potential to improve the situation with available resources where previously they thought it impossible given their lack of resources. Although limited, these emerging local opportunities for improvement are all the more important given that the present lack of resources will remain in the future a real problem given the political and economic context. They also are of prime importance in the process of restoration of autonomy and self confidence in the population.

These means of improvement result from different factors like examining the problems in their real context rather than in general with average measurements. Average measurements tend to conceal the real problems as well as the available solutions. In many cases, the exposure has to be assessed in an individual way in each specific context. Opportunities for progress also appear when the local actors are provided with new techniques or methods. They also appear in the working groups when individuals or institutions (stakeholders) accept their own efforts or own disagreements to achieve common goals considered as a priority (such as the health of children). This, of course, depends on the number of stakeholders involved in the process. More co-operative stakeholders usually identify more opportunities to improve a situation.

While starting with a few local volunteers aimed at one specific task, each group progressively extends or modifies its goals given its findings and the emerging potential of actions to improve the situation. The relevant stakeholders are then involved according to the nature of the revised goals. This process is a sort of dialectic between the structure of the group (the social system) and the proposed goals of the group (the project). This process makes it possible to gradually restore the usual interactions (economic, political, cultural) of the social network that have been damaged by the accident.

The progressive involvement of the stakeholders in each context of action also makes it possible to propose some concrete acceptable change as regards the radiological situation by taking into account not only the radiological risks but also the real risks at stake for all kinds of involved actors. One can mentione, for example, the political situation that may result from an increase of the public information and knowledge, the loss of incomes resulting from the retail of unmeasured products from the forest that may be contaminated, etc. While not being taken into account what is "really at stake" usually leads to strong resistance to change, and therefore makes it impossible to improve such a situation.

The practical projects of ETHOS and their provisional results are summarised.

The mothers group

Creation of the first working group

During the July 1996 mission most interviews performed by the ETHOS team members to establish contacts with the population of the village pointed out a strong concern about the health of children because of their day to day exposure to radiation. A first meeting was organised with about 10 voluntary mothers and several members of the ETHOS team to discuss this important issue more thoroughly. The discussions revealed the very approximate understanding by the mothers of the exposure pathways (external and internal) affecting their children. The lack of information to assess the radiological situation was also clearly identified as a factor favouring the feeling of anxiety and powerlessness among the mothers. Based on the general willingness of the mothers and the ETHOS team to try "to do something" to improve the situation, a first working group was created with most of the mothers previously involved and members of the ETHOS team. As a first action it was decided to gather data about the daily diet and activities of the children. Several mothers proposed to write down in notebooks this information for their own children for the period up to the next ETHOS mission.

Assessment of the situation

In October 1996, the notebooks were analysed during a series of meetings of the working group and it became evident for all participants that the collected data should be put in relation with the radiological situation concerning each family. A measurement campaign was then organised to collect information about the ambient dose rates in houses and gardens where children played and about the concentration of caesium in the food they ate. First ambient dose rate measurements were performed in a house by a few mothers with the help of ETHOS team using a measurement protocol established by the working group. Several food samples were prepared and brought for measurement at the school nursery where equipment was available.

Following this first positive experience, the mothers took the decision to perform themselves further measurements concerning their homes and food products using the local measurement equipment and devices provided by the ETHOS team. A second food contamination monitor has been installed in the village by the Chernobyl Ministry in the summer of 1997 to cope with the increasing number of samples to be measured.

About 20 houses have been screened by the group within a few months: dose rates inside rooms, near the stoves and in the gardens have been measured by the mothers themselves and reported on plans they keep at home and which they can discuss with friends (see Figure 3.10.1)

An effort was also made by the group to spread the experience and the results throughout the village. Measurements were shown to the population, and discussed in the course of meetings. A poster was also prepared and put up in the village by the mothers to inform people about the activities and to encourage diffusion of the work. Information on the activities and the results of the group were also continuously transmitted to the different actors interested in the development of the project at the local, regional (authorities in the district) and national levels (Ministry of Chernobyl).

Identification of means of improvement

The information collected by the mothers group with regard to the ambient dose rates measured in houses, gardens and recreational areas, as well as the study of the children's diet, have revealed that the situation was far from homogeneous. This resulted in the identification of positive aspects when low-level ambient dose rates, or categories of food with low contamination levels, were observed. Meanwhile, problematic situations were also pointed out in certain families, where categories of food more sensitive to contamination were measured. These observations have also been correlated with results of whole body measurements performed on children at school, making more sense to the mothers.

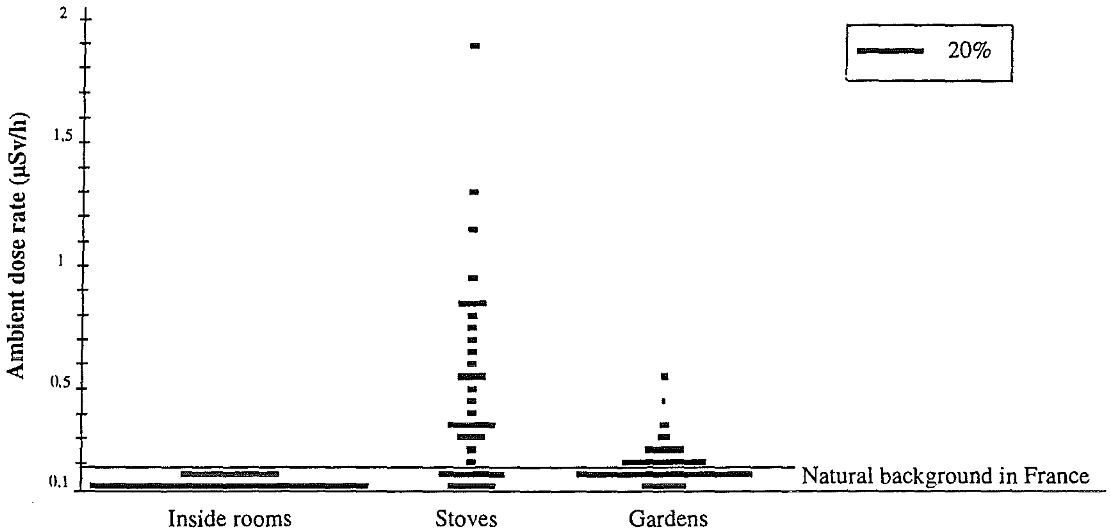

Figure 3.10.1. Distribution of measured ambient dose rates inside rooms, near stoves and in gardens

The measurements continuously performed by the mothers group, in addition to those of other groups in the village, such as the "milk group" and the "meat group", constitute a basis on which the mothers were relying, and from which they could base their choices for the children's protection. After having introduced information on natural background radiation in France, the group was able to elaborate a dose scale that gave, in a comprehensive way, direct information on how to respond to a given dose rate, in regard to the time spent (see Figure 3.10.2). The mothers expressed their regain of control over the external radiation in the following way: "Even if the radiation is high, we can speak of it. If it is normal, we can leave it aside. We have to be prudent and not to go where there is too much radioactivity".

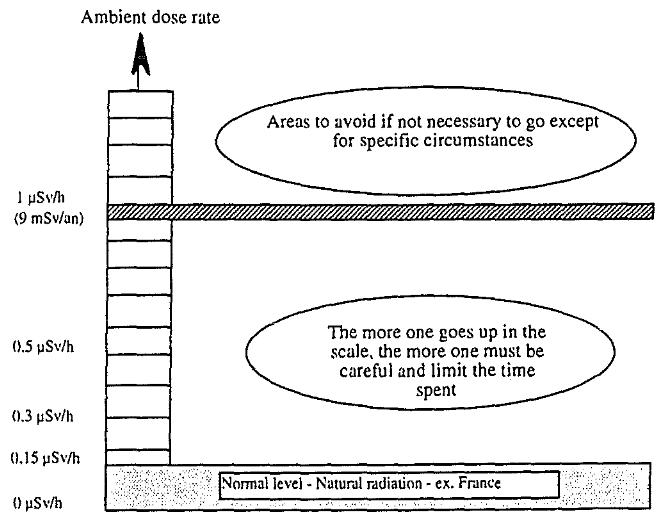

Figure 3.10.2. Dose rate scale performed by the mothers group

The analysis of the results on food contamination and children's diet brought the group to a better assessment of the daily intake of radioactivity. It appeared that the situation was different for each family, and that the daily intake of radioactivity was very sensitive to some categories of foodstuffs - milk, berries, mushrooms -, which directly influenced the total ingestion by several orders of magnitude for the same diet (an example of this sensitivity related to the diet of two children, is provided in Table 3.10.1).

Table 3.10.1. Sensitivity of the children's daily ingestion of radioactivity with food contamination and with the diet

		Children A		Children B	
Product	**Contamination range[a] (Bq/kg)**	**Diet[b] (g)**	**Ingestion[c] (Bq)**	**Diet (g)**	**Ingestion (Bq)**
Bread	10 - 60	250	2,5 - 15	200	2 - 12
Butter	30 - 400	10	0,3 - 4		
Vegetable soup	10 -100	100	1 - 10	100	1 - 10
Meat	10 -300	100	1 - 30	100	1 - 30
Stewed apples	10 -100	150	1,5 - 15	500	5 - 50
Sauerkraut	10 - 50	300	3 - 15		
Rabbit	10 - 300	100	1 - 30		
Potatoes	10 - 100	100	1 - 10		
Stewed berries	100 - 2000	200	20 - 400		
Potato soup	10 - 100	200	2 - 20		
Cocoa milk	10 - 2000	100	1 - 200		
Stewed potatoes	10 - 100			150	1,5 - 15
Buckwheat porridge	10			50	0,5
Milk	10 - 2000			100	1 - 200
Omelette with dripping	0 - 10			120	0 - 1,2
Salted cucumbers	0 - 100			100	0 - 10
Lard	10 - 300			50	0,5 - 15
Total (Bq/day)			**34,3 - 749**		**12,5 - 343,7**

(a) According to the measurements performed by the "Mothers group", the "Milk group" and the "Meat group"

(b) Estimates from the "Mothers group" results

(c) Min and max values according to the contamination range observed

This evaluation had direct consequences in attitudes towards children's diets. The mothers reached a stage where they are able to manage the daily ingestion of contamination of their children, by selecting food with lower contamination. The acceptance or the rejection of a food product because of its propensity to be highly contaminated became a responsible choice, belonging to the family. Moreover, these reflections led to the elaboration of an ingestion scale by reference to an annual budget (values of 20,000 Bq/y and 10,000 Bq/y were adopted as a reference for this scale), and allowed direct links to be made with limits on contamination adopted by the national authorities.

Construction of autonomy

The work performed by the mothers group has shown that it is possible to regain control of the management of the radiological situation at the family level through an individual approach. The mothers have built a common picture of the situation in their houses, and this re-construction of quality at home has brought about real changes in the way of perceiving and managing the radiological risk. As a mother said "Now it is possible to ask people for information. It is reliable".

The group has also discovered that individual choices as regards the contamination were possible to improve the situation. These choices can, for example, be to adapt the time spent by children according to dose rates measured, or to have direct control on the ingestion of contamination through the food given to children, providing mothers with real means to decide if they would accept or not to feed their children with products particularly sensitive to contamination. As a member of the group said during a meeting "If we are told what not to do or where not to go, we don't care, but if it depends on us, it is different".

The clean milk group

First contact with private milk producers and first elements of re-assessment

Direct interviews with the population of Olmany in July 1996, and a series of meetings with private milk producers, revealed a strong concern with respect to the daily consumption of contaminated milk by babies and children. Discussions with many producers have progressively drawn a picture of the way the population perceived the contamination of milk, seen as general and irreversible at the scale of the village. Meanwhile, many producers expressed a shared willingness to try to better protect their children with respect to the ingestion of contaminated milk.

During the first mission, a group of several voluntary producers and members of the ETHOS team collected the existing information on the contamination of private milk in the village for the year 1995. These measurements were provided by local and regional authorities, resulting from a periodic survey of the contamination of foodstuffs, conducted in the village since the Chernobyl accident. The results (Figure 3) caught the interest of many producers. On the one hand, the large proportion of very contaminated samples confirmed that the population was facing a serious problem of milk contamination. On the other hand, the diagram showed that "clean milk" was available in the village and this was received as good news.

The idea to isolate the clean milk emerged progressively in the discussions. The existence of clean pastures led some members of the group to envisage the creation of a specific sub-herd for babies and children. However, this general objective of producing non-contaminated milk, even restrained to children, was not directly conceivable without a clearer view of the real situation. Finally 10 voluntary producers decided to embark on an attempt to establish a "map of the milk " of the village to identify from where the clean milk was coming.

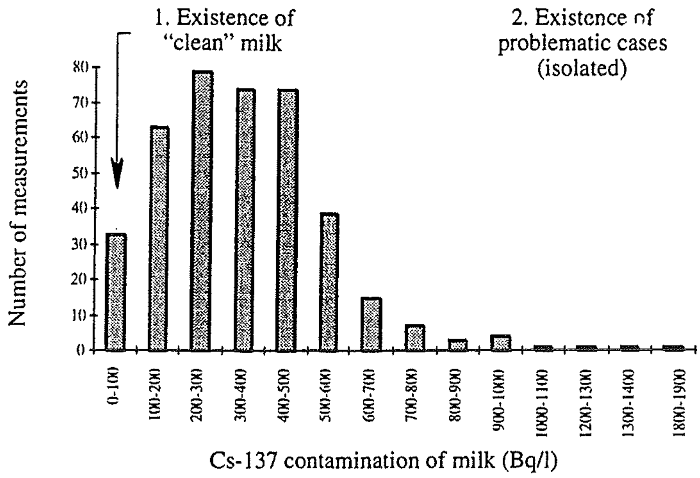

Figure 3.10.3. Distribution of milk measurements performed in Olmany in 1995

<u>The collective learning assessment process through measurements</u>

In a first step, the producers involved in the milk group focused their efforts on the measurement of the contamination of milk, hay and pastures. As far as possible, local measurement equipment was used. A key factor at this stage was the progressive construction of local know-how in the field of radiation, shared by all the participants in the project, and on which the group relyed.

Between the various missions of the ETHOS team, about 10 local producers of the group co-ordinated the activities with other producers in the village, with the kolkhoze and with those responsible for measurements of milk contamination. They organised the milk survey and helped other producers to involve themselves in the project. During missions, they shared the results with the ETHOS team. Meetings were held during which results from measurements were systematically discussed. Scientific and technical issues were solved, as far as possible, during the missions, through the elaboration of measurement protocols, preparing guidelines on which the milk group and the ETHOS team could rely.

Besides the radiological aspects, the results of the "milk mapping" allowed a better appraisal of the whole organisation of private production and its strong interaction with collective farming. In particular, it revealed two distinct organisations according to seasons. In winter, each producer has individual control over his resources. In summer, private cows are rounded up into 7 herds for which pastures are allocated by the collective farm.

This collective assessment played an important role in the dynamics of the working group. The better comprehension of the situation led to a tightening of the objectives with the possibility of implementing concrete actions with locally available means. Furthermore, it broadened the number of actors involved, opening new opportunities for negotiation and improvement at different levels - local (kolkhoze), regional (district) and national (Ministry of Chernobyl).

<u>The re-construction and improvement process</u>

At each stage of the project, the results from measurements were discussed and the ETHOS team helped the producers to interpret their measurements and to point out specific, individual, common or collective problems. The re-assessment process led to concrete actions such as looking for new 'clean' pastures for the herds of concern, creating sub-pastures with the less contaminated parts of the existing 'grazing routes', setting up a sub-herd devoted to the production of 'clean milk' for children. All these solutions were more or less acceptable to the producers taking into account their respective cost, complexity and expected effectiveness.

During the summer period, the information collected by the producers pointed out specific problems concerning two of the 7 herds in the village (see Figure 4), due to the fact that they were grazing on non-improved pastures. After negotiations between the private producers and the kolkhoze, herds n°1 and 2 were re-oriented in August 1997 towards improved pastures[3]. This re-organisation was made possible because of the consensus obtained between all producers and between the producers and the direction of the kolkhoze. Significant improvements were already observed by the end of the summer.

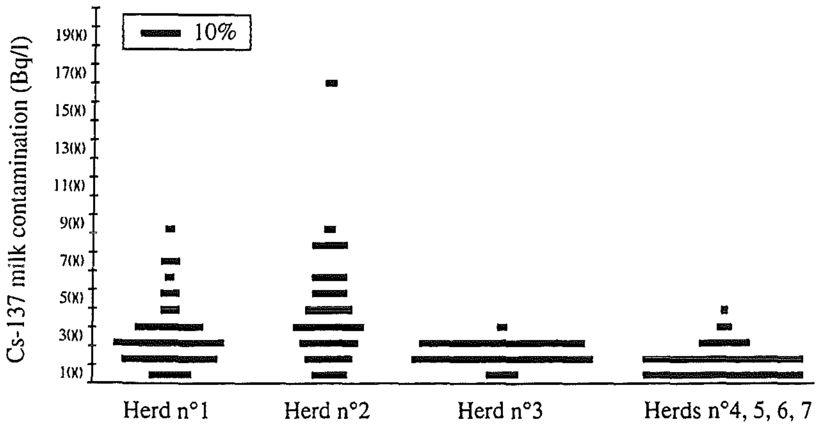

Figure 3.10.4. Comparison of the distribution of milk measurements during the summer period for the 7 private herds in Olmany

During the winter period each producer has an individual control of his own resources and this results in a wide distribution of the milk contamination between producers. Milk samples measured during the winter of 1997 were individually discussed with the producers with the largest problems in terms of milk contamination. These discussions led about 10 producers to reorganise their milk production taking into account their available winter resources: distribution of hay according to its level of contamination and the lactation period, distribution of ferrocyn adapted to the hay contamination, feeding of the animals with complementary foodstuffs when available (beets, potatoes). Each voluntary farmer prepared a protocol with the help of the ETHOS team taking into account calving periods, the available quantities of different quality of hay and ferrocyn (see Table 3.10.2).

The idea to isolate the clean milk emerged progressively in the discussions. The existence of clean pastures led some members of the group to envisage the creation of a specific sub-herd for babies and children. However, this general objective of producing non-contaminated milk, even restrained to children, was not directly conceivable without a clearer view of the real situation. Finally 10 voluntary producers decided to embark on an attempt to establish a "map of the milk " of the village to identify from where the clean milk was coming.

The meat quality group

The quality of meat appeared to be a concern from the first mission. Most of the meat (pork, poultry and eggs) of private farmers is produced by subsistence farming. The inhabitants don't really know the level of radiological contamination of their meat production but the overall situation of their village makes them think that it is highly contaminated.

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[3] The improvement of pasture is one of the national countermeasures adopted after the Chernobyl accident in the contaminated territories. It consists in a deep ploughing of existing pastures, followed by reseeding and fertilization.

Table 3.10.2 Individual optimised planning of animals feeding for winter production

	Cow 1		Cow 2		
Month	Hay (Bq/kg)	Ferrocy (Y/N)	Hay (Bq/kg)	Ferrocyn (Y/N)	Radiological quality of milk (Bq/l)
Nov					
Dec		*(Calving)*			
Jan					
Feb					
Mar				*(Calving)*	
Apr					

Private producers are concerned about giving their family meat products that are possibly contaminated. Some families do not even want to know the level of contamination of the meat, arguing they would have to eat it in any case.

The contacts with all involved actors (private producers, kolkhozes, shops...) in the Stolyn district have showed that none of them seems to have a precise idea of the level of contamination in private meat production. Meat contamination is only controlled at the market, at the abattoir and at the factory of Stolyn.

As a result of this lack of quality control, private producers are constrained to sell their meat production (live calves) to the kolkhoze at low prices. The private producers would rather sell meat for a higher price at, for example, the market of Stolyn. But they would have to slaughter their own animals, and then pay for transport to Stolyn, not being sure whether it could be sold because it could exceed the contamination limits.

Collective assessment of the radiological quality

The first step was to identify the actors involved in meat production and its sale. Interviews in Olmany and Stolyn showed how meat is produced, transformed, sold and eaten. Contacts with the private meat producers of Olmany led to a first meeting with volunteers in April 1997 during which it was decided to create a "meat quality " group. The ETHOS team and the meat producers defined three goals to be achieved successively. The first, considered as a precondition to any further actions, was to assess the level of contamination of the meat produced in private farms. The second was to attempt to produce enough clean meat all year round, particularly for children's diets. The third objective was to sell any clean meat surplus on the market.

The first action of the "meat quality" group has been to measure the radiological contamination of meat produced in Olmany. Protocols were designed by the participants for the more important categories of fresh meat. Pork was selected because it is the principal meat consumed in the village. Veal was also selected because producers were interested in examining the possibility to sell it at the market of Stolyn to increase their incomes. The kolkhoze is then feeding the animals with clean food during 40 days before to sell them to the abattoir of Stolyn. Nobody knows the need for such a cleaning process because the level of contamination of the life calves when sold by the farmers remains unknown and the radiological contamination of the meat is only measured afterwards at the abattoir. Eggs were also measured because they are usually used for children's breakfasts.

Pork and eggs were measured first and the private producers were surprised by the results which showed relatively low contamination. Twelve pieces of pork were measured in 1997 and only one sample was higher than 200 Bq/kg. The contamination of the eggs was below 25 Bq/kg. A map of Olmany was drawn to identify the origin of the measured eggs. The measurement campaign continues.

In order to be able to sell their calves directly, the producers group decided to develop a protocol to measure the external dose rate in contact with the animals in order to assess the potential quality of the meat. First tests were made with private producers in Olmany and the abattoir at Stolyn in April 1997[4].

Search for means of improvement

In July 1997 the meat quality group organised two meetings in order to improve the radiological quality of the meat and the incomes of producers. Different individual situations were analysed in detail. Reducing the contamination of meat appeared to be difficult because producers can hardly change herd feeding, except for veal production, and in this case, this may lead to an increase of the contamination of milk. A typical situation in Olmany is when a farmer has two cows and a calf and contaminated as well as clean hay. If he wants to produce clean milk, he can give the clean hay to one of the cows and use the milk for his family (see the "clean milk group" presentation). The contaminated hay is then given to the other cow whose contaminated milk is given to the calf which will be contaminated. Conversely the farmer can give the clean milk to the calf in order to produce clean meat but will then be short of clean milk for his family. Adaptation to seasons was also examined, e.g. feeding calves with contaminated milk in summer when the animals are fattened and then "cleaning" them with clean food in autumn, before slaughtering. The meat quality group decided to work in the future with the clean milk group to study more thoroughly these different cases to identify strategies that might avoid facing the dilemma of choosing between clean milk for children or clean meat to increase families' income.

Several means to increase the producer's incomes have been discussed. According to the first results, the contamination of the meat in Olmany is generally low enough to be sold on the market place or to the abattoir at Stolyn. In doing so, private farmers could significantly increase their incomes. However, it was recognised by all participants that such an approach would be facilitated by a certification system for meat throughout its whole production, thus bringing reassurance to potential buyers. As a result, the members of the group decided to study the creation of a pilot local laboratory in Olmany, where private producers could assess the quality of meat (not only radiological contamination) which could be the starting point for setting up a certification system involving the abattoir, the shops and the market place.

[4] The protocol used by the veterinary of the abattoir is based on a direct dose rate measurement in µR/h on the calf and more precisely localised on shoulders blade and legs. After measuring the ambient dose rate with a dose rate meter equipped of a collimated probe (1cm of lead), a second measure is performed. If the value read (on an analogical display) is higher than 1 µR/h compared to the ambient dose rate, the calf is considered as contaminated and refused. If not, the calf is killed and then, a measure of mass activity of meat is systematically done.

The young people project

Since the beginning of the project the members of the ETHOS team tried to enter into contact with the young people of Olmany (between 16 and 25 years old). However this important social group for the future of the village was resistant to being involved in the project and it was only in July 97 that a working group was created with the young people.

A preliminary step was to gather knowledge about their interests and occupations in order to facilitate contact with them and establish mutual trust. Individual interviews were carried out with groups of two or three young people at a time during the mission of July 1996. These interviews showed that young people were not at all interested in the radiological issue. During the mission of February 1997 several possible projects were proposed by the ETHOS team. From a choice between a sporting venture, an "ecological garden" and a video production, the last option generated some interest but also a lot of fears that they may fail in this task.

The ETHOS team encouraged the formation of a group whose objective was to prepare a video presenting the life and experiences of the young people as inhabitants of Olmany. The underlying goal was to enable them to express their emotions regarding their everyday life in a contaminated environment.

In July 97, the ETHOS team organised a training session to explain the proper handling of a video camera and its associated equipment : tripod, light, etc. This material was left in the hands of the newly formed video group, following the signing of a formal contract between the research team and the group, to ensure responsible use of the equipment. It was also decided by the video group that they would first prepare small films to learn the technique. After several discussions, the video group proposed to film the various facets of a year in the life of the village comparing behaviour before and after the Chernobyl catastrophe and a "scenario" presenting the seasonal activities of the village was finally adopted.

During the October 97 mission, the ETHOS team met up again with the video group to find out how they had progressed during its absence. The young people expressed the difficulties and successes they had experienced during the making of six short films of about twenty minutes each depicting the various aspects of their life in the village such as harvest time, fishing in the local rivers and lakes. Additional technical support was provided to the participants by the ETHOS team. The group will continue this work until the next mission in February 1998. Some interviews with people of the village already recorded will also be made by the group.

The development of the video group has not yet reached the stage where a process of re-assessment and reconstruction of various aspects of the young people's lives has been reached. They are still in the process of discovering the extent of their own capabilities and initiatives. However, it is expected that through the process of making a film, the young people will start to see their situation differently as they recount their own versions of daily life. This modified vision will hopefully become part of a more widespread reconsideration of the deeply affected aspects of their daily life as a consequence of the Chernobyl accident. If the quality reached in the first recording is maintained, the video film could be shown to the inhabitants of Olmany and to other villages of the district and could lead to meetings and discussions where young people of the video group could directly involve themselves if they wish.

The pedagogical project

From the first contacts with the inhabitants of the village of Olmany in March 1996, children appeared to be at the very heart of the concerns of the population. During the following mission in July contacts were established with the school of Olmany with the objective of studying the impact of the radiological context on the daily life of the children. Discussions with the Director, the school nurse, the person responsible for the library and several teachers allowed the ETHOS team to become more familiar with the local context and its consequences for the children.

In order to gather some material to be analysed, a first co-operation with the teachers was set up. Children were asked to prepare school essays describing their daily life and activities throughout the year to be sent to the children of a French school. Half a dozen classes participated to this action involving children from 11 to 16 years old. Some 98 essays were gathered. This material was translated and analysed by members of the ETHOS team. A selection of 20 letters were translated and sent to the children of a French school in a village of Normandy. Answers from the French children were sent back later on to Olmany.

The study of the letters revealed the problems encountered by children confronted by contamination which represent for them a very complex situation. Difficulties to cope with several inconsistent aspects of their daily life were observed. For example, while mentioning the high contamination of the forest surrounding the village and the official restrictions concerning the consumption of products from there, several children were describing their enjoyable daily activities in the forest and the pleasure in consuming the products from the forest. Another feature was their description of their summer stay in Europe organised by humanitarian organisations because they are living in a contaminated territory which implicitly led them to the feeling of being ill whatever their health was. It also appeared that the children were confronted to social and ethical incompatibilities characteristic of the post-accidental context which could have possible worrying consequences for their future development.

These findings led the ETHOS team to build a project with the school of Olmany and its 350 pupils in order to improve their living conditions, to help them to cope with this complex post-accidental situation and to build a more coherent picture of its various facets. Strong concern was expressed by the teachers of Olmany as regard this problem. As a result of the exchanges between the Director of the school and the ETHOS team, it was decided to start a first pedagogical pilot project involving 3 teachers aimed at the development of practical work with the children relating to the radiological situation of the village. This project was also discussed with the official responsible for education at the District level.

Until summer 1997, the teachers involved have actively developed their respective task. During the following missions progress was discussed and support provided to the teachers by the ETHOS team. Eventually the involved classes completed their projects in preparing a set of posters describing food chain contamination, the evolution of the demographic aspects of the village since the Chernobyl accident as well as a series of maps showing the geographical characteristics of the village and its surroundings.

This pilot action between the teachers and the children was a first attempt to address together both the objective reality of the contamination in the village and its theoretical aspects as developed in the school books. Another aspect of this experience was to enlarge the usual relation of the teachers with the pupils. Teachers have experimented a new kind of co-operation with the children by participating together in the gathering and interpretation of the available information.

Based on this first experience, a reflection took place with the teachers, the Director of the school and the authorities in charge of education at the District level in order to define the basis of a second project with the school. The objective could be to create the conditions for the children to better cope with the different facets of the complex situation they are facing and to establish a concrete link between the theoretical knowledge which they are currently taught at school and the practical dimensions of their everyday life in a contaminated environment.

The kolkhoze project

The involvement of the kolkhoze in the ETHOS project

The first contacts in July 1996 with the kolkhoze revealed the economic difficulties it had to face, and particularly the growing problems related to the implementation of the programme of countermeasures enforced after the Chernobyl accident by the national authorities. Several meetings with those responsible for the kolkhoze at the beginning of the project led to a better understanding of the different economic and practical aspects of the local implementation of these countermeasures and their sustainability in the Belarussian political and economic context.

Major findings from the other ETHOS groups in Olmany during the first year of the project pointed out the interactions between the private production system in the village and the kolkhoze production. Progressively, the role the kolkhoze could play in the advancement of the working groups emerged and its first direct involvement took place in April 1997 in relation to improvement of the private milk production, in particular with the attribution of improved pastures for summer and the provision of clean hay for winter. Furthermore, the data collected by the milk group during the summer clearly showed that the contamination of a significant part of the private production was below the limit accepted for milk transformation, while the fraction of the private milk production above this limit could be used by the kolkhoze to feed young calves. These findings were discussed between the milk group, the ETHOS team and the economist of the kolkhoze and a possible common management of the private and collective milk production was envisaged.

Contacts with other kolkhozes in the Stolyn district

During the July mission, the authorities of the district organized a meeting with the ETHOS team, the President of the kolkhoze of Olmany and two other Presidents of kolkhozes from the district to discuss possibilities of enlarging the ETHOS project outside Olmany. A series of visits were organised in the two kolkhozes facing very different situations both in economical and radiological terms. These visits allowed the ETHOS team to identify new factors affecting production in the district of Stolyn but also new opportunities to improve, or at least to maintain, the radiological quality of the products, in the general context of economic recession.

The firewood and ashes group

The measurements of ambient dose rates in houses, performed by the mothers group, identified higher dose rates close to and inside stoves. The mothers and the ETHOS team members agreed on the fact that this situation did not raise a serious problem with regard to the exposure of children because of the very short time they spend close to the stoves. However, the question of the possible impacts of the ashes which are generally spread over gardens as fertilisers was raised and beyond this specific practice, the question of the use of firewood for heating houses, cooking meals and heating water for laundry was also addressed.

Assessment of the real significance of the problem

This question caught the interest of the mothers, who collected and measured the contamination of ashes from several stoves in the village. The Cs-137 contamination levels ranged from 15,000 to 80,000 Bq/kg. A crude estimate performed by a member of the ETHOS team concluded that the additional contamination resulting from the spreading of contaminated ashes in gardens may contribute to a significant increase of the ground contamination of these areas (see Figure 7). The involved mothers, joined by several foresters, expressed their interest in investigating this problem in more detail, to check if it was significant or not, in radiological terms.

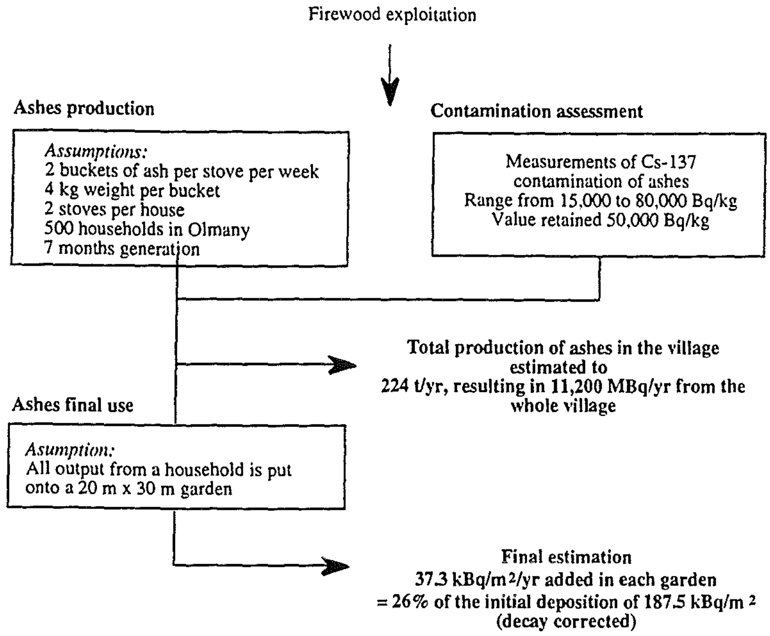

Figure 3.10.7. Rough estimation of ashes production

Initiation of a project-system with local volunteers

During the October 1997 mission of the ETHOS teams, a member of the district forestry living in Olmany took the responsibility of performing investigations on the origin of the firewood used in the village, its contamination, the quantities as well as the corresponding quantities of ashes produced and their final uses. An assessment protocol was established with the ETHOS team. Depending on the first results, a new working group may be created with the objective of reducing the radiological impact of ashes.

3.10.6 A provisional appraisal

Eight missions representing about 400 man-days have been accomplished since the beginning of the ETHOS project allowing real progress in the seven working groups aimed at concrete improvements in radiological safety and quality of life in Olmany.

The first achievements can be summarised as follows:

In terms of radiological safety culture, the involved inhabitants (about 1/4 of the adults) together with the ETHOS team have built common representations of the radiological situation pervading the village, such as the food contamination process, the contamination pathways of the environment (pasture, forest), the ambient dose rates and the resulting external doses, etc. They can now manage for themselves radiological measurements, such as ambient dose rates and food contamination and they have a better understanding of the basic radiological concepts.

In terms of quality of life in the village, as a result of the working groups, inhabitants have discovered significant means to reduce their radiological exposure (external and internal doses) and notably the doses to the children. Private farmers have identified actions to improve the radiological quality of their production (notably milk) through a better use of available resources (clean and improved pastures, ferrocyne, clean hay, etc.). The project will certainly improve the economic value of local products and resources as soon as a certification system can be implemented for managing the radiological quality of the products. Other actions, such as the domestic energy production project, will avoid or reduce the re-contamination of the village.

In terms of autonomy of the local population, inhabitants of the village have voluntarily participated in working groups for which objectives have been collectively set. They have taken initiatives for successful actions they previously thought impossible. There is a growing self confidence in the population.

In terms of co-operation and social trust, ETHOS has had a positive effect on the social climate. Better co-operation has been established between the local actors and the existing administrative framework. Local decision makers are showing a growing interest in enlarging the project. However, the conditions for effective dissemination of the approach have yet to be developed and demonstrated.

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3.11 Implementation of RODOS in Eastern Europe

The implementation of RODOS is one of the key objectives of the cooperation with the partner institutes in the East European countries. In particular, these are Poland, Czech Republic, Slovak Republic, Hungary, Romania, Belarus, Ukraine and Russia.

As part of this activity, the existing resources for the installation of RODOS in emergency centres (e.g. organisational structures, meteorological and radiological networks to connect to, geographical and environmental data available) are investigated. Based on the results of this investigation, the efforts to install RODOS in emergency centres can be optimised.

The first task for each contractor was to define the administrative environment in which the RODOS System has to be implemented. After the investigation of the administrative aspects of the implementation of RODOS in emergency centres, the next step was to make a survey of the physical resources for the implementation of the RODOS System. These are in particular

- the hardware to be used for the RODOS System,
- the on-line connections
- the geographical and environmental data

This task was finished in late 1997 and the results are described in detail by each country in a report describing the current status of implementation.

3.11.1 Conditions of the implementation of RODOS in the different countries

Due to different national regulations and physical resources in each country, the RODOS System will be implemented in different ways in emergency centres. Using the flexibility of RODOS, this can be achieved by modifying the interfaces and adapting the modules.

Poland

The President of the National Atomic Energy Agency (NAEA) is responsible in Poland, for crisis management in case of nuclear emergency. As a consequence the Centre for Radiological Events (CEZAR) has been created under NAEA supervision. CEZAR should be seen rather as a functional body than a separate department in NAEA. During the emergency situation personnel in several departments of NAEA, will constitute CEZAR together with experts from the Central Laboratory for Radiological Protection (CLRP), the Institute of Atomic Energy (IAE) and other institutions. During normal operation the staff of the Department of Radiation and Nuclear Safety of NAEA is responsible for monitoring the radiation situation having access to the national radiological monitoring network provided by CLRP.

The National RODOS Centre (NRC) shall be located in CEZAR of NAEA. CEZAR is also the designated operator and maintainer of the RODOS system and shall maintain the communication links and monitor the input/output of the RODOS system in normal operation and in emergencies.

The following institutions shall interact with the CEZAR:

Central Laboratory for Radiological Protection (CLRP): Provides the connection with the national radiation monitoring network. Interactive user in normal operation. Access for the control of the installation, testing and validation of the installed software with different scenarios.

Institute of Atomic Energy (IAE): Interactive user and supplier of dedicated real-time meteorological prognosis databases based on appropriate links. IAE will also play a role of the Technical Support Organisation. Access for the control of the installation, testing and validation of the installed software with different scenarios. IAE - a part of the Swierk Centre is the only place in Poland, where nuclear facilities are located.

Institute of Meteorology and Water Management (IMWM): Supplier of real-time meteorological monitoring data, providing access to the GTS of the WMO. Interactive user in normal operation. Access for the control of the installation, testing and validation of installed software with different scenarios.

Hungary

The National System for Nuclear Emergency Preparedness (NSNEP) has been established in Hungary in 1989 by the Order of the Government to prevent and mitigate the consequences of an nuclear accident. The permanent Secretariat of the Governmental Committee of the Nuclear Emergency Preparedness (GCNEP) is responsible for the emergency preparedness in normal situations, e.g. for the planning and organisation of the personnel and technical resources required in emergency situations. During emergency situations it provides administrative and technical support to the Governmental Committee, which is responsible for the handling of nuclear emergencies and decision making.

The decision making at the GCNEP is supported by the Technical Scientific Advisory Board (TSAB) and by the Emergency Information Centre (EIC) of the GCNEP.

Civil Defence is responsible for the operation of a nation-wide network of stations for gamma dose-rate measurement including the operation of the EIC for early warning purposes. Additional stations of Army and the Meteorological Service and the Ministry of Environmental Protection and Regional Policy are also connected to the System.

The responsibility for the collection and processing of laboratory data is with the National Environmental Radiation Monitoring System (NERMS) Information Centre operated by the National Research Institute for Radiobiology and Radiohygiene (NRIRR).

The Nuclear Power Plant at Paks operates a database for its on-line data both from the stack and from the vicinity of the plant, which is updated every 10 minutes. Based on the on-line data from the meteorological mast and from the stack monitoring or the on-line monitoring stations a prognosis of the near-range transport and dose around the plant could be provided.

The central organisations of the NSNEP and their main tasks relating to the nuclear emergency preparedness are:

- GCNEP (decision making)
- Operative Staff (evaluation, recommendation to decision, leading and controlling the execution of decision)

- TSAB (advising) .

According to the decision of the Governmental Committee on Nuclear Emergency Preparedness (GCNEP) the National RODOS Centre (NRC) of Hungary will be installed at the Emergency Information Centre of GCNEP. The main tasks of the institutions, organisations interacting with the NRC are the following:

GCNEP EIC: designated operator and maintainer. Maintaining the communication links and monitoring input/output of RODOS system in normal operation and in emergencies. Supplier of radiological data of the Countrywide Radiation Monitoring Warning and Surveillance System.

National Environmental Radiation Monitoring System Information Centre (NERMS IC): provides the connection with the national radiation monitoring network. Interactive user in normal operation. Access for the control of the installation, testing and validation of the installed software with different scenarios.

KFKI Atomic Energy Research Institute (KFKI-AERI): interactive user in normal operation. Access for the control of the installation, testing and validation of the installed software with different scenarios.

Hungarian Meteorological Service (HMS): supplier of real-time meteorological monitoring data, providing access to the GTS of the WMO.

Interactive user in normal operation. Access for the control of the installation, testing and validation of the installed software with different scenarios.

Hungarian Atomic Energy Commission (HAEC): CERTA of HAEC is supplier of source term data. Passive user.

Nuclear Power Plant (NPP Paks): supply of radiation values acquired by the plant radiation monitoring system. Supplier of source term data. Passive user

Romania

The Romanian RODOS Group comprises scientists from three distinct departments of the IFIN-HH, a legal entity which is under co-ordination of the Ministry for Research and Technology, by means of the Institute of Atomic Physics.

To accomplish its activities related to customisation and implementation of an operational RODOS system in Romania, IFIN-HH established necessary connection and/or collaborations, as follows:

- connections with all governmental authorities which have representatives in CCANCOC, for logistic and legal support;
- collaborations with institutes having specific professional profiles, such as:
- Institute of Environmental Research and Engineering (ICIM) for RODOS system connection to radiological networks; by its Environmental Radioactivity Laboratory (LRM), ICIM (Institute under CNCAN's co-ordination) is the national scientific administrator of the Romanian environmental radioactivity surveillance network;

- National Institute of Meteorology and Hydrology (INMH) for specific data and the connection of the RODOS system to regional/national meteorological networks;

- "Fundulea" Agriculture R&D Institute, "Basarabi" Agricultural Research Station and "Brashov" Agricultural Research Station, for modelling and countermeasure data;

- Institute of Public Hygiene and Health (Bucharest), for demographic and nutrition data;

- Institute of Military Topography, for maps and associated countermeasure data.

All of the above mentioned institutes are legal entities functioning under subordination or co-ordination of the appropriate ministries with specific responsibilities as parts of the CCANCOC.

Belarus

The radiation control on the territory of Belarus is carried out to diminish the consequences of contamination by the nuclear substances that have come from the NPPs of the adjoining states. The radiation control is carried out in three zones : zone A - the territory contaminated owing to the Chernobyl's nuclear catastrophe; zone B - territories of the possible radioactive influence made by NPPs of adjacent states; zone C- the rest territories.

The system of radiation control includes State , departmental and public control. The State one is conducted by the Ministry of Health (dosimetric control of radiation of population and radioactivity of contaminated food-stuffs), BELSTATESTANDART (control over measurement means), STATECOMHYDROMET . The latter is a main organisation that is responsible for methodical support and management in estimation of the radiation situation of environment. Adding to that the Committee conducts radiation monitoring (exposure dose rate -57 stations, natural fall-outs - 26 stations, aerosols concentration in the atmospheric air - 6 stations, radioactive contamination and radionuclides migration - on 181 reference sites and landscape - geochemical testing grounds).

In the Republic of Belarus there is functioning the Special Commission for Emergencies attached to the Council of Ministers. It is headed by the vice-premier. The Commission involves the following institutions: the Ministry for Emergencies; the Headquarters of Civil Defence; the State Committee for Hydrometeorology; the Ministry for Health (Protection); other State bodies.

Ukraine

The decision making on off-site nuclear emergency actions in Ukraine is managed by the following governmental authorities:

- Ministry of Environmental Protection and Nuclear Safety (MEPNS), that includes Administration of Nuclear Regulation (ANR MENPS);

- Ministry of Emergency Situations (founded in 1996 as a successor of the former Headquarters of Civil Defence and the Ministry of Chernobyl Problems). (MES)

- State Committee on Hydrometeorology (UkrHYDROMET).

- Department of Nuclear Power Production of the Ministry of Energy (successor of the former GOSATOM)

- Company "ENERGOATOM" - the agency founded in 1997 that operates the Ukrainian nuclear power plants.

- Emergency Department of the Cabinet of Ministers

State Emergency Commission (SEC) chaired by the first Vice-Prime Minister works in each national scale emergency situation. In the emergency due to the nuclear accidents the SEC would work based on above mentioned authorities between which MES would enforce countermeasures at the national level.

The Government Information Analysis System (YIAS NS) started to be developed in 1995 as the system of the Emergency Department of the Cabinet of Ministers to integrate information from the information systems of different ministries to support the work of the State Emergency Commission (SEC). In 1997 the MES started to be agency responsible for the SIAS development, support and maintain. The server of YIAS NS is installed in Emergency Response Centre of MENPS.

The National RODOS Centre shall be located at the Emergency Response Centre (ERC) of MEPNS/NRA. Also the central processing unit of the GAMMA 1 radiation monitoring system is located in ERC, as also server of SIAS.

The ERC receives both routine and emergency information from nuclear power plants (NPPs) and other sources. Then it independently analyses the information and disseminates conclusions to MEPNS officials, other Ukrainian authorities, the public, and international organisations. The ERC facility provides the organisation, technical tools, and communications for nuclear and ecological experts of MEPNS to perform these functions in accordance with requirements of Ukrainian law, decisions of the Cabinet of Ministers, and international agreements. The ERC functions in two modes, "normal" and "emergency."

NORMAL OPERATIONS -- The *ERC personnel* ensure the readiness of the ERC by testing and improving equipment, maintaining procedures, and conducting exercises. The all-hours *Duty Officer* regularly monitors the status of each NPP and receives calls about unusual situations, analyses the information and, if it is necessary, relays such calls to senior officials, who decide if an unusual situation requires special attention.

If the unusual situation does not require emergency procedures, MEPNS officials review reports and data received in the ERC, decide what actions (if any) should be taken to improve safety, and inform others as appropriate. Certain events are described and classified according to the International Nuclear Event Scale (INES) by the designated National INES Officer. This information is shared with other countries, who use INES as a common system for describing and comparing events.

EMERGENCY OPERATIONS -- If the First Deputy Minister decides to activate the ERC emergency plan, specially trained personnel are directed to report to the ERC immediately. In the ERC they organise into the following groups (see Table 3.11.1):

- A *Data Analysis Group* analyses technical data and information and prepares short summaries with recommendations for the Executive Group. The Data Analysis Group includes experts in reactor engineering and operations, population protection, and the environment.

- A *Liaison Group* consults with the Data Analysis Group, exchanges information with other organisations, and prepares official statements for review and approval by the Executive Group. The Liaison Group also briefs the media and answers questions from the public. It includes experts in working with the media, in international relations, and in procedures for information exchange with IAEA. The ERC includes work areas for representatives of the Ministry of Ukraine for Emergencies and Population Protection from Consequences of the Chernobyl Accident and of the State Committee for Use of Atomic Energy to ensure good communication with those critical organisations.

- An *Executive Group* reviews summaries and recommendations from the Data Analysis Group, together with any other information that they may have received, and decides what actions should be taken. The Executive Group also approves official statements for external organisations and the public, and manages all ERC operations to ensure that the MEPNS/NRA mission is fulfilled. The Executive Group is led by the First Deputy Minister.

- A *Technical Support Group* ensures that all functions of the ERC continue throughout an emergency. Members of the Technical Support Group must be experts in maintaining communications and technical support equipment, as well as in using alternative methods in case of failures that cannot be corrected quickly.

Duty Officer in Area 1 communicates with the NPP, calls experts to the ERC, and relays initial information to

Data Analysis Group in Areas 3 and 4, which analyses outputs of data systems and other sources, then briefs

Executive Group in Area 5, which makes decisions, consulting as necessary with other authorities, and relays them to

Liaison Group in Area 6, which writes and disseminates reports, arranges media sessions, and answers questions.

Feedback is very important to help ensure accuracy: the Liaison Group verifies information with the Data Analysis Group as it prepares statements for final approval by the Executive Group; each group has the opportunity to see that its views are understood correctly.

A rest area is also provided adjacent to Area 1. Major support equipment (such as a telephone PBX, LAN servers, UPS equipment, and a copier) is located in Area 2.

Since 1991 IMMS CC is involved into the research and development activities for the RODOS in the fields of hydrological modelling, system development and optimisation of early countermeasures efficiency. The hardware and software system of RODOS PRTY 1.0 has been installed in IMMS CC in the frame of JSP-1 project at spring 1994. The system is used as for the R&D works, including RODOS adaptation and customisation, as for the wide scale RODOS presentation for the Ukrainian emergency management institutions. This first experience reveals also the main problems of the RODOS implementation in Ukraine taking into account the specifics of national measurement networks, GIS standards, management of the regions surrounding six Ukrainian nuclear power -- Chernobyl NPP, Rivno NPP, Khmelnitsky NPP, Zaporozhe NPP and South Ukrainian NPP, adaptation of the basic input information for the RODOS running in the Ukraine, specifics of the Ukrainian nuclear emergency management institutions.

Table 3.11.1. Information and Emergency Centre Functional Areas

AREA NO.	FUNCTION	AREA, M^2
1	Duty Officer	16,80
2	Support	12,55
3	Data Analysis	38,60
4	Data Support & Entrance	31,08
5	Liaison	26,05
6	Executive	28,76
	Total	**153,84**

Russia

In the Russian Federation, a series of regulations are in force to control the announcement of a radiological emergency, real-time information transmission, special assistance to affected facilities and population protection measures in the event of a radiation accident. By these regulations, in the case of an accident at nuclear installations, the Federal Service of Russia on Hydrometeorology and Environmental Monitoring (Roshydromet) is directed to play an active role in emergency response actions on a national level.

The responsibility for response to radiation - related emergencies rests with the Ministry of Atomic Energy of Russia (Minatom) and Roshydromet of them Minatom is providing the monitoring in the area of nuclear facilities (normally, 30km zone around facilities) and Roshydromet is responsible for the monitoring on the entire territory of Russian Federation.

In the framework of the bilateral agreement between Minatom and Roshydromet, efforts are being made to set up a distributed system for collection, processing and presentation of data on the radiation situation around nuclear power plants (NPP) and other nuclear facilities (NF), both at normal operation and in emergency. The information sources in the system are automated systems of monitoring of the radiation situation at NPP and NF (Minatom) and territorial system of radiation monitoring (Roshydromet). Collection and processing of data at the information network is performed by emergency centres of NPP and NF and territorial specialised centres of Minatom and Roshydromet.

In this context, Roshydromet has established a specialized centre for providing real-time and prognostic information about the radiological situation in the territory of Russia (Emergency Response Centre). The Emergency Response Centre (ERC) has been based in SPA "Typhoon" in Obninsk and its primary responsibility is to provide information support in dealing with the consequences of a nuclear accident. The ERC works in close collaboration with organizations which, by Russian regulations, will be involved in emergency response (c.f. Fig 3.11.1).

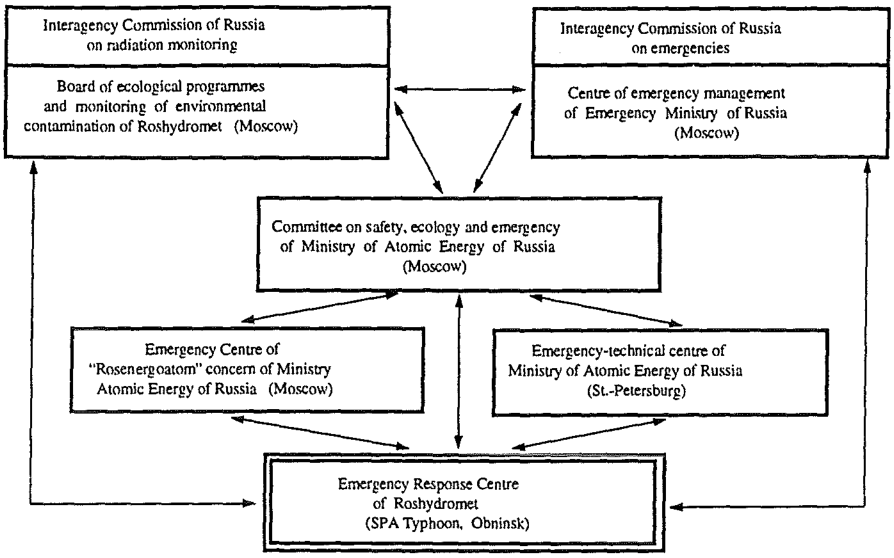

Fig. 3.11.1 Structure of information interaction

Tasks, functions and administrative structure of the ERC of Roshydromet

ERC of Roshydromet is in charge of the collection and analysis of radiation monitoring data from Roshydromet Radiological network on the territory of the country and for this purpose it also works in contact with coordination and management bodies of Roshydromet (Emergency Response Working Group, Board of Ecological Programmes and Environmental Contamination Monitoring).

In preparation and presentation of data on the radiation situation in Russian Federation in case of a nuclear emergency, ERC of Roshydromet collaborates (c.f. Fig) with Emergency Technical Centre of Ministry of Atomic Energy of Russia (St-Petersburg), Emergency Centre of "Rosenergoatom" concern of Russia (Moscow) which provides interaction with NPPs, and Centre of Emergency Management of Ministry of Emergency (Moscow) which receives expert support from Nuclear Safety Institute of Russian Academy of Sciences (Moscow) in case of a nuclear emergency. The above organizations act as National Centre of Russia on radiation monitoring and information support to decision-making in case of a nuclear emergency. In the framework of this National Centre, coordination lies with Centre of Emergency Management Ministry of Emergency. Efforts of the emergency centres of Ministry of Atomic Energy are coordinated by the Committee on Safety, Ecology and Emergencies.

In accordance with the above main goals of ERC of Roshydromet, it consists of:

- Operative department (round-the-clock operation; radiological situation data base; data preparing and offering to all interested institutions);
- Software and information department (provision of functionality and modification of computer, telecommunication and program means; design of new software for operative data processing and development of geoinformation system);

- Expert-analytical department (development of scientific-methodological basics of analysis and control over radiological situation in emergencies; design of physical-mathematical models of predicting of radionuclides transportation into environment).

3.11.2 The hardware environment in the different countries

The hardware used for the RODOS System will be similar in all the implementations, only the additional environment (e.g. computers to connect to networks or to other emergency installations) differs due to the particular integration into the emergency process.

The basic hardware environment is

- HP-9000 workstation
- HP-UX 9.05 or 10.20 operating system
- FORTRAN , X11R5, OSF/Motif1.2, HP-ALLBASE/SQL or INGRES for HP
- 128 MB or more RAM
- 2 GB or more HDD
- DAT, CD-ROM,
- RODOS PRTY 3.0
- WAN connection
- X-terminals or other workstations
- Postscript Printer

3.11.3 The connections to on-line networks in the different countries

Examples of the connections to on-line networks in different countries are given in the next sections.

Romania

Upon the Romanian territory there are working 3 nuclear reactors; two of them are research reactors (2 MW and 14 MW) and the third is the CANDU-600 power reactor of the first unit of the Cernavoda NPP which was inaugurated during 1996 year.

For each of them have been elaborated, by their users, the Response Plans in Case of Nuclear Emergency according to our Republican Standards for Nuclear Safety (NRSN).

There are in progress activities aimed to bring up to date the intervention plan in case of nuclear accident at Bulgarian NPP which is located in Kozlodui, a settlement situated very close to the south border (the fourth nuclear risk zone) which is on the Danube river; the bringing up-to-date of this plan will be made taking into account the recommendations of the IAEA expert missions.

To cope with the task of radiological monitoring in this nuclear context, there are two main kind of radiological networks:

- a national one (the National Network for Governmental Radioactivity Monitoring, RNSRM), which is under administration of ICIM from Ministry of Waters, Forests and Environmental Protection (MAPPM);

- networks for each of the four nuclear risk zones around the above mentioned installations.

RNSRM comprises at present 46 monitoring stations scattered over the whole country, some of them on mountains, in the Danube Delta and near NPP at Cernavoda and Bechet (NPP Kozlodui-Bulgaria). Besides these non-automated stations, at Cernavoda and Bechet were also installed two local networks for quickly warning, with automatic measuring (gamma dose rate) and data transmission. All of the 46 monitoring stations are equipped with adequate devices for the measuring of gamma dose rate in atmosphere. The two automated local networks (at Cernavoda and Bechet) constitute the first nuclei of the future automatic network for alarming and monitoring the environmental radioactivity (RAAMRM); only this RAAMRM will be suitable for the RODOS requirements which need real-time/ on-line data measurement and transmission. This new RAAMRM will be implemented using the structure of the existing RNSRM network by improving the measuring equipment and, especially, by introduction of a fully automated, modern system for data transmission.

Especially for the Kozlodui and Cernavoda NPP's off-site there is a Laboratory for Environmental Radioactivity (LRM) which makes use of radio-transmission for real-time gamma dose monitoring.

For off-site radioactivity monitoring there are also available different mobile units as follows:

- 2 land-vehicles for sample drawing and gamma dose rate measurement; one of them is the property of Environmental Radioactivity Monitoring Station (SCRMI)-Cernavoda and the other one is the property of CANDU-NPP Cernavoda;

- 6 land-vehicles, equipped for gamma dose rate measurement and sample drawing, pertain to the Civilian Protection Inspectorates in 6 different districts;

- 6 autolabs, 4 of them pertaining to Radiation Hygiene Networks being subordinated to Sanitary Police Inspectorate in 4 districts; the owners of the other two are the Institute for Hygiene and Public Health and IFIN-HH;

- 2 helicopters of the military forces, equipped for aerial search and dose measurements.

The control of radioactive contamination level of foods and water is assured by more than 20 Radiation Hygiene Laboratory (LHR) which are subordinated to the Ministry of Health.

The control of the level of radioactive contamination of foods is under responsibility of the Central Laboratory for Animal Products Control - LCCPOA-(from Ministry of Agriculture) and its 13 zonal laboratories.

The equipment and instrumentation of the existing national radiological monitoring networks are not able yet to fulfil the requirements of the RODOS system for on-line & real-time delivering/receiving data.

Until the situation changes, our RODOS equipment needs special software to manage the technical reality.

There are 4 Meteo Tower placed, as a rule, near nuclear installations i.e. in Bucharest (Magurele and Afumatzi), Cernavoda and Pitesti localities.

There are also potentially transferable in real time to RODOS data base meteorological data from the modern towers which are installed and operated on some of our international airports in south-east areas (Constantza-Kogalniceanu, near Cernavoda CANDU-NPP and Bucharest-Otopeni) and in north-west area (Cluj and Timishoara).

The national meteorological network in Romania is administrated by INMH-Bucharest which belongs to MAPPM. Measured meteo data are, for the time being, off-line collected, from 210 territorial stations, towards 6 regional forecast centres and from there toward INMH; a new data set is available after a minimum one hour interval.

INMH-Bucharest receives also (and stores in an Internet host computer together with those from national network) meteorological data via WMO network; these are data measured at ground level and/or forecast data using SYNOP, TEMP, GRID or GRIB formats.

For analysis and forecast of data INMH makes use of the METEO FRANCE model allowing 24 and 48 hours forecast, at different levels: ground, 1500 m, 3000 m and 5000 m.

Ukraine

The ***Gamma-1 System*** relays real-time radiation readings from sensors that are 2 to 30 km from NPPs. If the readings reach high levels that could indicate a radioactive release, the system transmits an alarm to consider protective actions. The existing pilot system was developed under the TACIS program of the European Union. The system includes gamma dose-rate monitors and a weather station near Zaporozhye and Rovno NPPs, as well as an alpha/beta aerosol monitor near Rovno NPP and a gamma monitor for water effluent from that plant. Windows-NT server of GAMMA-1 is installed in the ERC. The Ukrainian Ministry for Emergency Situations also has access to the Gamma System.

The ***Remote Monitoring System (RMS)*** will soon provide independent real-time data about operations at Zaporozhye Unit 5, along with site meteorological and radiological conditions, to analysts in the ERC. The pilot system at Zaporozhye NPP was developed under a co-operative program with Germany.

A nation wide non-automatic radiological monitoring system by UkrHYDROMET is in operation with monitoring stations in the 30-km-zones of all NPPs. A special information centre is able to determine the atmospheric dispersion by using the data provided by national meteorological and radiological monitoring systems and with the help of the WMO network. The system computer and communication equipment are old and not appropriate for the real-time on-line informational exchange.

An automatic system for control of radiological situation (*ASKRO*) for environmental monitoring is being installed by GOSTATOM for the protective zone of every NPP. ASKRO does not include forecasting and decision support capabilities. ENERGOATOM as a successor of the GOSATOM now considers aims at the establishment of Emergency Response Centres at each of the Ukrainian NPPs and of the National Crisis Centre, based on the ASKRO network and

UkrHYDROMET data. The ASKRO systems are on different levels of readiness for different nuclear power plants. For Zaporozhe NPP pilot version of ASKRO will be ready in 1998.

In the R&D RODOS centre in the IMMS CC it was installed the workstation HP-9000/735, received from EC in the frame of the JSP-1 programme of the Chernobyl programme. The RODOS software is updating in correspondence with released by FZR versions of it.

Dedicated telephone lines and equipment at each NPP and in the ERC allow communications with NPP personnel independently of public telephone systems. The equipment is being upgraded to test quasi-simultaneous transmission of voice and data from Zaporozhe and Rovno NPPs during emergencies.

Another data link has been established under the GAMMA project which provides the connection between the GAMMA system in around Zaporozhe NPP and Rivvno NPP and Kiev- ERC.

The ERC also has access to public systems, and access to the special Government Information Analysis System that provides for exchange of information and analyses about extraordinary situations. The system connects the basic Ministries and Departments of Ukraine.

The European Community plans to link several European regional centres for high-speed exchange of radiological and meteorological data during extraordinary situations such as a nuclear power plant accident. The project, currently called the "***Prototype System***," will permit participating countries to react quickly to a radiological emergency in any one of them. One of the regional centres will be at the Crisis Centre of the Russian Committee for Hydrometeorology in Obninsk, which will be linked to the Ukrainian State Committee for Hydrometeorology. In turn, the ERC will be connected to the Ukrainian State Committee for Hydrometeorology with high-speed data links that will allow the ERC to use its automated information systems to full advantage. The tender on "Prototype System" will be open in January in the frame of the TACIS programme.

Russia

To fulfil its tasks of radiological monitoring on the territory of Russian Federation, Roshydromet relies on 1460 hydrometeorological stations (HMS) and monitoring posts (OP) forming part of territorial departments of hydrometeorology and environmental monitoring of Roshydromet (24 territorial departments and Moscow Center of hydrometeorology and environmental monitoring).

The activities of these bodies include:

- gamma radiation dose rate is measured in 1304 points;
- aerosol samples are collected on horizontal collectors to measure total beta activity of fall-out in 438 points;
- in 51 points aerosol samples are collected with fitters to measure concentration of radioactive aerosols in the surface layer of the atmosphere;
- in 11 points aerosol samples are collected with vertical collectors to measure concentrations of radioactive aerosols in the surface atmospheric layer;
- samples of precipitation are collected to measure tritium in 32 points;

- samples of freshwater are collected in 17 points to measure tritium;
- samples of freshwater are collected in 53 points to measure strontium-90;
- samples of sea water are collected in 12 points to measure strontium-90.

ERC is engaged in round o'clock exchange and analysis of various types of information including text, binary and graphic data. At present, ERC is connected with Global Telecommunication System (GTS), the meteorological network and monitoring network of Roshydromet in which data exchange is arranged on the base of the meteorological telecommunication system (MTS) of Roshydromet and Emergency Centre of "Rosenergoatom" Concern of Ministry of Atomic Energy of Russia. This makes it possible to receive and process on-line the following types of information:

- data of meteorological forecasts for the Northern hemisphere from prognostic centres including Moscow, Washington, Bracknell, Reading in codes GRID (text) and GRIB (binary);
- data of meteorological observations from meteorological stations of the world in codes SYNOP, TEMP, SHIP and PILOT;
- data on the radiation situation from the observation and monitoring network of Roshydromet (telegrams in codes RHOB, WOZDUX);
- data on the radiation situation around the Russian nuclear power plants. The daily volume of data received and processed is about 20 MB.

Other types of data can also be received and processed.

Given the software developed in ERC of SPA "Typhoon" is used, a remote access to real-time ERC database can be arranged. To pass data via E-mail (INTERNET), the request-answer method is used. At present the remote users of ERC database are Rosenergoatom Concern, Kalinin NPP, Smolensk NPP and Kursk NPP.

3.11.4 First implementation steps

Adaptation of the RODOS System

After the release of RODOS Version 3.0 in autumn 1997, the contractors started to adapt the RODOS System to their local conditions. This task consists mainly of the translation of the user interfaces into the local language and the configuration of the Real-Time Data Interface for the available real-time data. Due to the late release of the Version 3.0, these tasks are still pending.

Collection and loading of data

The investigation of the data formats used for environmental and geographical data showed, that the efforts to transfer this data into RoGIS can be shared. Most of the contractors had geographical data in the ArcInfo data format available, which can be directly loaded into the RoGIS database. Using the library of translation modules, most of the other data formats available (e.g. MapInfo) were covered. Thus, most of the countries do have geographical data available in RODOS now.

Additional data, such as population distribution, shielding factors or land use can either be calculated out of the existing data or taken from European wide data sources.

3.11.5 References

The environment in which the RODOS System will be installed in the different countries and the current status of the implementation is described in the following documents:

- RODOS(WG1)-TN(97)06: Status of the Implementation of RODOS in the Czech Republic
- RODOS(WG1)-TN(97)07: Status of the Implementation of RODOS in the Ukraine
- RODOS(WG1)-TN(97)08: Status of the Implementation of RODOS in Hungary
- RODOS(WG1)-TN(97)09: Status of the Implementation of RODOS in the Slovak Republic
- RODOS(WG1)-TN(97)10: Status of the Implementation of RODOS in Poland
- RODOS(WG1)-TN(97)11: Status of the Implementation of RODOS in Belarus
- RODOS(WG1)-TN(97)12: Status of the Implementation of RODOS in Romania
- RODOS(WG1)-TN(97)01: Implementation of RODOS in Emergency Centres

They are continuously updated by the contractors. The actual versions of these documents are available from the contractors.

4 Summary of main achievements

The RODOS project was an important activity within the 3rd Framework Programme of the European Commission. Effective collaborative links and working arrangements between both West and East European partners had already been established within this past project phase. Therefore, there was no initial or transient starting phase of the contract. On the contrary, the work described in the Technical Annexes of the five separate, but fully integrated, contracts with the EC could be started immediately and/or continued without delay on the basis of existing co-operation between partners. Some 40 institutes from about 20 East and West European countries are now participating in what is the second phase of the project.

Given the scale of the project and the large number of geographically dispersed participants, particular attention has been given to the arrangements for the management of the project. A matrix approach has been adopted with overall co-ordination being achieved through the RODOS Management Group comprising representatives from the EC, the co-ordinators of the respective contracts and independent members. Control of the resources within each contract is exercised by the respective co-ordinators; the technical work, integrated across all contracts, is managed through twelve Working Groups. Each Working Group has responsibility for a specific technical area and, *inter alia*, for ensuring that the project tasks are completed on schedule and in accordance with the project specification.

Since RODOS is to be deployed in emergency centres for operational use, the project management has a heavy responsibility to develop appropriate quality assurance procedures to enhance the stability, maintainability and reliability of the delivered software. Therefore, the following instructions have been developed:

- a variety of guidelines for the consistent development of well documented and readable software;
- procedures for the static testing of software;
- standards for documentation, including an auditable description of the verification and validation tests performed by the contractors.

However, RODOS is a multi-institute, multi-national project. Most quality assurance methods adopted within industry apply to the development of software within a single organisation in which there is a uniform culture and style. All the institutes within the consortium of RODOS contractors have their own internal quality assurance guidelines, each different in detail from the rest, though not different in their objectives. Thus, in developing the RODOS quality assurance procedures, these differences had to be taken into consideration. A consensus has been reached and the quality of RODOS is being verified and validated, but progress in the first half of the project has been slower with fewer tangible outputs than had been planned. Nonetheless, there is a schedule being put in place to ensure that all software verification and module validation is completed on time; the project management are confident of this being achieved in the second half of the project.

The work performed and the progress achieved within the reporting period can be separated into deliverables and on-going R&D activities. Deliverables are software components and their documentation developed by the contractors for incorporation in the RODOS framework and methodology. Three types of RODOS software have been developed:

- *RODOS pilot version PV3.0* with models, data bases and the resulting functionality for operational application in emergency centres;

- *RODOS prototype version PRTY3.0* with prototype models and data bases incorporated in addition to those in the corresponding pilot version, which require further development and/or integration work and testing; in addition, complementary

- *stand-alone programs* under development which will complete the RODOS methodology.

The *on-going R&D work* mainly comprises the development of new methodologies, the improvement of models and the extension of data bases for broadening the functionality and applicability of the RODOS system.

The content and functionality of the existing RODOS versions, the status of the stand-alone programs and the achievements of on-going research are summarised.

4.1 The RODOS pilot version 3.0

The most important milestone has been achieved: namely, the first operational version RODOS PV3.0 has been produced during the contract period 1996-97. Compared to previous versions and as planned in the working programme, it is no longer a prototype but a pilot version for installation and (test-) operational use in emergency centres. The applicability of version PV3.0 is still limited to the early and intermediate phases of emergency response and to distances of several tens of kilometres from an accidental release.

The software framework of RODOS PV 3.0 has been further enhanced in its functions by the incorporation of, *inter alia*: the program, real-time databases and the geographical information system RoGIS, together with the geographical database; new user-friendly interfaces for selecting and specifying the interactive and automatic modes of operation, for input of source term, meteorological and countermeasure data, and for graphical presentations of results; an extended SQL syntax allowing for database applications with the database management systems ALLBASE and INGRES. User guides exist in German and English versions together with a draft system manual.

The comprehensive atmospheric module MET-RODOS has been designed and its near-range part has been system-integrated. It consists of the Local-Scale Pre-processor LSP and the Local-Scale Model Chain LSMC. The local scale pre-processing program LSP maintains the local-scale system with actual and forecast local scale wind fields and corresponding micro-meteorological scaling parameters by intensive pre-processing and by use of local scale wind models. The local scale model chain integrates the puff dispersion model RIMPUFF and the segmented plume model ATSTEP.

Weather data and dispersion meteorology are provided in real-time via on-line connections to local meteorological observations (from on-site meteorological towers or sodars) or via network connections to national or international meteorological services. Forecasts in up to 48 half hour steps of ground-level air and wet deposited concentrations including dose rates can be produced, both on the local scale and on the European scale (see PRTY3.0).

The transfer of radionuclides from the plume to terrestrial foods, as well as the resulting radiation exposure, are modelled in the Deposition Module, the Food Chain Modules, and the Dose Modules. As results of the deposition calculation, deposited activity onto 18 species of agricultural plants and soil are input to the Terrestrial Food Chain and Dose Module, FDMT. Activity intake by animals is considered by season dependent feeding practices. The products considered in the Food Chain Module presently comprise 22 feedstuffs (17 based on plants, 4 based on animal products and feeding water) and 35 foodstuffs (17 plant products, 17 animal products and drinking water). The relatively large number of products results from the need to reflect properly the diversification of plant species in reality. The estimation of doses is performed via all external and internal exposure pathways of importance during and after the passage of the radioactive plume; the endpoints are collective and individual organ doses for people of different ages.

The Early Countermeasure Module ECM:EMERSIM determines the areas for early emergency actions, such as evacuation, sheltering and distribution of stable iodine tablets, simulates these actions and calculates the individual doses with and without countermeasures. Different spatial and temporal patterns of countermeasure combinations can be chosen and evaluated.

The Late Countermeasure Module LCM:FRODO determines the extent and duration of relocation, decontamination and food restrictions on the basis of user-supplied criteria. The interaction between countermeasures can be considered to varying extents. For example, the effect of decontamination on the extent and duration of relocation and the need for and duration of food restrictions can be considered. LCM:FRODO provides information to allow early screening of possible strategies, identifying those which may be effective in the short term and those which may be effective in the long term, and therefore worthy of further investigation. This screening process also allows the dismissal of options which are clearly not worthy of further investigation. Early screening is a valuable part of any decision support system, in that it allows the more detailed consideration of options to be focused on those most likely to be of benefit.

The module HEALTH quantifies stochastic and deterministic health effects in terms of individual risks and the number of people affected; the economic costs of these health effects together with those associated with emergency actions and countermeasures are quantified in the ECONOM module.

For agricultural countermeasures, a mode of running LCM called the 'decision mode' has been defined to provide information on a number of countermeasure options and combinations of these options for a single food to the Evaluating subsystem (ESY) of RODOS, to enable countermeasure strategies to be evaluated using a wide range of information including effectiveness, costs, health effects and feasibility considerations.

4.2 The RODOS version PRTY 3.0

In parallel to the version PV3.0, the more extended prototype version PRTY 3.0 contains all those software components, which are available in draft versions, only partially integrated in the operation system, or still being tested. After final approval, they will complement the existing software in one of the next pilot versions.

The long range model chain has been established by nesting the outputs from the local scale model chain to the Eulerian long-range model MATCH. The interface between RIMPUFF and MATCH has been created together with an interface for accessing meteorological data of the forecast model HIRLAM.

A separate (outside MET-RODOS) stand alone atmospheric model chain for dealing with severe complex terrain has been developed and partially integrated in RODOS. It comprises the pre-processors DELTA and FILMAKER for describing the topography of the terrain and for converting meteorological data, and the Eulerian model ADREA in combination with the Lagrangian model DIPCOT for calculating meteorological fields and atmospheric dispersion, respectively. The ADREA model is a diagnostic and prognostic non-hydrostatic flow model that accounts for self-generating thermally induced circulations caused by differential heating, such as local sea-breezes, valley slopes, drainage winds, etc.

A complete hydrological model chain has been developed and integrated with its own user interface. The individual models cover the relevant transfer processes in the hydrosphere, such as run-off of radionuclides from watersheds following deposition from the atmosphere (RETRACE-1 and RETRACE-2 for small and large watersheds, respectively), transport of radionuclides in river systems (RIVTOX) and the radionuclide behaviour in lakes and reservoirs (LAKECO and COASTOX). The resulting contamination of water and fish is input to the Aquatic Food Chain and Dose Module

FDMA, which simulates the transfer of radionuclides from contaminated water and fish to man and the resulting radiation exposure.

The prototype version PRTY3.0 was installed at nearly all contractors' institutes; in addition, the pilot version PV3.0 was installed at institutes in China and Portugal on the basis of special software agreements with the RODOS Consortium of contractors.

4.3 Stand-alone software

Complementary to the software incorporated in the RODOS system, stand-alone programs have been developed either in near final or draft versions. Some of these programs are the result of ongoing R&D activities in individual institutes; dependent on the progress achieved by the end of the project, they will

- build part of the final RODOS versions,
- need further research activities and development work before they reach the status of operational applicability,
- remain stand-alone programs because integration in the system will not be possible or is considered not to be necessary, nevertheless they will remain significant contributions to the RODOS methodology.

A concept for software validation within the project has been elaborated, which describes a consistent QA procedure for RODOS. Commercial software for automated checking of software quality indicators was purchased and installed for use by all RODOS software developers. Software developed by the contractors can be sent via the Internet for automatic QA testing. A confidential protocol is produced and returned to the sender.

Work on the STEPS code package (Source Term Estimation based on Plant Status) started at the beginning of 1997, and major progress has been achieved. A quality assurance programme has been elaborated, agreed by all contractors and put in operation. The specification of the interface between STEPS and RODOS has been written and approved. A software development plan has been drawn up, distinguishing basically three different main modules describing the behaviour of the fuel, the primary system and the containment, complemented by a common data acquisition module. As STEPS should be applicable to any type of light water reactor, the containment module distinguishes classes of containments; each containment class is subdivided in a sequence of boxes, and the phenomena inside each box are described by an analytical approach. Preliminary considerations have led to a two box model for Western type PWRs, a one box model for VVER 230 reactors and a four box model for BWRs. A first software version of the containment module together with its manual have been developed. The technical specifications and the basic physical modelling of the primary system and fuel modules have been elaborated, and the architectural design for integrating the individual modules in the STEPS code package exists.

An alternative source term module, RODOS_STM, has been developed which uses plant data to determine the likely source term characteristics and their probability. RODOS_STM employs a Bayesian belief network to calculate the conditional probability of different source term categories based upon plant status. It is built upon the understanding of a reactor's behaviour developed during a probabilistic safety analysis. Although the main RODOS system is being built on a UNIX platform, RODOS_STM has been developed on a PC using the DXPRESS belief net shell. This designed choice has been made so that the system is able to capture plant data easily. The output from RODOS_STM is linked to the main RODOS system via a simple file.

Two pieces of work are approaching the issue of estimating the source term from stack, on-site and near site monitoring data. Firstly, a bootstrap method is used to estimate the source term from site periphery gamma dose rate monitors. It provides an estimate of the mean value of source term and a confidence interval for it. The source term estimated by this methodology is an integral value. Therefore, the (pre)calculated characteristics of isotopic composition of release are needed for a dose projection. Totally 54 sequences of the accidents and 46 corresponding isotopic compositions were evaluated for VVER 440/213 reactors for LOCA and containment by-pass releases. These sequences correspond essentially to the source term categories used in RODOS_STM, thus allowing the methods to be linked within a model chain in the RODOS system.

The second strand of development on source term estimation and prediction uses standard least-squares techniques to near-site gamma dose rate monitors. The least squares fitting is based upon the use of an atmospheric dispersion model, currently ATSTEP or RIMPUFF. It is being ported into the RODOS UNIX environment and will include nuclide specific source term estimation based on stack monitoring and an interface to the source term categories of RODOS_STM together with in-situ gamma spectrometry measurements.

For data assimilation within atmospheric dispersion models, a prototype BayesRIMPUFF has been developed. This is a modification of the RIMPUFF module, which uses novel dynamic belief net methodology to update predicted concentrations, deposition and dose rates in the light of monitoring data. The current prototype software is only applicable to single nuclide releases under a single layer wind-field. One of the strengths of BayesRIMPUFF is that the model naturally accepts the output RODOS_STM and can deal with monitoring data from stack, periphery, near site and distant monitoring.

To improve the modelling of evacuation, the module ECM:EVSIM has been developed for estimating the time evolution of the spatial distribution of the population during the early countermeasure phase. The model takes into account traffic flow and speed in order to estimate temporal changes in population distribution within the area being considered. It also contains an analysing module that evaluates the efficiency of the simulated evacuation. EVSIM exists as a draft stand-alone program with its own user interface for data input and presenting results, however, running on the RODOS workstation and with appropriate interfaces for accessing the system's data bases.

The prototype version of the STOP model, which will optimise evacuation routes with respect to different criteria, such as route length, dose saved, starting time and costs, has been developed as a stand-alone version with its own user interface and graphical presentation of results.

The conceptual structure of the evaluation subsystem ESY of RODOS has been developed: it consists of a coarse expert system (CES) filter, a multi-attribute value and utility theory (MAV/UT) ranking module and a fine expert system filter (FES). The current CES module, which is built upon constraint satisfaction methods, reduces those worthy of further consideration to under 1000 in about 95% of the tests performed until now. The countermeasure strategies which satisfy the constraints of the CES are passed to the MAV/UT module. Currently two such modules are being developed: HERESY and M-CRIT. Both operate interactively through graphical interfaces to communicate with a variety of decision makers who may possess qualitatively different skills and perspectives. They rank the countermeasure strategies in a short list. Intuitive justifications for choices and underlying uncertainties inherent in the predictions will be provided via the FES. Thus the system will support decision makers in modifying rules, weights and preferences and other model parameters as well as understanding the consequences of each change.

The international RODOS polling and data exchange system has been established at JRC/EI. The system is polling four RODOS contractors in the EU member states (Greece, Finland, Germany) and four RODOS contractors in the Central and Eastern European countries (Russia, Poland, Hungary) every fifteen minutes. A monitoring system keeps track of the data exchange activities and is sending an acknowledgement via email to the RODOS data exchange participants.

The activities on the European database so far relate to the implementation, extension and maintenance of EUROGRID. Contributions were received following the request for providing information on what data are needed by the RODOS developers and users and promising contacts have been established with the co-ordinators of other relevant projects (SAVE, RESTORE and ESA).

4.4 Results of on-going R&D work

Especially for the use of the radioecological models for several regions in Northern and Eastern Europe or in parts of the Alps, a special module is under development for semi-natural (forest) pathways, FDMF. It considers mushrooms, berries and game and quantifies the internal and external exposure from contaminated forests. After reviewing the present status of tritium modelling, a first module describing the transfer of tritium through foodchains, FDMH, has been developed. A dose combination module is under development which combines results from these and the FDMT and FDMA food chain and dose modules.

As the models for food chain transfer have been originally developed for Central Europe, many model parameters need to be adapted to the conditions of other regions. The selection of appropriate radioecological regions, with relatively uniform radioecological conditions, is predominantly determined by prevailing agricultural production regimes, growing periods of plants, harvesting times, feeding regimes for domestic animals, human consumption habits, etc.. Typically, a country is subdivided into 1 to 5 such radioecological regions. Radioecological regions have been defined for Czech Republic Hungary, Poland, Romania, one part of Russia, Slovak Republic, and Ukraine, and the collection of the radioecological data has started.

Data collection on the use and effectiveness of countermeasures started in the middle of 1997 primarily in Central and Eastern Europe, but also in some EU countries. This will provide the possibility to extend the present data base for some agricultural countermeasures and to allow the application of LCM:FRODO over larger areas of Europe.

The version of RIMPUFF that incorporates data assimilation is currently being modified to overcome the limitations of handling only a single nuclide and a limited version of the windfield without calculating gamma dose rates. The modified version will be incorporated into a model chain with the source term belief net being developed for source term predictions.

A Bayesian hierarchical model for data assimilation in the deposition module has been developed. This allows for the combination of information from any kind of source like predictions from model calculations, direct measurements from monitoring stations or expert judgement. Other advantages are that such a model can be easily adapted for other parts of the model calculation in FDM, and it allows for a smooth transition from pure model predictions to data measurements when more and more data becomes available.

The Long Term Countermeasure module LCM is being extended to look at a wide range of combinations of agricultural countermeasures so that strategies of countermeasures for individual foods can be evaluated within RODOS. The implications of relocation on the further use of agricultural land in the relocated area are also being addressed.

A concept for data assimilation in the RIVTOX module for rivers has been developed. A simple statistical updating module is currently under development to update the predictions of contamination downstream from the points at which monitoring measurements have been taken. However, for lake and ground water runoff models, the data assimilation issues are more complex since the dispersion is far from unidirectional with time. An initial examination of the numerical solutions of dynamic systems models used within these modules suggests that Kalman filtering techniques might enable a Bayesian approach to be tractable. But much further work is needed.

In order to test and develop ESY, the Evaluation Subsystem of RODOS, a programme of workshops is being held with decision makers across a number of European countries. To date, five have been completed in Germany, Belgium, UK and France, and three further are being organised in Finland and in the Netherlands. Actually one of the remaining three has been held recently, but the results are still being analysed. In each of these the emergency managers who would be responsible for the countermeasures are presented with an hypothetical accident scenario in their own region of responsibility. The five workshops held and analysed to date have focused on early phase decision making. The RODOS system was used to simulate the accident and outcomes, with and without possible protective actions.

The "Computer based training course: Decision support for off-site emergency management in the early phase of a nuclear accident" was developed using RODOS PV3.0 as a training and demonstration tool. The course is directed at radiological advisors or people with comparable qualification and function in emergency management teams. The course was held in 1996 and 1997 with altogether about 50 participants from a large number of European countries. The "Computer based training course: Decision support for off-site emergency management in the later phase of a nuclear accident" is currently being developed. The course will first be held in early 1999.

A guideline is being developed for the preparation, organisation and evaluation of emergency exercises depending on the type of an exercise. It will describe the different tasks and means and will give recommendations for preparing the scenarios. Attention will be paid to the content of similar guidelines already published by international bodies.

As a basis for future training courses and exercises, data on the Chernobyl accident are being collected and elaborated for generating post-Chernobyl scenarios in RODOS. They comprise ground and foodstuff contamination and information on early emergency actions, population distribution and the traffic net within and outside the 30 km zone.

The ETHOS approach is being implemented most satisfactorily in the village of Olmany in the Stolyn District, Belarus Olmany is characterised by a rather low contamination level (in the range of $3{,}7{,}10^4$-$5{,}5{,}10^5$ Bq/m^2) with a few relocated people. Seven projects have been set up, with a total of about 50 inhabitants involved. The initially achievements include: the involved inhabitants can now make their own radiological measurements (external dose, food contamination) and they have gained a better understanding of basic radiological concepts; they have discovered significant margins of initiative to reduce their radiation exposure and notably that of their children; private farmers are able to improve the radiological quality of their production; and finally, there the social climate in the village has improved as result of the ETHOS project.

5 Research to be performed in the remainder of the project

The activities in the remainder of the project will mainly concentrate on the development of the fully operational, customised and comprehensive version PV4.0 of the RODOS system until mid 1999. All results of R&D work not having reached the status of operational applicability at that time will be incorporated in the prototype version PRTY4.0. The following paragraphs summarise what will be achieved within the next three half years. All software components mentioned as deliverables, will build part of the RODOS version indicated:

Mid 1998 **RODOS version PV3.1**

Full functionality of the RODOS user interface will be implemented by this stage. All system databases will be finalised. Food chain transfer and dose assessment will be completed for aquatic and terrestrial pathways simultaneously. Secondary pathways will be incorporated in the hydrological model chain and agricultural data on Sr-90 will be available. The demographic and geographic databases will be improved and extended to all European countries. Plant damage conditions and release categories for NPPs of WWER-type will be defined. Sensitivity analysis and explanation software will be integrated for the early and intermediate phase.

RODOS version PRTY3.1

Prototype complex terrain modules will be incorporated. Meteorological forecasting modules will be developed and documented. The long-range atmospheric dispersal model chain will be fully integrated and coupled to forecast data. The modules for simulating and optimising evacuation will be further developed and adapted to NPPs in the CIS. Data assimilation of gamma spectrum observations with regard to future emission forecasts will be investigated. Draft software on the effectiveness of decontamination and relocation and the prototypes of source term estimation modules (stand-alone) will be ready. Data assimilation and uncertainty handling for the food and hydrological chain models will be prototyped. An evaluation system for countermeasures of the early and later phases will be built. Prototype data interfaces will be integrated.

End of 1998 **RODOS version PV3.2**

A database adapter for ORACLE will be available. Tools, functionalities and user interfaces of the RODOS operating system (OSY) will be extended. The long-range atmospheric dispersal model chain will be fully integrated. Stand-alone versions of the final evacuation module and the corresponding optimisation routines. Food chain transfer and dose assessment will be extended to include long-term releases. Final software for evaluating the effectiveness of agricultural countermeasures for mixed deposits and for decontamination. The full hydrological model chain will be integrated and completed with/coupled to countermeasure models. Stand-alone versions of source term evaluation modules providing input to RODOS. Quality assurance of data handling techniques will be applied. Sensitivity analysis and explanation software will be completed and integrated.

RODOS version PRTY3.2

Communication paths will be installed between RODOS systems in different countries. Models for releases with water vapour and over explosive / powerful heat sources will be developed. Data assimilation in near-range atmospheric dispersal will be implemented. Radioecological and countermeasure models and data will be customised for Eastern and Northern European countries. Within the module HEALTH it will be possible to assess the early health effects as well as the risk of the stochastic somatic effects for the present and future generations of the population living in the contaminated areas. Within ECONOM, the monetary costs from applied early and late countermeasures, as well as those of the expected health effects will be evaluated; the models will be customised to Eastern European countries. Some propagation of uncertainty to later models in the chain will be possible. A graphical interface for handling management by exception of data assimilation techniques will have been implemented. Review to see how/if the preliminary findings of the ETHOS approach could be integrated in RODOS; final reports describing the implementation of the ETHOS methodology.

Mid 1999

RODOS version PV4.0

The user interface will be able to support users of wide ranging technical abilities. Training modules will be implemented utilising realistic data to provide hands-on experience of RODOS. Food chain transfer and dose assessment modules will be fully integrated. Aquatic and terrestrial countermeasure systems will be completed and fully incorporated into the RODOS model chain. Semi-natural and natural environments and the special radionuclide tritium will be included in the radioecological models. The HEALTH and ECONOMIC modules will be extended and tested The deposition monitoring module will be finally integrated. The final versions of the "monitoring modules" for data assimilation in the food chain and hydrological models will be integrated. A short list of countermeasure strategies together with a report detailing the strengths and weaknesses of each, will be provided to the decision makers. Sensitivity analysis and explanation software will be integrated.

RODOS version PRTY4.0

A source term estimation module including uncertainty assessment will be ready as stand-alone program. Data assimilation techniques will have been validated against real time data. A coherent mechanism for data assimilation will have been integrated into the model chains and a consistent methodology for the propagation of uncertainties will have been elaborated and incorporated for the early phase predictions. Synthesis report on the whole experimentation of the ETHOS approach and the lessons for wider application of the approach. The GIS-based European data base will contain geographical and radioecological data as far as accessible.

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7 Executive Summary

R&D, carried out within what has come to be known as the first phase of the RODOS project, came to an end in the fall of 1995 with the issue of the second prototype of the RODOS system (PRTY 2.0). The system has been further developed under the auspices of the Nuclear Fission Safety Research Programme within the Commission's 4th Framework Programme (1994-1998) on a cost shared basis between the Commission and the participating institutes and/or their national sponsors. This is being carried out within five separate, but fully integrated, contracts with the EC. Some 40 institutes from about 20 East and West European countries are now participating in what is the second phase.

Given the scale of the project and the large number of geographically dispersed participants, particular attention has been given to the arrangements for the management of the project. A matrix approach has been adopted with overall co-ordination being achieved through the RODOS Management Group comprising representatives from the EC, the co-ordinators of the respective contracts and independent members. Control of the resources within each contract is exercised by the respective co-ordinators; the technical work, integrated across all contracts, is managed through twelve Working Groups. Each Working Group has responsibility for a specific technical area and, *inter alia*, for ensuring that the project tasks are completed on schedule and in accordance with the project specification.

As the major milestone, the first operational version RODOS PV3.0 has been produced. Compared to previous versions and according to the planning of the work programme, it is no longer a prototype but a pilot version for installation and (test-) operational use in emergency centres. The applicability of version PV3.0 is still limited to the early and intermediate phases of emergency response and to distances of several tens of kilometres from an accidental release.

The key elements of the pilot version PV3.0 are: software engineering tools and graphical interfaces for communication with the user; the complete geographical information system RoGIS ; established quality assurance methods designed for software development and integration; a diagnostic and prognostic near-range atmospheric dispersal model chain; improved and extended food chain and dose assessment modules for all relevant exposure pathways; simulation models for early and late countermeasures together with data bases on their effectiveness; health and economic modules.

Significant progress has been made in a number of research areas, and some of the resulting software components have already been incorporated in the prototype version PRTY 3.0: a nested atmospheric model chain for consistent calculations from the near range to the borderlines of Europe, coupled to weather forecast data; a model chain for atmospheric dispersion in areas with complex topographic features; the definition of radioecological regions in Europe and the collection of corresponding data; a complete hydrological model chain (run-off, rivers, lakes) adapted to the river Rhine system and its tributaries; draft stand-alone modules for simulating and optimising evacuation on the site-specific traffic network; the structural design and first versions of source term programs for early estimating the likely release characteristics using in-plant data and information; methods and draft software for estimating the source term and the environmental contamination patterns by assimilating near-site radiological monitoring data; concepts and methods for data assimilation in food-chain and hydrological models; the conceptual structure and first program versions of the evaluating subsystem of RODOS; establishment of an international polling and data exchange system; design and development of a GIS-based European database with geographical and environmental data relevant for the RODOS application in Europe.

Important results emerged in on-going research areas: RODOS based training courses for radiological advisors on decision support for off-site emergency management in the early phase (held twice) and the later phases (under development) of a nuclear accident; structure and content of guidelines for the preparation, organisation and evaluation of emergency exercises; performance and further planning of workshops with emergency management teams and decision makers for designing and testing the evaluation subsystem; successful implementation of the ETHOS approach in Belarus.

The main objectives for the remaining contract period, which is scheduled for completion in mid 1999, are to extend the system to its full functionality, i.e., to be applicable to all phases of emergency response and at all distances from a potential release. Particular attention will be given to the following aspects: development of modules to predict the characteristics of potential releases from information on the status of the plant; completion and final testing of the meteorological and hydrological model chains; development of improved methods for the assimilation of judgement, model predictions and measurements; treatment of uncertainties; customisation of models and data for application in Nordic and East European countries; coupling of RODOS to local, regional and national meteorological and radiological monitoring data; realisation of the data exchange between RODOS systems in different countries; completion to the extent possible of the European database; operational applicability of the evaluating subsystem; synthesis of and lessons learnt from the whole experimentation of the ETHOS approach for its wider application and implementation in RODOS; training courses for future users, emergency management teams and decision-makers.

About seven years after the start of the RODOS project, the vision of a comprehensive real-time and on-line decision support system that would find broad application in East and West Europe is within reach in the form of a state-of-the-art software system with models and data incorporated and operational functionalities, that go far beyond the characteristics of existing systems. This was already apparent at the end of the European Commission's 3rd Framework Programme, when prototype versions of the system for test-operational applicability and for supporting the ongoing R&D activities were installed at many of the contractors' institutes. Half way through the start of the 4th Framework Programme, this progress has manifested in an operational version for installation in emergency centres, and a number of countries, both in East and West Europe, have taken the decision to install the RODOS system as decision support tool for managing nuclear accidents. In particular, the German Ministry of Environment will install the RODOS system centrally for use by the individual Federal States and the Federal Government. The potential role of RODOS as part of a wider European network has become evident. The existence of such a network would promote a more effective and coherent response to any future nuclear emergency in Europe. The interest currently being shown in the system by many EU and Eastern European countries augurs well for its future use.