The RODOS System: Decision Support For Nuclear Off-Site Emergency Management In Europe

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INTRODUCTION

Experience gained after the Chernobyl accident clearly demonstrated the importance of improving administrative, organisational and technical emergency management arrangements in Europe. The more important areas where technical improvements were needed were early warning monitoring, communication networks for the rapid and reliable exchange of radiological and other information and decision support systems for off-site emergency management. Administratively, the most pressing need was to promote greater coherence in response to any future emergency; a lack of coherence contributed to the loss of public confidence in how the consequences of the Chernobyl accident were managed in different European countries. The scope and content of the European Commission's research, in the area of nuclear emergency management following the Chernobyl accident, were largely determined by these needs.

Under the auspices of its RTD (Research and Technological Development) Framework Programmes, the European Commission has supported the development of the RODOS (Real-time On-line DecisiOn Support) system for off-site emergency management. The main objectives of the RODOS project were:

- to develop a comprehensive and integrated decision support system that is generally applicable across Europe,
- to provide a common 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 project began modestly in 1989 with a small number of partners. Participation and geographical coverage increased progressively during the 3rd and 4th European Commission Framework Programmes. By the end of the 4th Framework Programme, some 40 institutes from about 20 countries in the Union and in Eastern Europe (CEEC and NIS) were actively involved in the project. Its main objective was the development of a quality assured, fully operational, customised and comprehensive version of the RODOS system that would be generally applicable throughout Europe with appropriate interfaces to plant safety information, radiological and meteorological networks, and associated evaluation, validation and training packages. The RTD has been carried out within seven separate, but fully integrated, contracts. The paper summarises the status of the RODOS project and system at the beginning of the year 2000; a comprehensive description of the RODOS project and system is given in the Final Report of the European Commission's 4th Framework Programme (1).

FEATURES AND DESIGN OF RODOS

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.

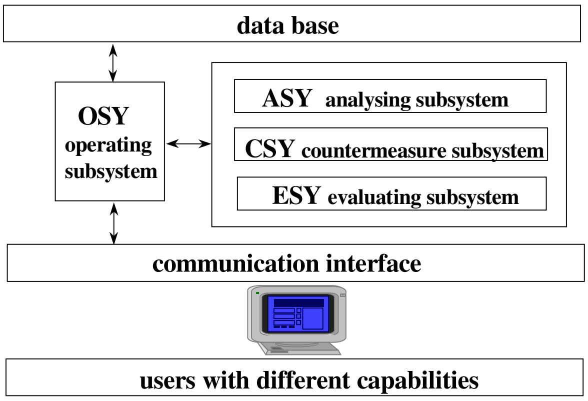
The RODOS system can provide decision support at four distinct levels:

- Level 0: acquisition and checking of radiological data and their presentation, directly or with minimal analysis, to decision makers, along with geographical and demographic information.
- Level 1: analysis and prediction of the current and future radiological situation (i.e., the distribution over space and time in the absence of countermeasures) based upon information on the source term, monitoring data, meteorological data and models.
- Level 2: simulation of potential countermeasures (e.g., sheltering, evacuation, issue of iodine

tablets, relocation, decontamination and food-bans), in particular, determination of their feasibility and quantification of their benefits and disadvantages.

- Level 3: evaluation and ranking of alternative countermeasure strategies by balancing their respective benefits and disadvantages (e.g., costs, averted dose, stress reduction, social and political acceptability) taking account of societal preferences as perceived by decision makers.

Most decision support systems that have been developed to an operational state are limited to levels 0 or 1. A few extend to level 2 or even level 3 but, in general, are limited in the range of countermeasures they address or in the completeness of benefits and disadvantages that are considered. RODOS is unique in providing support to level 3 for all practicable countermeasures.



The conceptual RODOS architecture is split into three distinct subsystems (see Fig.1), which are denoted by Analysing Subsystem (ASY), Countermeasure Subsystem (CSY) and Evaluating Subsystem (ESY).

Fig.1 Conceptual structure of the RODOS system

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 UNIX based operating system OSY. 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.

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 a distributed database allowing for a decentralised data management and the parallel execution of multiple task operations. The distributed database comprises: 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. A database manager gives the programs of the RODOS system access to the data stored in these databases with a unique interface format. It converts the requests from the programs into a request to the appropriate database and enables multiple clients to access multiple database servers.

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. 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.

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 protection). 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.

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.

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.

STATUS OF THE RODOS DEVELOPMENT

Two versions of RODOS exist at the beginning of the year 2000:

- The ***RODOS pilot version PV 4.0*** with models, databases and the resulting functionality for operational application in emergency centres, applicable in all distance ranges and accident phases.
- The ***RODOS prototype version PRTY 4.0*** with prototype models and databases 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*** are available or still under development which will complete the RODOS methodology in future. The content and functionality of the existing RODOS versions and the status of the stand-alone programs are summarised as follows.

The RODOS pilot version PV 4.0

The pilot version PV 4.0 comprises the following software modules:

The complete operating system (OSY) with *inter alia*: the program and real-time databases and the geographical information system RoGIS, together with the geographical database; interfaces for selecting and

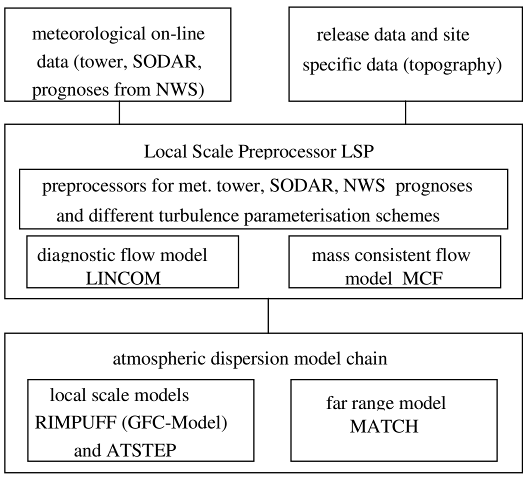


Fig.2 The local scale model chain and long range atmospheric dispersion model chain

specifying the interactive and automatic modes of operation, the input of source terms, meteorological and countermeasure data, and graphical presentations of results; an extended SQL syntax allowing for database applications with the database management systems ALLBASE and INGRES. The graphical software package RtGraph offers tools and functions for accessing and evaluating the RODOS real-time database. User guides exist in German and English together with a draft system manual.

The complete Local-Scale Model Chain, LSMC, which calculates the atmospheric dispersion and deposition of the released radionuclides up to distances of about 80 km, comprises the Local-Scale Pre-processor

LSP, the puff dispersion model RIMPUFF and the elongated puff model ATSTEP (see. Fig. 2). LSP provides the local-scale system with actual and forecast local scale wind fields and local boundary layer variables by intensive pre-processing of the meteorological input data and by use of local scale wind models.

Weather data and forecasts 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 (NWS). Prognoses of ground-level air, dry and wet deposited concentrations including dose rates in up to 48 half hour steps are produced on the local scale.

The applicability to farther distances is mainly a result of the integrated far range atmospheric dispersion model MATCH with an interface for accessing meteorological data of the Danish forecast model HIRLAM. Through its coupling to the local scale model chain LSMC, a complete model chain is realised and consistent dispersion calculations are possible from the near range to large distances in the European scale.

The transfer of radionuclides from the plume to terrestrial foods, as well as the resulting radiation exposure, are modelled in the Terrestrial Food Chain and Dose Module, FDMT, which comprises the Deposition Module, the Food Chain Modules, and the Dose Modules (see Fig.3). Activity intake by animals is considered using season dependent feeding practices. The products considered in the Food Chain Module can be adapted to the specific situation in the different parts of Europe; the default list of products presently comprises 21 feedstuffs (17 based on plants, 4 based on animal products) and 33 foodstuffs (17 plant products, 16 animal products). 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.

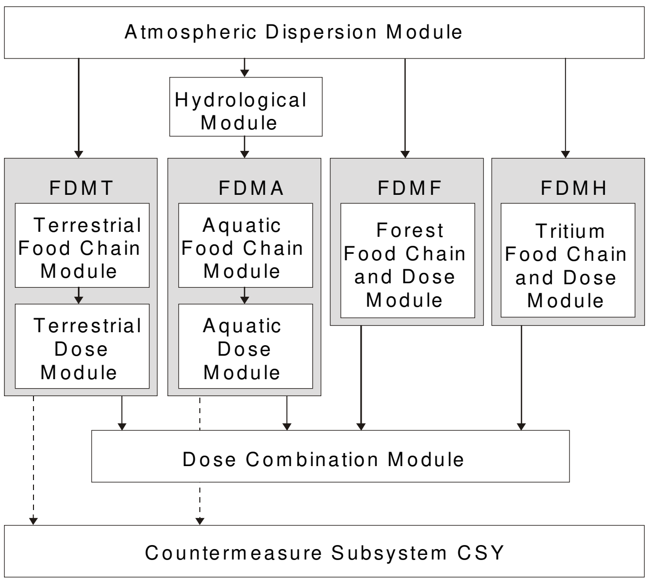


Fig. 3 Food chain and dose modules integrated in RODOS

For several regions in Northern and Eastern Europe or in parts of the Alps, an additional specialised radioecological model has been developed for semi-natural (forest) pathways, FDMF. It considers transfer of radionuclides to mushrooms, berries and game and quantifies the internal and external exposure from contaminated forests. After reviewing the present status of tritium modelling for emergency response purposes, a simple module describing the transfer of tritium through foodchains, FDMH, has also been developed. The dose combination module, DCM, combines results from these and the FDMT food chain and dose modules.

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, LCMT, provides rapidly produced summary information on the extent and duration of any required relocation and food restrictions on the basis of user supplied criteria, and more detailed information on possible countermeasures which may be promising, both in the short - medium term and in the longer term. If intervention is indicated, the objective is then to identify appropriate countermeasures and to provide sufficient information on their consequences to assist in the development of a practical countermeasure strategy. Three major groups of countermeasures are considered: relocation of the population, decontamination of inhabited and agricultural land and agricultural countermeasures. The interaction between countermeasures can also be considered to varying extents. For example, combinations of two different, but complementary, food countermeasures can be investigated and the implications of relocation on the further use of agricultural land in the relocated area can be studied.

For agricultural countermeasures, a mode of running LCMT 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 ESYlate (see under RODOS PRTY 4.0) of RODOS to enable countermeasure strategies to be evaluated using a wide range of information including effectiveness, costs, health effects and feasibility considerations.

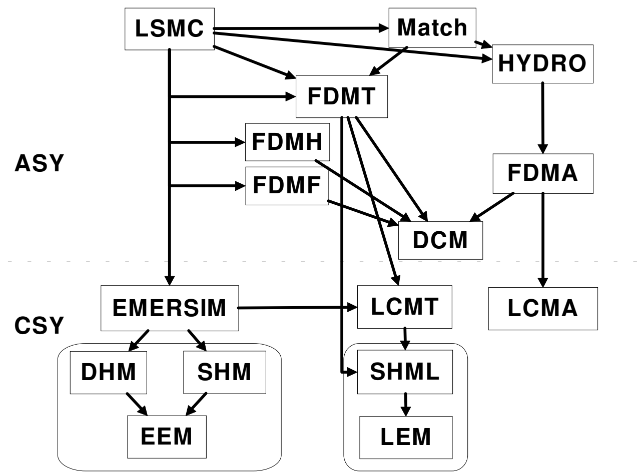


Fig. 4 Information flow between the subsystems ASY and CSY

The modules DHM and SHM quantify deterministic and stochastic health effects resulting from early emergency actions 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 early economic module, EEM. Correspondingly, the module SHML calculates the stochastic health effects from late countermeasures, and LEM determines the associated economic costs. The interconnection of the modules described in this section is schematically shown in Figs. 3, 4.

The RODOS prototype version PRTY 4.0

The prototype version PRTY 4.0 contains all those software components, which are available in draft versions, only partially integrated in the operation system, or still being tested, in addition to the modules in PV 4.0. After final approval, these additional components of the system will complement the existing software in one of the next pilot versions.

An 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 (HYDRO) 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. Direct consumption of water and feeding contaminated water to animals are considered as well as usage of contaminated water for irrigating crops.

The aquatic countermeasure module LCMA 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; these are disposal and/or stopping of fish production, storage and processing. Limited countermeasures that can be applied to the aquatic environment and which have a direct impact on the activity concentrations in fish have been included in close collaboration with the developers of the hydrological model chain. The treatment of lakes using potash, liming or mineral fertilisers has been included for a series of lake types and for prey and predatory fish. A database has been compiled containing time dependent reductions in activity concentrations in fish for a series of implementation times. For drinking water, only the stopping of water production is considered.

As described under PV 4.0, the long term countermeasures module LCMT produces in its “decision mode” lists of potential agricultural measures together with long lists of potential attributes as input to the evaluating subsystem ESYlate for late countermeasures. There is an initial window in ESYlate in which the key attributes actually to be used in the analysis are selected by the user. The module has a variety of input windows in which the weights and attribute scores may be entered, or they can be read form the RODOS database. The emphasis in ESYlate is on sensitivity analysis. The assumption is that one models and understands values best by using simple linear functions and investigating the sensitivity of the conclusions to variations in many subsets of weights and attribute scores.

The complementary software components of PRTY 4.0 are available to interested users on request.

Stand-alone software

Complementary to the software incorporated in the RODOS system, further stand-alone programs have been developed which are either in near final or draft versions. They will

- build part of future 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 it has been decided that they should not form part of the main functionality of the RODOS system; they will however remain significant contributions to the RODOS methodology.

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 with the development of a prototype software package applicable to every type of light water reactor operating in the European Union (2).

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, which may be transferred by disk, modem or network.

Two pieces of work have approached 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. 54 sequences of 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 on data from near-site gamma dose rate monitors. The least squares fitting in the Off-Site Source Term module OSSTerm is based upon the use of the atmospheric dispersion model ATSTEP. It has been implemented into the RODOS UNIX environment with appropriate interfaces to the meteorological and radiological real-time data.

For data assimilation within atmospheric dispersion models, a prototype BayesRIMPUFF has been developed. This is a modification of the RIMPUFF code, 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, it runs on the RODOS workstation with appropriate interfaces for accessing the system's databases.

The conceptual structure of the evaluation subsystem ESYearly of RODOS has been developed for emergency actions in the early phase of a nuclear accident: 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 actions 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. Two submodules have been 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 are provided via the FES. Thus the system supports 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. The system is polling eight RODOS contractors in the EU member states Belgium, Denmark, Finland, Germany and Greece and six RODOS contractors in the Central and Eastern European countries (Belarus, Hungary, Poland, Romania and Russia) 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.

RESULTS OF COMPLEMENTARY SCIENTIFIC INVESTIGATIONS

The operation of RODOS in emergency centres requires agreement from the responsible authorities, installation of appropriate hardware and software, on-line connections to networks of meteorological and radiological data and customisation of the RODOS databases and application software to local, regional and national conditions. This includes

- Translation of the user interfaces into the national language/s.
- Collection and input of static data such as
  - site and plant characteristics,
  - geographical data (e.g., elevation), map data, traffic network and statistical data of special objects,
  - statistical data on grids, e.g., population, radio-ecological parameters (see below), agricultural production, soil type and semi-natural environments (forests),
  - hydrological data for watersheds, rivers and lakes,
  - emergency management data for early, intermediate and late countermeasures.
- Connection of the RODOS Real-Time Database to the networks of
  - radiological data, such as stack emission data, local and national monitoring data,
  - site meteorological data from at least one meteorological tower,
  - meteorological forecasts.

Each of these tasks has been completed as far as possible on a national level by the participating institutes in the Czech Republic, Hungary, Poland, Romania, Russia, Slovak Republic and Ukraine, in close co-operation with each other and the developers of the RODOS system.

As the models for food chain transfer have been originally developed for Central Europe, an important task in connection with the customisation of RODOS for use in other regions of Europe is the adaptation of the many model parameters in the food chain and dose module FDMT. 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 been completed to a large degree.

A Bayesian statistical model for data assimilation in the deposition module has been developed. This allows for the combination of information from any kind of source such as predictions from model calculations, direct measurements from monitoring stations or expert judgement. Other advantages are that such a model can be 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.

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 the Evaluation Subsystem of RODOS, a programme of workshops was held with decision makers across a number of European countries: five have been completed in Germany, Belgium, UK and France, and three further have been organised in Finland and in the Netherlands. In each of these the emergency managers who would be responsible for the countermeasures were presented with a hypothetical accident scenario in their own region of responsibility. 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 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 April 1996 and November 1997 with altogether about 50 participants from a large number of European countries; it was repeated in Russia in May 1998. The complementary "Computer based training course: Decision support for off-site emergency management in the later phase of a nuclear accident" developed within the 4th Framework Programme was first held with a European wide audience in April 1999.

Guidelines have been developed for the preparation, organisation and evaluation of emergency exercises for a range of exercise types. They describe the different tasks and training methods and give recommendations for preparing the scenarios. Attention was given 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 have been 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.

Within the RODOS system, the ETHOS project has been developed to explore a new approach for managing post-accidental situations, based on decentralisation and direct involvement of local stakeholders affected by the consequences of the accident. This project has been 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 $3{,}7\cdot10^4$-$5{,}5\cdot10^5$ Bq/m^2) with a few relocated people. Seven projects have been set up, with a total of about 50 inhabitants involved. The achievements include the following: 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, the social climate in the village has improved as result of the various actions implemented within the project.

INTERNATIONAL CO-OPERATION

The development of RODOS over the past decade has been achieved through the successful integration of state-of-the-art knowledge in Europe across a wide range of disciplines; these include information and communication technologies, meteorology, atmospheric dispersion, radio-ecology, health physics, economics, emergency management, decision theory, etc. The most successful and tangible outcome of the project has undoubtedly been the development of the RODOS system itself and its increasing deployment in national emergency centres. It is important, however, not to overlook the less tangible benefits of the project. Effective working arrangements and links have been established between some 40 institutes (having competence in various aspects of emergency preparedness and response) in about 20 European countries. This network, which is unprecedented, augurs well for the future. It will contribute to the more cost-effective use of resources for the further improvement of decision support for nuclear emergencies. More importantly, it will enhance trust and confidence between people, which is essential for responding effectively and coherently to any future nuclear accident that may have implications on a European scale.

The international co-operation in the field of emergency management has been strengthened by co-operation agreements between the RODOS Consortium and the

- Danish Emergency Management Agency (DEMA), who operate the ARGOS system,
- Lawrence Livermore National Laboratory (LLNL), who operate the ARAC centre,
- Japanese Atomic Energy Research Institute (JAERI), who operate the SPEEDI system.

The RODOS-ARGOS co-operation strives at taking mutual benefit of software developments and improving decision support and data exchange in general, and thus will further enhance European harmonisation of emergency response. The main purpose of the triangular collaboration between RODOS, ARAC and SPEEDI is to develop and demonstrate an emergency information exchange protocol based on the Internet technology and to evaluate the prototype information protocol application for technical feasibility and mutual benefit through simulated (and real) events.

The RODOS Users' Group commenced in September 1998 with support of the European Commission for a period of two years. The Users' Group provides a forum for the exchange of experience between different users of the RODOS system and with those responsible for its development; this interaction is expected to improve both the quality and efficacy of the system and how it is used. The main objectives of the Users' Group are: to stimulate effective communication between developers and users; to share technical know-how and experience; to identify defects and limitations of the RODOS system during operation; to identify further R&D needs; to promote RODOS and its use in nuclear emergency situations as well as in training and exercises; to enhance communication and to exchange experiences with users of decision support systems other than RODOS.

Participants in the Users' Group comprise: representatives of those institutes responsible for installing, customising and operating the RODOS system and/or which have expressed an interest in using the system within their countries in the near future; and the main system developers. Institutes from about ten European countries are currently participating the Users' Group.

FUTURE PERSPECTIVES

With the completion of the operational version, PV 4.0, of the RODOS system, the vision of a comprehensive real-time and on-line decision support system that would find broad application throughout Europe has been substantially realised. This version of RODOS comprises state-of-the-art software, models and data and includes operational functionalities that go far beyond those in other existing systems. It has reached sufficient maturity and robustness to constitute an ideal tool for training purposes in off-site emergency management.

A number of countries, both in the Union and in Eastern Europe, have decided to install RODOS as a decision support tool in their national emergency centres. With support from the Ministry of Environment, RODOS is currently being installed centrally in Germany for use by the individual States and the Federal Government. Portugal, Spain and Finland have installed the system for pre-operational use in their emergency centres and installation is under consideration in Greece for the same purpose. Requests have been made from Austria and the Netherlands to install the system to evaluate its potential for future use nationally and a similar request is anticipated from Italy. With support from the European Commission's TACIS and PHARE nuclear safety programmes and ECHO, RODOS is being implemented in Poland, the Slovak Republic, Hungary and the Ukraine and is scheduled for implementation in the Czech Republic and Slovenia in 2000. Implementation is foreseen in Bulgaria, Romania and in some NIS in 2002. The interest currently being shown in RODOS by EU and East European countries augurs well for its future use, in particular as a framework or platform to promote more effective and coherent emergency response and information exchange at a European level.

The main objectives of any future RODOS related RTD should be to further enhance the system with a view to ensuring its full operational and practical applicability in emergency centres. Future RTD should be driven by the needs of the users and the establishment of a strong interaction and feedback between users and the RTD community is vital in this respect. Priority areas for future RTD include: development of improved modules for predicting the characteristics of potential releases based on information on the status of the installation; realisation of Web-interfaces for the platform independent access by remote users not familiar with the RODOS system; extension of the functionality of RODOS to nuclear accidents with long release durations (i.e., more than half a day); development of improved methods for the assimilation of judgement, model predictions and measurements in the areas of atmospheric dispersion, food-chain transfer, dose assessments and hydrology; treatment of uncertainties; operational applicability of the evaluating subsystem; realisation of the data exchange between RODOS and other operational decision support systems; completion to the extent possible of the European database; application of RODOS in training courses for users, radiological advisors and decision-makers, and in performing emergency exercises on the local, regional, national and international levels.

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Further general information on the RODOS project and system are available from the RODOS Homepage http://www.rodos.fzk.de. Specific information, in particular, copies of the Final Report of the RODOS activities within the European Commission's 4th Framework Programme (1), can be obtained from the RODOS secretariat (rodos@rodos.fzk.de).

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