Problems to be solved

The Chernobyl accident had a profound effect on emergency preparedness and post-accident management world-wide and, in particular, in Europe. Deficiencies in arrangements for dealing with such a large accident, at both national and international levels (e.g., in world trade in foodstuffs), led to many problems of a practical and political nature. Many lessons were learnt and considerable resources have since been committed to improve emergency preparedness and post-accident management in order to avoid similar problems in future.

Improvements have been made at national, regional and international levels and have been diverse in nature. More, however, needs to be done to ensure a timely and effective response to any future accident.

A number of needs emerged from the experience in Europe of responding to the Chernobyl accident. These included:

• a need for a more coherent and harmonised response across Europe and during different stages of an accident (in particular, to limit the loss of confidence of the public in the measures being taken by the authorities for their protection);
• the exchange of information and data in an emergency that would enable neighbouring countries to take more timely and effective action; and
• a need to make better use of limited technical resources and avoid duplication.

The RODOS project was established to respond to these needs. It began in 1989 and increased in size through the 3rd and 4th Framework Programmes. Within the 4th Framework Programme more than 40 institutes from about 20 countries in the Union, CEE and FSU were actively involved in the project (see Figure 1). The project was implemented through seven separate, but fully integrated, contracts.

Achievements

Because of the scale of this project, the achievements are described at two different levels: firstly, with regard to the strategic goals of project (i.e., the development of a comprehensive and broadly applicable decision support system) and, secondly, the more notable technical achievements in the elements comprising the system.

Strategic

A comprehensive decision support system (RODOS) has been developed that is broadly applicable within and across Europe. It is suitable for use in national or regional nuclear emergency centres and is capable of providing coherent support at all stages of an accident (i.e., before, during and after a release has occurred), including the long term management and restoration of contami-
The system can support decisions on the introduction of a wide range of potentially useful countermeasures (e.g., sheltering and evacuation of people, issue of iodine tablets, food restrictions, agricultural countermeasures, relocation, decontamination, restoration, etc.) for mitigating the health, environmental and economic consequences of an accident. It is applicable to accidental releases to the atmosphere and to various aquatic environments. Appropriate interfaces exist to local and national radiological monitoring data, to meteorological measurements and forecasts, and for its adaptation to local, regional and national conditions in Europe.

The installation of the system for (pre-operational) use in many national emergency centres exemplifies the success of the system and its potential for achieving more coherent and effective response to any future accident that may affect Europe.

European co-operation in the field of emergency management has been strengthened by a co-operation agreement between the RODOS Consortium and the Danish Emergency Management Agency (DEMA), which operates the ARGOs system. It strives to derive mutual benefit from software developments and promote decision support and data exchange in general.

The main purpose of the collaboration on a broader international scale has also been achieved with the establishment of a triangular network between the RODOS community and similar decision support systems being developed and used in Japan (WSPEEDI) and the USA (ARAC). An emergency information exchange protocol, based on Internet technology, has been developed and its potential and technical feasibility are being evaluated with a view to enhancing response at a global level.

Technical

The RODOS concept of decision support, data assimilation and uncertainty handling

The RODOS system provides coherent decision support at all levels ranging from largely descriptive reports, such as maps of the predicted, possible and, later, actual contamination patterns and dose distributions, to a detailed evaluation of the benefits and disadvantages of various countermeasure strategies and their ranking according to the societal preferences as perceived by the decision makers (see Figure 4). It is also able to perform 'what-if' calculations, allowing investigation of how the situation may develop under different scenarios. Using modern decision analytic techniques (MAV/UT - multi-attribute value and utility models), it provides support for the emergency managers in evaluating the overall efficacy of possible countermeasure strategies. Moreover, emergencies involve uncertainty, e.g., in the scale of the release, the accuracy of radiation monitoring data, weather conditions, the reliability of expert judgement, and the success in implementing countermeasures. Data assimilation techniques combine model predictions and monitoring data in order to move smoothly from pure model predictions (in the pre-release phase) to the real situation (in the post-release phases). The Bayesian decision analytic approach permeates the whole RODOS architecture and software; it addresses all issues relating to uncertainty and data assimilation in a manner which fits coherently with the decision analytic techniques used in evaluation. No decision support system of this scale had achieved such broad functionality in other contexts, much less one as demanding as a nuclear emergency.

Diagnosis and prognosis of the radiological situation

RODOS provides continuously updated fast and comprehensive assessments of the radiation exposure of the population following the accidental releases of radioactive material (or the threat of such a release) to the atmosphere and/or the aquatic environment.

The dispersion and deposition of material released to the atmosphere is predicted using a nested chain of models. The models consistently simulate dispersion and deposition processes over two distinct ranges, the near range within an area of 160 km x 160 km and the far range up to thousands of kilometres. The models included in RODOS...
were selected from the many available as those best able to meet the operational demands of the system. Estimates of the current plume position (diagnoses) are automatically updated typically every 10 min, the situation after plume passage (prognoses) is recalculated typically every 30 min. A complementary model package is included to predict dispersion over terrain of high complexity, e.g., mountains. Appropriate interfaces exist to meteorological measurements and forecasts of numerical weather prediction models of European national weather services.

The hydrological model chain in RODOS is comprehensive. It covers the dispersion of released material into and through most aquatic environments (e.g., rivers, reservoirs, lakes, estuaries, coastal waters, seas, etc). In addition, the transfer of material deposited from the atmosphere (e.g., by run-off from catchments) to various water bodies is modelled. Many models are included in the system with different levels of complexity and detail enabling the user to choose the most appropriate depending on the application and desired output.

Prototype uncertainty and data assimilation methods have been developed, which are 'primed' either with the air concentrations or the deposition predicted by the atmospheric dispersion models, or with food contamination from the food chain modules, and update their diagnoses and prognoses as monitoring data (e.g. gamma dose rates, ground deposition or food contamination) arrive. For the times after the plume has passed, krigging techniques exist, which enable estimates of the contamination and uncertainties to be made purely on the basis of data bases of radiological monitoring data and measurements. Uncertainty handling and data assimilation have been introduced in the river models to update the predictions of contamination downstream from measurements made upstream. Theoretical investigations exist for the other parts of the hydrological model chain.

Exposure from all pathways of potential importance are assessed both during and after the passage of a radioactive plume (e.g., external radiation from radioactive cloud, external radiation from material deposited on the ground and on skin and clothing and internal radiation from the inhalation of airborne material and ingestion of contaminated foodstuffs. The transfer of radioactive material to foodstuffs (both commercial and natural), and subsequently to man, is modelled taking account of seasonal variation (e.g., state of crop growth); special tools allow actual data bases to be used in case of an emergency, and thus improve the predictive power of the models. Differences in agricultural practice and climatic and soil characteristics are considered by adapting the data bases of the applied models to various regions of Europe: this makes RODOS a unique tool to apply a consistent approach of dose assessment on a multinational level. Comparable models are used to assess exposures from radioactive material in different aquatic environments (e.g., drinking water, irrigation of crops, fish consumption, etc.). Estimates are made of exposure of individuals (with average and special habits) and the population as a whole.

Measurements to reduce radioactivity concentrations in freshwater fish and drinking water are also analysed for situations where contamination of streams, rivers and lakes has occurred. Measures range from changing the source of drinking water supplies and processing fresh fish to applying fertilisers to lakes to reduce the uptake of radionuclides into the fish feeding in the lakes.

**Figure 3: Terrestrial exposure pathways considered in RODOS.**

**Extents and implications of emergency actions and countermeasures**

The RODOS system simulates and estimates in a coherent and comprehensive approach the timing, extent and duration of all those countermeasures that can be implemented to limit the health and environmental impact of an accident. Intervention strategies adopted in the different European countries can be implemented. All available information on the following types of intervention have been integrated and synthesised in the corresponding models and the data-bases belonging to them:

- sheltering;
- distribution of stable iodine tablets;
- evacuation;
- decontamination of inhabited areas;
- temporary and permanent relocation;
- and the following agricultural countermeasures:
  - 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;
  - decontamination of agricultural land by ploughing and soil removal.

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to the implementation of countermeasures in individual countries has been collected. This has made it possible to give constructive guidance on the use of the RODOS database on countermeasure effectiveness and technical feasibility for specific areas of Europe.

**Evaluation of countermeasure strategies**

MAV/UT based prototype software has been developed to enable the user to compare and evaluate the benefits and drawbacks of different countermeasures’ strategies (e.g., risks, costs, feasibility, public acceptance, perceptions, social, psychological and political implications and preferences or values of decision makers, etc.). Rules weights and preference functions are encoded and applied to a list of alternative countermeasures to provide a ranked short-list to decision makers together with those rules and preferences that determined the order of the list. Intuitive justifications for choices and underlying uncertainties inherent in the predictions are also provided. The evaluation software assists users in modifying rules, weights and preferences and other model parameters as well as exploring the consequences of each change. The importance of this exploration cannot be overemphasised. Any decision support system helps decision makers not by making the decision itself, but by enhancing the decision makers’ understanding of the problem, the issues before them and their value judgements. They are then better able to make the decision because of this greater understanding.

**Software design of the RODOS system**

RODOS is a modular structured system and has a client-server architecture that allows it to be distributed across a network of computers. The modules are written in ANSI C, C++ or FORTRAN. The inter-connection of all program modules, the input, transfer and exchange of data, the display of results, and the different modes of operation (interactive and automatic) are controlled by a specially designed UNIX based operating system, which provides an integrated environment for the application software provided by the contractors. Databases exist for storing model parameters and geographical data and for retrieving and processing meteorological and radiological real-time data.

There are two user interfaces adapted to the needs of different users. The first is based on X-Windows for UNIX and is intended for qualified operators and system developers (user category A). This interface offers full access to all system functions, model parameters and stored data. The second interface (user category B) is based on the design of Internet sites using well-established WWW technology. It is intended for users (user category B) not needing permanent access to the system (e.g., only during an emergency or in exercises), such as radiological advisers, decision makers, etc (see RODOS MIGRATION, pp 40).

**Further developments**

Based on the experience gained in exercises, in training courses and during its (pre-operational) use, the existing version of RODOS will be improved and completed to reach full practical and operational applicability in national emergency management arrangements. The most important R&D activities are: computer platform independent communication tools between the RODOS system and remote users both nationally and internationally; more general applicability and robustness of the application software in the areas of meteorology, radioecology and countermeasure simulations; data assimilation methods for improving the model predictions on the basis of measurements and for quantifying uncertainties; evaluation techniques for supporting the decision making process; data exchange tools for facilitating the direct information transfer between neighbouring countries.
Rodos FP4 Information Column

Part 2

Title: Real-time On-line DecisiOn Support system for off-site emergency management in Europe. (RODOS)

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