



Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft

Wissenschaftliche Berichte
FZKA 7015

Migration of RODOS to Practical Applicability

J. Ehrhardt (Ed.)

**Institut für Kern- und Energietechnik
Programm Nukleare Sicherheitsforschung**

Dezember 2004

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**Forschungszentrum Karlsruhe GmbH
Postfach 3640, 76021 Karlsruhe**

**Mitglied der Hermann von Helmholtz-Gemeinschaft
Deutscher Forschungszentren (HGF)**

ISSN 0947-8620

urn:nbn:de:0005-070150

Abstract

The report summarises the objectives and the results of the project “Migration of RODOS to practical applicability for supporting decisions in operational emergency response to nuclear accidents” (RODOS migration), EC contract No. FIKR-CT-2000-00077, from 1 October 2000 to 31 December 2003. RODOS, a real-time on-line decision support system for off-site nuclear emergency management, has been developed with support from the European Commission for more than a decade, and significant additional funds have been provided by many national RTD programmes, research institutes and industrial collaborators.

The overall objective of this project was to enhance the operational versions of the RODOS system for supporting and increasing its broader acceptance and dissemination in Europe through an improved practical applicability in emergency centres with respect to: the reality of data network conditions, different categories of users both in emergency centres and remote, for a broad spectrum of release types, for different environmental conditions and characteristics, and for training and exercises. In this way, the resulting new RODOS versions lead to practicable improvements in providing the emergency management teams and those involved in decision making with fast, reliable, consistent and comprehensive information in case of a nuclear accident.

Zusammenfassung

Verbesserung der praktischen Anwendbarkeit des RODOS Systems

Der Bericht beschreibt die Zielsetzung und die Ergebnisse des Projekts “Migration of RODOS to practical applicability for supporting decisions in operational emergency response to nuclear accidents” (RODOS migration), EC contract No. FIKR-CT-2000-00077, vom 1. Oktober 2000 bis zum 31. Dezember 2003. RODOS, ein Echtzeit-Entscheidungshilfesystem für das externe Notfallschutzmanagement nach kerntechnischen Unfällen, wurde über mehr als zehn Jahre mit Unterstützung der Europäischen Kommission entwickelt, wobei bedeutende Mittel von einer Vielzahl nationaler F&E-Programme, Forschungsinstitute und Industriepartner bereitgestellt wurden.

Die Hauptzielsetzung des Projekts war die Ertüchtigung der operationellen RODOS Versionen zur Erzielung einer größeren Akzeptanz und eines breiteren Einsatzes in Europa durch die Verbesserung der praktischen Anwendbarkeit in Notfallschutzzentren im Hinblick auf: die Eigenschaften real existierender Datennetzwerke, ein breites Spektrum von Freisetzungskarakteristika, unterschiedliche Umgebungsbedingungen, sowie den Trainings- und Übungseinsatz. Die neu entstandenen RODOS Versionen führten zu deutlichen Verbesserungen bei der Bereitstellung von schnellen, verlässlichen, konsistenten und umfassenden Informationen für die Notfallschutzteams und den im Entscheidungsprozess involvierten Personenkreis im Fall eines kerntechnischen Unfalls.

Preface

The report summarises the objectives and the results of the project “Migration of RODOS to practical applicability for supporting decisions in operational emergency response to nuclear accidents” (RODOS migration), EC contract No. FIKR-CT-2000-00077, from 1 October 2000 to 31 December 2003. The following institutes and staff members contributed to the scientific work performed and its documentation in this report:

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The delegations were funded by the EC under the contracts FIKT-CT-2001-50022, FIKR-CT-2002-50025, FIKR-CT-2002-50026 and FIKR-CT-2001-00156.

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1 Executive summary

The operational version PV4.0 of the RODOS system, released by the end of the 4th Framework Programme, has been installed for (pre-) operational use in a number of East and West European countries. The work performed under the “RODOS migration” project of the 5th Framework Programme aimed at enhancing the system to provide a decision support tool fit for practical use in emergency centres by improving the broader applicability and robustness of its software components. This will help promote its wider acceptance and dissemination in Europe, and – together with the forthcoming networking of RODOS systems installed in many countries, lead to practicable improvements in the efficacy and coherence of off-site emergency management in Europe.

A key element of the work performed within the project was the development of an end-user interface, which is based on the wide spread WWW technology implemented on all kinds of computer platforms. In this way, the existing networking facilities (INTERNET) can be used and end-users can operate RODOS with hardware and software tools available to them. A Web-interface for remote active users (Category B) allows the user to specify the conditions of individual runs which are then run on operationally installed RODOS systems. The Web interface also comprises an interface for passive users (Category C), which enables remote users, with access rights, to receive results from RODOS in a standardised form.

Concerning the application software, the two most important improvements are the extension of the RODOS applicability to long duration releases of up to 47 days and the generalisation of the meteorological pre-processing tools with respect to many types of meteorological data and forecasts, dispersion conditions and topography. Other activities have lead to important supplementary model features and functions of the RODOS system:

- the inclusion of methods for identifying and inserting the actual crop development status at the time of the accident,
- quantification of doses to workers performing countermeasures,
- more flexibility in the forest foodchain and dose models and their extension to countermeasures,
- the possibility of specifying local and regional data on building shielding in inhabited areas in a shielding grid,
- a pre-processor for calculating correction factors in case of non-standard dose rate measurements.

As a consequence of requests from the users' community, activities initially not planned were started during the course of the project and have been completed. These are:

- the coding of much more flexible user input facilities for source term information,
- the completion of the RODOS data base with site and plant data for all European NPPs, and
- conversion of the format of a uniform European geographical data base and its distribution to all RODOS users.

Furthermore, the whole hydrological model chain prepared under FP4 was implemented in RODOS, an activity not covered by the work programme of this contract.

Finally, two validation studies have been successfully completed which demonstrate the good agreement of measured data from contaminated areas in the US and in the vicinity of Chernobyl with results from the RODOS system.

The developed and/or updated software components have been integrated in the operational version PV5.0 of RODOS released in May 2002 and the version PV6.0 released in March 2004. The latter version also integrates new modules allowing for assimilation of measurement data in near range atmospheric dispersion and food chain calculations developed under the DAONEM project.

None of the existing decision support systems in Europe provides these new features as described above; the improvement and extensions made to the RODOS system will significantly improve the accuracy of its diagnostic and prognostic capabilities and its operational applicability as a whole.

2 Objectives and strategic aspects

The overall objective of this project was to enhance the operational versions of RODOS for supporting and increasing its broader acceptance and dissemination in Europe through an improved practical applicability in emergency centres with respect to: the reality of data network conditions, different categories of users both in emergency centres and remote, for a broad spectrum of release types, for different environmental conditions and characteristics, and for training and exercises. In this way, the resulting new RODOS versions lead to practicable improvements in providing the emergency management teams and those involved in decision making with fast, reliable, consistent and comprehensive information in case of a nuclear or radiological accident.

Three sub-objectives have been identified to achieve this overall objective:

- Development of advanced communication tools enabling computer platform independent interaction between the RODOS system and remote users of different skills and needs.
- Enhancement of the more general applicability and robustness of the RODOS application software in the areas of meteorology, radioecology and countermeasure simulations.
- Validation of complete model chains of the RODOS system as contribution to its quality assurance.

These sub-objectives have been achieved by complementary software developments and the extension of system functions where necessary, by performing validation studies to demonstrate the adequacy and accuracy of the methods, models and data bases incorporated in RODOS, and by the application of RODOS in emergency exercises.

The further enhancement of RODOS is supported by a number of complementary RTD projects, such as DAONEM, EVATECH and MODEM /1/, which have already and will contribute with substantial methodological and software developments to extend the functionalities and capabilities of the system. The close interaction with these projects, among others organised through the participation of FZK as co-ordinator of this project, will lead to a fast integration of these developments into operational RODOS versions.

The broad acceptance of models, methods and data bases incorporated in RODOS combined with the possibility of customising them to the different regions and countries in Europe, and an increasing multi-national exchange of experience with the system itself established under

under the DSSNET¹ network, will help promote its wider acceptance and dissemination in Europe.

This dissemination started over more than four years ago with the installation of the operational RODOS version PV4.0 in Poland, the Slovak Republic, Hungary, the Ukraine, Finland, Spain, Portugal and Germany, and will continue in the next few years with Austria, the Czech Republic, Slovenia, Bulgaria, Romania, Russia and other West European countries currently investigating the integration of the system in their emergency management arrangements.

The increased installation and use of RODOS in national emergency centres has, amongst others, the following economic and technological advantages: (1) it will serve as a platform for cost effective developments in the future; in particular, through sharing of technical know-how / experience and complementary software developments, unnecessary duplication in maintaining and updating the system will be avoided; (2) the common identification and promotion of complementary RTD work concentrated on one system instead of many diverse ones is much more cost effective and has a higher chance of finding financial support; (3) it influences the further development of other decision support systems, such as the ARGOS system, in which the same models, data and functionalities have been and will be incorporated; in this way, the increasing similarity between systems will equally lead to a uniform information basis and decision support after radiological accidents across Europe.

With the future networking of the RODOS systems operating in the national emergency centres of the above mentioned countries, the early notification in case of a nuclear accident will be significantly improved by a fast, comprehensive and consistent exchange of all information relevant for the emergency management in neighbouring countries. This will be highly beneficial in the context of the Community Legislation and its implementation in practice, in particular the Council Decision on Community arrangements for the early exchange of information in the event of a radiological emergency and the Council Regulations laying down maximum permitted levels of radioactive contamination of foodstuffs.

¹ DSSNET: Improvement, extension and integration of operational decision support systems for nuclear emergency management (contract FIR1-CT-2000-40076)

3 Scientific and technical description of the results

3.1 Web-based user interface (WP1)

3.1.1 Problem description and objectives

The X-Window based user interface of the RODOS system provides full functionality for controlling all processes, managing different kinds of data resources and data structures, incorporating new applications, defining all transactions and presenting all results calculated by the system. It is based on the Client-Server architecture for operation in the UNIX environment.

To enable access to a centrally installed RODOS system by remote users from all kinds of computer platforms with Internet browser, a new interface had to be developed. It is based on the commonly used and platform independent WWW technology. The layout and content structure of the WWW interface, especially the front-end aspects, have been designed and developed with a unique standardised interface layout and information structure under due consideration of the needs of the RODOS users.

3.1.2 Research performed and progress achieved

The interaction between the RODOS system and its users has three main objectives: (1) operation of the system in its automatic and interactive modes including the processing of meteorological and radiological on-line data, and the choice of module chains for performing the necessary calculations; (2) input of data defining the accident situation, such as source term information, intervention criteria and timing of emergency actions; (3) selection and presentation of results in the form of spatial and temporal distributions of activity concentrations, areas affected by emergency actions and countermeasures, and their radiological and economic consequences.

Interactions with RODOS users of Category A

In its standard installation for so-called users of Category A, the RODOS system is accessed via network (ISDN lines) connected X-terminals using the client/server protocol Internet/X (see Figures 4.1.1, left side, and 4.1.2, right side). The RODOS application software provides various X-based graphical user interfaces (GUIs) for enabling the user interactions with the RODOS system on all three items (1) to (3) mentioned above. The GUIs display information to a user and capture data and actions from a user. The X Window System Software is used to generate these GUIs.

The GUI applications are on the RODOS side X clients that communicate with the X display server on the user's site via the X protocol over the TCP/IP Internet protocol. Therefore, a user can access the RODOS system through the TCP/IP networking tools implemented

implemented on any Internet connected X desktop machine, such as Unix workstations from different vendors, X- Terminals, Linux PCs, and PCs with X-Emulation. The GUI applications provide direct access to all functionalities of the RODOS system.

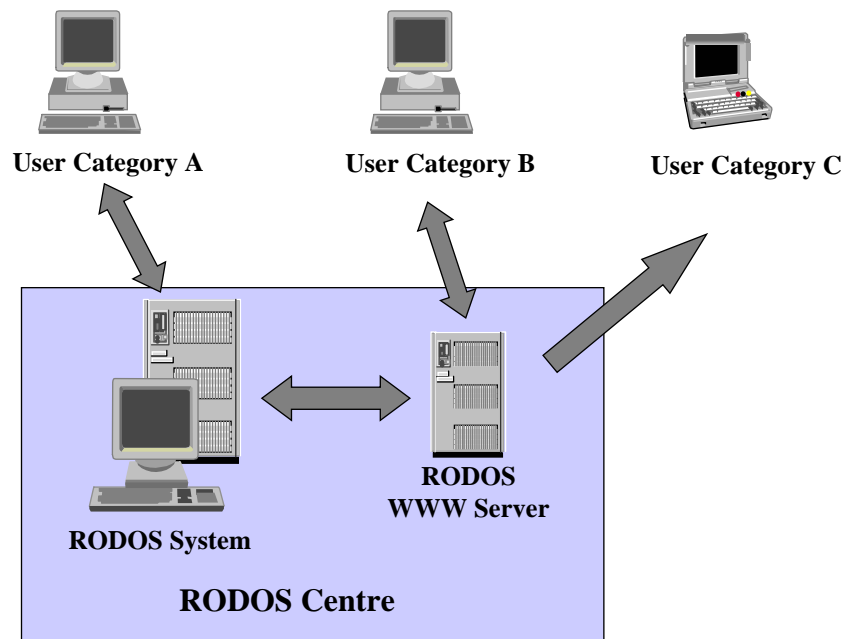


Figure 4.1.1 Interaction with remote users

In addition, particular applications provide interfaces to external program developers to integrate a new application or to modify the data structure and the just-in-time services of an existing application. A user can trigger or interrupt the automatic processing mode, execute applications simultaneously, modify data, delete data, import data sets from the database, move data into other application, change a lot of configuration files, and so forth. For achieving certain results, a user must know, which applications should be selected, how to interact with the application dialogs, which sort of initialisation data have to be assigned, how to do the applications interfacing, which sequence should be chosen to trigger the actions or applications, and so on. This kind of flexible interaction implies that an experienced user should operate the RODOS system to obtain useful information. By this method of flexible interaction, the system responds immediately, because the user interacts directly with in-memory active processes.

Web-enabled access to the RODOS system

Main objective of the Web-enabled access to the RODOS system was to allow remote users for defining their requests interactively on each kind of computer platform with Web browser and to get back the requested

requested information from the RODOS system via Internet/Web. Two types of Web-based interfaces have been realised for so-called RODOS users of Category B and C:

Category B: Active user with access to the RODOS system via Web Browser. The interaction with RODOS is limited to the items (2) and (3) mentioned above: the Category B user can only define interactive runs via input forms and select results from predefined information. He has no access to data bases and cannot operate RODOS in its automatic mode.

Category C: Passive user with access via Web Browser only to RODOS results produced by users of Category A or B.

The Web client/server interaction is schematically shown in Figure 4.1.2. The Category B users define their requests to the RODOS system via an interactive Web-based interface. The corresponding HTML file is sent to the RODOS Web server. It transforms the information into RODOS compatible data, initiates the corresponding RODOS processes and runs, produces an HTML results file and returns it to the Web browser. The Web browser receives the HTML file, it interprets the page content and displays the page.

In this way, the software framework acts as a helper system or stand-by server between a Web client and the RODOS system. It plays the role of a server from a Web-client perspective, whereas it plays the role of a client from the RODOS perspective. In the following it is referred to as “RodosWeb Server”. Figure 4.1.2 (left side) shows the client/server model of the RODOS/Web connectivity.

The conceptual software design of the Web-based user interface distinguishes altogether four system software components for enabling the Internet/Web-based communication between the user and the RODOS system via the RodosWeb Server and the Rodos dispatcher (see Figure 4.1.2). The RodosWeb Server incorporates the following software tools:

The **HTTP server** waits for incoming requests and services the requests as they come in. Once the Web server receives a request, it then finds the requested HTML file and returns it to the user’s Web browser. The Web browser receives the HTML file, it interprets the page content and displays the page.

The **Web applications** handle the creation, parsing and transformation of Web requests, and the generation of Web responses. In particular, they contain the Web-based user interfaces.

The **Web dispatcher** provides the interfaces for communicating with the RODOS dispatcher, as well as for sending/receiving data to/from the RODOS system.

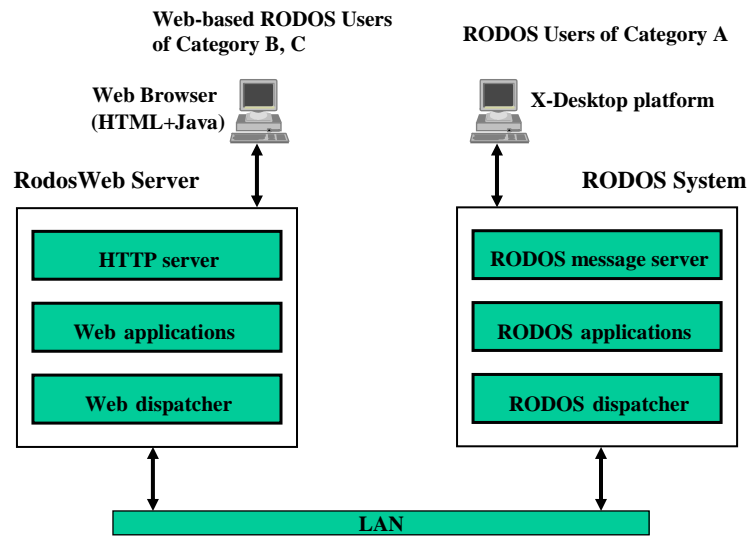


Figure 4.1.2: Rodos/Web conceptual design

The *RODOS dispatcher* provides the interfaces for communicating with the Web dispatcher, as well as for receiving/sending data from/to the RodosWeb server. It provides the interfaces for communicating with the RODOS applications.

The following freeware tools have been used to implement the functionalities of the RodosWeb Server:

- The standard Java 2 development environment for developing Web applications: Java SDK and RTE v1.3 for HP-UX 11.0.
- The Apache Web server software providing features for serving the Web applications and HTTP connections: HP Apache-based Web Server 2.0 for HP-UX 11.0.

These software packages are provided by Hewlett-Packard for installation on HP Workstations and Servers. For additional information see <http://www.hp.com/>.

The complete software package for users of Category B and C has been implemented in RODOS version PV5.0. It has been widely tested by a number of emergency management organisations during the 3rd emergency exercise of the DSSNET network.

3.2 MS office and GIS interface to the RODOS data base (WP2)

3.2.1 Problem description and objectives

The results of RODOS are either presented graphically or in alphanumeric form as provided by the RODOS system. Much more flexibility will be offered for the users, in particular, those with remote workplaces on different computer platforms, if the results can be further processed with RODOS independent complementary software tools available on the local computer. This offers the possibility of converting RODOS results in forms of presentations demanded by the users' working environment and required for inclusion in the users' documents. To that purpose, an export facility will have been generated that produces and converts the result data of the RODOS databases in a generalised format for these external software products. This service is also available via the WWW interface.

3.2.2 Research performed and progress achieved

All data relevant for decision support are stored in a results data base and can be presented as graphics and partially printed in alphanumeric form as tables and/or diagrams. To improve the capabilities of the system, complementary software tools should be available on a local computer of a remote end-user allowing for an independent processing and conversion of information from the RODOS system. The following functional requirements for such software tools can be defined on the system level as follows:

- Conversion of RODOS data files (RTTF, Source Term, Local Weather Prediction and RODOS results) into Microsoft Office documents (primarily: Microsoft Excel and Microsoft Word; additionally: Microsoft PowerPoint and Microsoft Access)
- Possibility to have an user defined and an automatic mode of conversion
- Ability to control the conversion rules/parameters
- Easy installation and de-installation of the system.
- Scalability of the system, i.e. the software code can be easily expanded to extend the conversion to other RODOS data formats.
- In addition to these requirements, the software tool has to be flexible and fault-tolerant.

The fact that the software tools must be distributed forced to define the way of interaction between Windows and UNIX platforms. There are several possibilities to accomplish this task. Among others, three possible ways of interaction were analysed:

- via Web services
- via CORBA
- via File Transfer Protocol

After evaluation of the pros and cons, the Web services technology was selected for the development of the software tools.

The software architecture of the software tool system can be subdivided into two main parts: the *server side* and the *client side*. The server side is running on a local computer with the Microsoft Windows XP/2000 Operating System. The client side is a UNIX host with the installed RODOS system (see Figure 4.2.1).

Development on the Server side

On server side, the system was implemented by using the Microsoft .Net Framework. This is at present the standard framework for developing Microsoft compatible products. Microsoft emphasises that .Net enables an unprecedented level of software integration through the use of XML Web services. However, the connectivity of the software is not the only advantage of this technology. One of the key features is that applications can be written in any language supported by the Common Language Infrastructure (e.g., Visual Basic, C++, C#). Another important point is the fact, that .NET is an integrated part of the Microsoft product platform.

The user of the conversion tool expects an automatic conversion without any user interaction. Only the data to be converted has to be defined somewhere. To fulfil these requirements, the Microsoft Office Automation was applied.

There are two different ways to run the conversion for the Automation: in *local* and *remote* modes.

- Local mode implies that the source files for conversion are located on the same host where the Office Automation starts – on a computer which runs under Microsoft Windows XP. That is only possible when RODOS data are already transmitted to this host. This mode was designed mainly for test purposes.
- Remote mode implies that the source files for the conversion are located on another host (Windows or UNIX) but not on that one from where the Office Automation starts.

A conversion request by a user is defined by a web based interface. The advantage of such a solution is a uniform access to the conversion tool. Requests are coming to a single interface from any host in the RODOS network. The web service for this interface is implemented in the web application *RoOffice* running under the Internet Information Server (IIS).

Development on the Client side

The client side is the host where the RODOS system is located.

It was necessary to develop a web application to support the data conversion via the web interface. This application (called *rooffice*) is a java-based set of servlets (with complementary classes) as well as support libraries, building and installation scripts. When this application is installed and running (under Tomcat web server), remote web based RODOS users are able to connect to the system and select RODOS data for conversion (see Figure 4.2.1)

The web application performs the following main functions:

- creating an XML description of the conversion rules
- connecting to the Windows host's web service and sending data for the conversion
- asking the web service if the results are ready
- receiving results (Office documents) from the Windows host
- providing web links to the converted Office documents.

For the connection from the *rooffice* web application to the web services, the Apache AXIS 1.0 RC2 library was used. Apache AXIS 1.0 RC2 is an implementation of the SOAP ("Simple Object Access Protocol"). The converted RODOS data can be downloaded from the web application *rooffice* and opened in Microsoft Office. The *winRodos* application was created in case a user works on a PC under Windows and RODOS data are already transmitted to that host. It runs under Windows and has a specific interface for the conversion of the RODOS data. As shown in Figure 4.2.1, this application requests web services on the host where the real conversion is performed. *winRodos* can be run on any host in a network under Windows that has access to the RODOS WebServer.

Software implementation

The work performed included the functional specification, development of software, integration in RODOS and test and validation of the whole system. A prototype simple conversion software system was initially developed from the overall specifications. It was then refined with support of users of the tool to realise a system which fulfils the needs of the end-user.

Several aspects of this work, mainly the use of web services can be applied to the development of the RODOS system in future. It can play an important role as a bridge between UNIX and Windows platforms, in particular between a .Net/COM component environment on the one side and the UNIX component environment (most likely CORBA) on the other side.

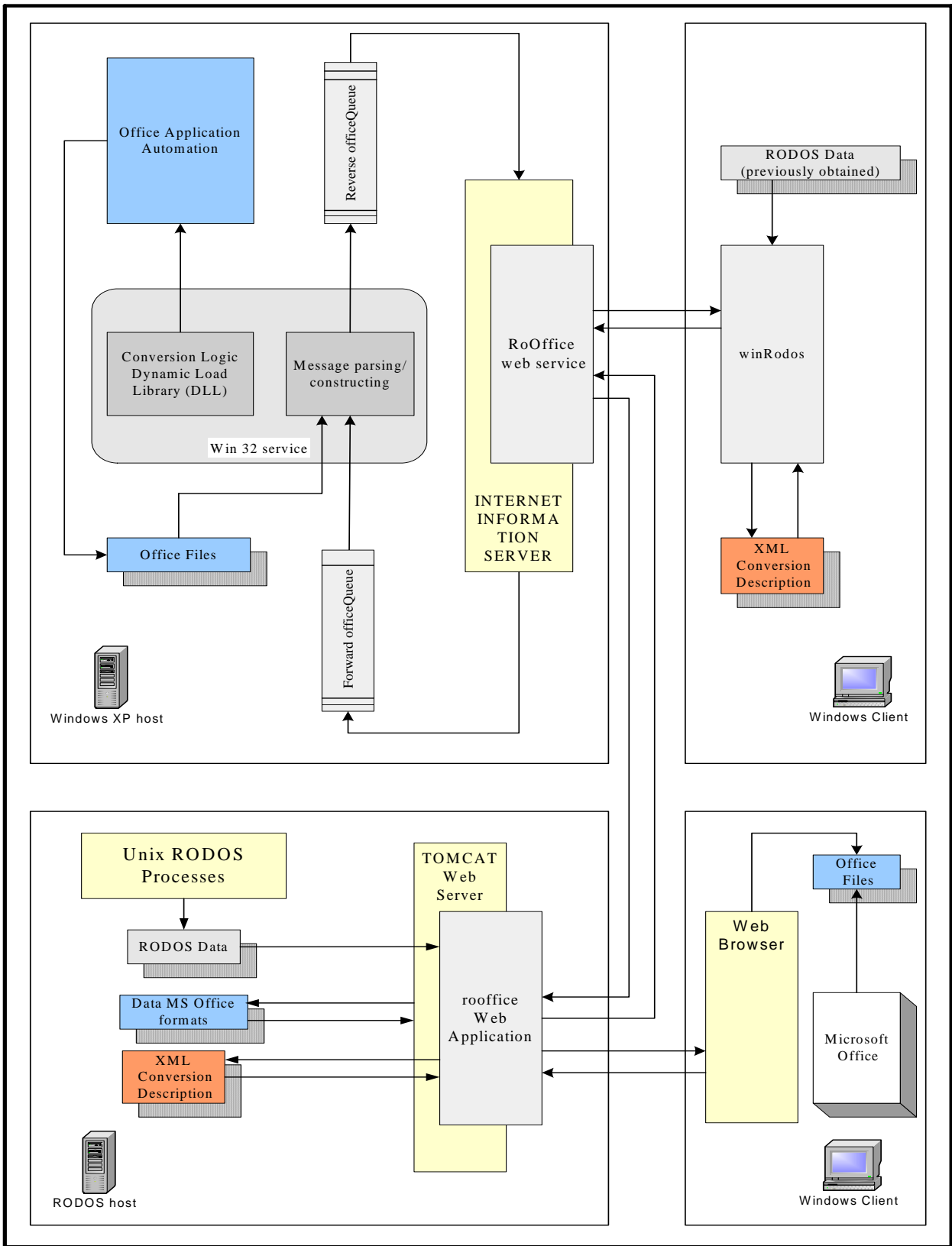


Figure 4.2.1 Architecture of the software tool system

3.3 Long-term releases (WP3)

3.3.1 Problem description and objectives

The RODOS version PV4.0 was limited to radioactive releases up to 12 hours. This limitation was introduced for faster achieving operability with the system and application software. Accidental releases of both Western and Eastern type nuclear power plants can last up to several days. Therefore, the RODOS software had to be modified to allow for releases of longer duration.

The main objective of Work Package 3 is the extension of RODOS to cope with long lasting atmospheric releases in both the automatic and the interactive mode of application. RODOS version PV4.0 was still limited to a release duration of maximum 12 hours and a prognosis period of 24 hours. With the new functionality the maximum duration of both the release and the prognosis period for atmospheric dispersion calculations were prolonged to more than one month. This is in particular important in the automatic mode where diagnostic atmospheric dispersion calculations of ALSMC can now last for weeks including a 24 hour prognosis into the future.

The new functionality required modification of nearly all modules implemented in RODOS version PV4.0. In particular, the module packages ALSMC for local scale atmospheric dispersion, EMERSIM for early emergency actions, FDMT for terrestrial food and dose calculations, and LCMT for longer term countermeasures of terrestrial pathways, were completely restructured, their interfaces partly revised and new functionalities added. This coding work required much more manpower than expected from the initial design. In particular the re-coding of the near range atmospheric dispersion module ALSMC with the dispersion model ATSTEP was also influenced by the newly developed meteorological pre-processor (WP5). The four revised modules build the core of RODOS versions PV5.0 and PV6.0.

In addition, the users requested modifications of the source term input; therefore this task was added to the working programme (see Chap. 4.11). The RODOS version PV4.0 provided 5 different modes of source term input which can be used at any time of the accident but the bottleneck was their missing interconnection. This means that it was not possible to switch in the automatic mode from one input form to another during an ongoing release.

The main aim of the newly introduced work package was to overcome this problem of source term input and to structure these input facilities more user friendly and error save.

3.3.2 Research performed and progress achieved

Atmospheric dispersion module (ADM-ALSMC)

As integral part of the atmospheric dispersion module ADM, the source

source term module was modularised and subdivided into three major parts, the first one dealing with the user input, the second performing the basic source term calculations and the third one providing the appropriate source term in the prognostic (30 minutes) or diagnostic (10 minutes) time step. The input format progressed from the fixed timing of 30 minutes to a completely flexible one which allows the user to define arbitrary time intervals with source term information. In total, 24 time slots are now available to define the source term over the maximum period of 47 days; periods without a release have not to be explicitly provided.

The flexible selection of the input mode and the possibility to switch between them at any time of the RODOS operation forced to model the time dependency of the inventory of the reactor at any time after the start of the release. This enables to switch from release fractions of the inventory for a nuclide group to the amount of Becquerel released for a nuclide group and vice versa. The only exception is the use of single nuclides if no release group is associated with it.

This new feature requires the application of so called 'dynamic' input windows to allow the conversion during run-time of the module. In addition, the data base structure had to be revised and a new file based structure had to be build up. This resulted in a restructuring of the complete RODOS model data base, which was necessary to become as flexible as possible.

The dispersion model of ALSMC, ATSTEP, had to be restructured in a way that it runs now for up to 47 daily sub-cycles in the prognostic mode. This was necessary to save computer resources, as a continuous operation of ATSTEP would have required too much memory. Each of the daily cycle runs shares resources thus limiting the shared memory size to values below 64 MB which is a critical point in the operation of the system. However, it also turned out that system functions had to be added to allow for an optimised storing and retrieving of data into and from the data base. Otherwise, several Gigabytes of disk space are required for a long lasting prognosis run. In addition, the dose functions calculating the relevant information for the early emergency simulation module EMERSIM had to be extended to provide more potential dose information.

To achieve the extended functionality in the automatic mode, the restore functionality of ALSMC had to be extended. Between each of the 10 minute diagnostic steps, ALSMC is terminated and thereafter had to be restarted. The extended restore functionality comprises among others the interface to the foodchain and dose module FDMT which will retrieve from RODOS version PV5.0 onwards all required information from the diagnosis calculation to perform a run starting from the beginning of the release. This was limited in RODOS version PV4.0 to results from the prognostic calculations performed every 30 minutes within the

minutes within the automatic mode.

Foodchain and dose module FDMT

FDMT had to be completely restructured to cope with the new functionality of releases of up to 47 days. The new version of FDMT, integrated in RODOS versions 5.0 and 6.0, calculates food contamination and doses individually for each deposition day provided by the ADM, and adds up the food contamination and doses from all deposition days. As a consequence of this, the time grid on which food contamination and doses are calculated had to be expanded from 56 to 94 time steps.

According to the needs of the Deposition Monitoring Module DeMM (developed under the DAONEM project), the deposition calculation had to be moved from FDMT to an extra Deposition Module DepoM which has to be run before FDMT. This allows DeMM to update the estimated deposition data using measured dose rates and in-situ gamma spectrometric measurements, before they are used as input for the food chain calculations. In the automatic mode of RODOS, DepoM and FDMT are running in one program group.

Within the scope of FDMT restructuring, extensions of its functionality have been made in order to enable it to make use of the results of the Food Monitoring Module FoMM, which has been newly developed in the framework of the DAONEM project. FoMM adapts model parameters of the food chain model within their estimated range of uncertainty using measurements of activity concentration in feed and foodstuffs. The adapted parameters are used by FDMT instead of the default parameters for the food chain calculations.

The interface to the Long-term Countermeasure Module LCMT had to be substantially revised since using the existing structure for long term releases would have increased the requirements for shared memory of the data interface FDMT-LCMT far beyond the technical limits. Therefore, transfer of data from FDMT to LCMT is now partly via shared memory, and partly via files.

The definition of the default results of FDMT has been revised in order to meet the requirements of the new web based interface for different user categories.

Early emergency simulation module EMERSIM

In the design phase it was decided, that the early emergency simulation module EMERSIM should perform detailed calculations only for a limited time period of 24 hours. However, EMERSIM does take into account the potential doses from previous days in case of a longer term release. These doses will be used to determine whether a certain intervention level has been exceeded at any time during the release and

thus will define areas where potential actions might have been initiated in the past.

To realise this concept, EMERSIM was extended to include sub-modules that calculate the necessary potential dose arrays for the various countermeasure types. In addition, new graphical output was developed to include information of the extent of intervention areas as a function of time.

In the Automatic mode, the detailed simulation of countermeasures covers the fixed prognosis time of 24 hours as can be seen in Figure 4.3.1. The red and the yellow lines give the consequences without and with emergency actions, respectively.

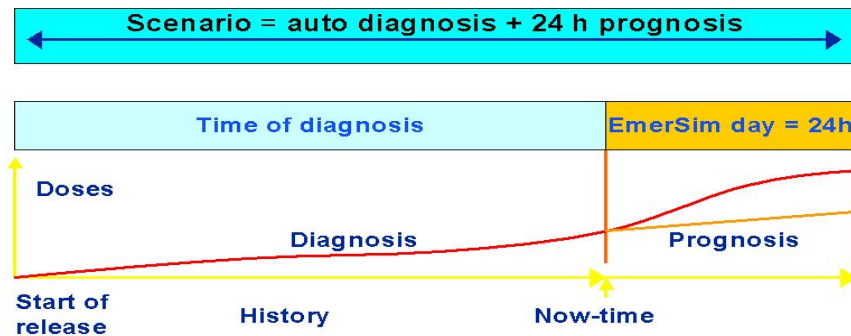


Figure 4.3.1: EMERSIM calculation procedure in the automatic mode

In case of the interactive mode, the detailed simulation period is limited to the last day of the scenario (see Figure 4.3.2).

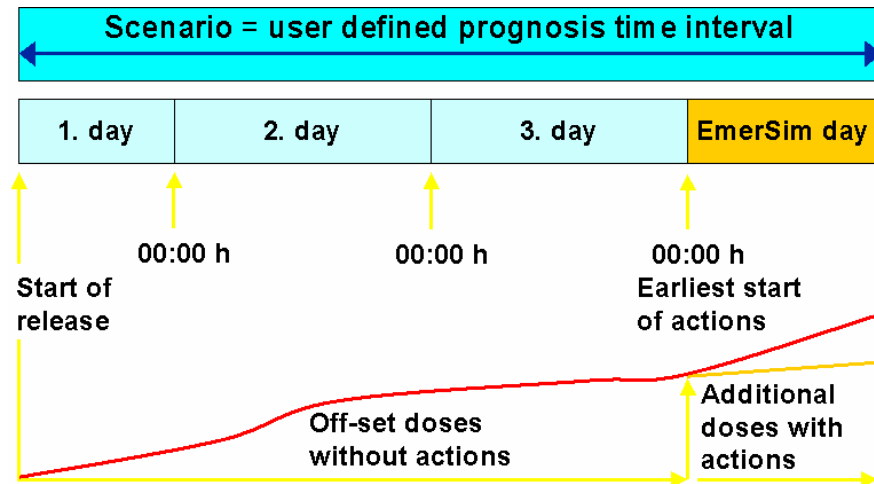


Figure 4.3.2: EMERSIM calculation procedure in the automatic mode

From the experience of the use of the new EMERSIM in RODOS PV5.0, the conclusion can be drawn, that the limitation of the simulation period to either one calendar day or 24 hours in the prognosis mode

prognosis mode should be overcome. However, conceptual work might be necessary to understand the requirements of the decision makers in case of long term release.

Long-term countermeasure module, LCMT

With the revised structure of earlier modules in the RODOS chain to accommodate long duration releases, LCMT also required extensive restructuring, both internally and in the interface with FDMT. The impact of extending LCMT for long duration releases required major changes to the modelling approach to take account of the added complexity of implementing countermeasures either during or after the release phase. The modelling approach has been kept robust with the objective of making the results easy to interpret by the user /2/.

The countermeasures considered within LCMT were reviewed with respect to whether it was likely that these may be implemented within the period during which an extended release could be expected. It was decided that most countermeasures could be implemented on this timescale, although some of the agricultural countermeasures were unlikely to be implemented on timescales of less than a year as described in /3/. The countermeasures that it is assumed can be implemented before the release has ended are listed in the Table 4.3.1 below.

Agricultural countermeasures:
Food disposal or stopping food production
Food processing
Storing food
Animals removed (wholly or partially) from contaminated feed
Addition of sorbents to animal feeds/gut
Relocation
All decontamination options implemented in inhabited areas

Table 4.3.1 Countermeasures that can be implemented during passage of the plume i LCMT

The user now has much more flexibility in the choice of when countermeasures are implemented with respect to when the release occurs and its duration. However, the onus is now on the user to consider whether the early application of a countermeasure is a reasonable action given the situation being assessed. The most likely

situation in which a user might reasonably want to apply countermeasures before the release has ended is where a large initial release is followed by a long period at a very low release rate. The potential negative impact of implementing countermeasures while a release is still on-going will be reflected in the doses received by workers implementing the countermeasures, for example the workers may receive additional doses from inhalation of the plume. The estimation of doses to workers implementing countermeasures is further described under WP 4 (Sect. 4.4).

3.4 Extension of the long term countermeasure module (WP4)

3.4.1 Problem description and objectives

Two areas were identified in which the long term countermeasures module (LCMT) should be extended. Within earlier versions of RODOS, the areas in which the impact of implementation of countermeasures could be considered was restricted and based on criteria rather than being selected by the RODOS user. Also, the module did not include a capability to estimate doses that would be received by workers implementing the various countermeasure options in inhabited and agricultural areas. The objectives of this work package were to introduce the option into LCMT for the user to have flexibility in selecting the areas over which it is assumed countermeasures are implemented and calculations performed and the development of a sub-module to estimate doses to workers implementing countermeasures.

3.4.2 Research performed and progress achieved

Task 1: Flexibility in selection of countermeasure areas

The capability of LCMT has been extended to allow the user more control over the areas in which LCMT assumes that countermeasures are implemented and LCMT performs some calculations /4/, /5/. The areas that the user is likely to want to define or modify are:

- The area in which relocation is considered.
- The area in which decontamination is implemented.
- The area in which food countermeasures are considered.
- The area in which ingestion collective dose calculations are performed.

Whilst running the LCMT module, the user has the flexibility to define the areas listed above and also, if a previous set of results are available, to modify the areas to look at the impact of changing the areas in which countermeasures are considered. Developments in the RODOS interface functionality mean that LCMT can exploit the use of dynamic windows during the running of the module. This means that it is possible to first define areas by criteria and then for the areas to be modified by the user without having to run the program twice.

The areas in which countermeasures are considered can be defined in a number of ways depending on the countermeasure. In general, these can be grouped into the following:

- The use of dose or activity concentration criteria to define areas

- Definition of areas graphically by indicating spatial areas on a map using the mouse (via the computer screen)
- Definition of an area to be the same as an area adopted for another countermeasure, for example, implementing decontamination in the area where people have been previously evacuated.

The options available to the user for decontamination of inhabited areas, relocation of people and agricultural countermeasures are listed below in Table 4.4.1.

For relocation and decontamination, in addition to defining the area in which countermeasures can be considered, the user has the option to modify graphically the area that has been set within the module in a previous calculation. This can be used to explore the effect that changing the area chosen has on the endpoints calculated.

Countermeasure	Options
Decontamination	Decontaminate in all areas that have received deposition Decontaminate based on dose criteria Decontaminate where evacuation has been implemented Decontaminate in a user defined area
Relocation	Relocate based on dose criteria Relocate in a user defined area Relocate where evacuation has been implemented
Relocation + decontamination	Decontaminate where relocation is implemented Decontaminate in a user defined area
Agricultural countermeasures	Consider countermeasures where activity concentration criteria are exceeded Define a spatial area within which countermeasures are considered when criteria are exceeded

Table 4.4.1: Options allowed for defining areas in which countermeasure implementation can be considered

In previous versions of LCMT, the calculation of collective doses from ingestion has been carried out for the area defined by that exceeding the activity concentration criteria in the absence of countermeasures. Flexibility has been added to the module so that the user has the additional option of defining an area that is independent of that defined by countermeasure criteria for the calculation of collective dose. This enables the user to compare strategies that are applied in different areas in a consistent way and allows comparison between runs of LCMT carried out with different food activity concentration criteria.

Task 2: LCMT sub-module for estimating doses to workers implementing countermeasures

A new sub-module has been written for LCMT which estimates the doses that would potentially be received by workers implementing countermeasures /6/. The countermeasures considered are decontamination in inhabited areas, relocation of the population and agricultural countermeasures.

The estimation of worker doses within LCMT is intended to scope the scale of exposures likely to arise during the implementation of countermeasures and to provide a means of comparison between different countermeasures implemented to protect the public. In order for the estimates of doses to provide a basis for comparison, it is important that they are calculated in a consistent manner. The overall modelling approach has therefore been to breakdown each of the countermeasures modelled within LCMT into the individual tasks that they involve. In principle, each task is modelled in the same way, for all countermeasures that involve it. Given the uncertainties and variability inherent in the model estimates, this approach has been further simplified by identifying groups of similar tasks and modelling them as a single generic task. Doses arising from the task of waste disposal are not included as this topic is not included in RODOS version PV6.0.

The following steps have been taken in developing a modelling approach:

- For each countermeasure option considered in RODOS, worker tasks involved in implementing countermeasures, for which exposure should ideally be calculated, have been identified. Exposures arising from normal tasks that would continue whether the countermeasure is implemented or not, e.g. milking, have not been included.
- For each worker task, the relevant exposure pathways have been identified.
- Task/pathway combinations that can be modelled in a generic way have been grouped. Tasks and exposure pathways for which doses are expected to be small compared to others have been removed. This was done with the help of the results from the calculation of worker doses for agricultural countermeasures carried out in the EC funded STRATEGY project /1 /.
- An overall modelling approach was developed based, as far as possible, on the 'STRATEGY' methodology (for agricultural countermeasures only), taking into account available data and its quality and the need to implement the methodology within the structure of RODOS.

The modelling approach implemented in LCMT best uses the information available within the RODOS system, calculates doses using approaches that are consistent with those used for calculating public doses (where appropriate) and which provides a robust way to compare the doses to workers from implementing different countermeasures. The generic exposure pathways that are included in the estimation of worker doses are given in Table 4.4.2 below.

Generic pathway	Notes
External (outdoor/in vehicle)	Includes external dose from activity deposited on the ground to workers outdoors and to workers implementing countermeasures whilst in vehicles eg tractors, lorries etc.
External (indoors)	External dose to workers indoors from activity deposited in the environment
Enhanced resuspension (outdoor/in vehicle)	Includes resuspension dose both from activity deposited on the ground to workers outdoors and to workers implementing countermeasures whilst in vehicles eg tractors, lorries etc. The effect of enhanced resuspension from the mechanical action of the vehicle can be considered.
Enhanced resuspension (indoors)	Resuspension dose to workers indoors from activity deposited in the environment.
Inhalation of plume (outdoor/in vehicle)	Includes inhalation dose from the plume to workers outdoors and to workers in vehicles, eg driving tractors whilst implementing various agricultural countermeasures, driving trucks/lorries and driving buses/cars.
Inhalation of plume (indoors)	Inhalation dose from the plume to workers implementing countermeasures indoors.

Table 4.4.2 Generic exposure pathways included for doses to workers implementing countermeasures

The use of personal protective equipment (PPE) can reduce the doses workers received but it can also decrease the work-rates that can be achieved. The user will have a choice whether PPE is used by the workers. If the user selects that PPE is to be used, doses from inhalation of the plume and inhalation of resuspended material are assumed to be zero and a work rate appropriate for working whilst wearing PPE is used for other exposure pathways. Conversely, if the user selects that PPE is not to be used, doses from inhalation pathways will be calculated and a work rate appropriate for working without PPE used. If the user does not think PPE will affect the work rate, the work rates specified in the underlying data files can be changed. For example, it may be appropriate to assume that PPE will not influence the work rate of

the work rate of vehicle drivers.

The endpoints calculated by the sub-module are summarised in Table 4.4.3 below.

Endpoint	Notes
Location collective dose (manSv)	The location collective dose is the estimate of the sum of doses received by all workers involved in implementing the countermeasure within a grid square. It is the total effective dose summed over all radionuclides. This endpoint is presented as a map for each pathway considered.
Total collective dose (manSv)	The sum of location collective dose over all grid squares. This endpoint is presented as a summary statistic for each pathway considered
Location maximum individual dose (Sv)	The location maximum individual dose is the estimated dose received by a worker at a location performing the task that is estimated to give the highest dose. The doses are summed over radionuclides. This endpoint is presented as a map summed over each pathway.
Overall maximum individual dose (Sv)	This is the highest value for 'location maximum individual dose' found at any location. This endpoint is presented as a summary statistic summed over each pathway.

Table 4.4.3: Endpoints calculated within the worker dose sub-module of LCMT

A set of default data to support the methodology has been provided for each of the countermeasure options included in LCMT. The structure of the data files enables the user to take into account any protection offered to workers either from the types of equipment they are using or from personal protective clothing and respirators etc and the impact of these on the work rates that can be achieved, as described above.

3.5 Meteorological pre-processor (WP5)

3.5.1 Problem description and objectives

Atmospheric dispersion models (ADMs) are employed in the context of RODOS to diagnose and predict the radionuclides air-concentration and ground-deposition. A complete set of gridded meteorological data is of great importance for the accurate outcome of ADMs. The meteorological information, on the other hand, is available, except rare occasions, at locations different that the computational grid of the ADMs.

The objective of WP5 has been to develop and integrate the RODOS Meteorological Pre-Processor (RMPP) that acts as interface between the incoming meteorological information and the ADMs. To this extend the code utilises the available weather observational and/or forecasting data coming from individual meteorological stations and/or national/international weather services which cover the greater area of interest, processes them, and produces complete meteorological information into a pre-requested three-dimensional gridded domain. The product of RMPP is used by ADMs.

The stations or the grid points of the weather prediction codes form a random or uniform meteorological network. The input data may include wind speed and direction, air temperature, humidity, pressure, precipitation intensity, net radiation, surface heat flux, cloud cover, mixing layer height and atmospheric stability. These are then processed to provide more complete and systematic information on a three-dimensional computational grid, in such a generic manner that most of the present ADMs can recognise and exploit.

In the framework of RODOS, a “Data Pre-Processor” (DPP) provides the input of RMPP. The DPP is in turn connected to the RODOS geographical database and to the sources of the meteorological information. The output of RMPP is connected to the RODOS ADMs and to the RODOS graphics system.

3.5.2 Research performed and progress achieved

The basic requirements were set out during the design phase and were described in the report RODOS(RA2)-TN(00)-01. According to these, the RMPP should:

- be an independent module of the RODOS system, to allow for flexibility in the construction of module-chains and usage of alternative ADMs with the same input meteorological information;
- be able to cope with a wide range of possible input meteorological data, measured, forecasted or both;

- deliver information to a wide range of atmospheric dispersion models, Eulerian and Lagrangian (puff or particle type);
- be three-dimensional, allowing for non-uniform computational grid in all three dimensions;
- be suitable to be used in complex topography
- have short execution times (~10s/time step), to be usable in the framework of a real-time decision-support system

The RMPP developed on the above specifications has a modular structure. It consists of a geometry module, dealing with the geometrical configuration of the application, and a main meteorological processor, calculating all the requested output meteorological variables. Both modules have been based on existing software already developed at NCSRD, Environmental Research Laboratory, namely the meteorological pre-processor FILMAKER.

The functional specifications and data description of the developed RMPP are provided in the report RODOS(RA2)-TN(04)-01.

The main meteorological processor is executed within the time loop (once per time step), while the geometrical processor is executed once, before the start of the time loop (Figure 4.5.1). The geometrical processor and the meteorological processor receive input data from the data pre-processor. The meteorological processor delivers output data to RODOS to be used by the ADMs. Communication between the modules is achieved via the shared memory.

The data pre-processor is connected to the incoming meteorological data and the RODOS geographical database. It processes the steering options and assures that a consistent set of input parameters is handled to the meteorological processor at a certain time step. This includes exception handling if data are missing. The geometrical processor handles the information related to the computational grid. The main meteorological processor calculates the meteorological parameters required by the atmospheric dispersion models by interpolation or by specific models.

Detailed description of the computational methods used in the geometry module and the main meteorological processor is provided in the report RODOS(RA2)-TN(04)-02.

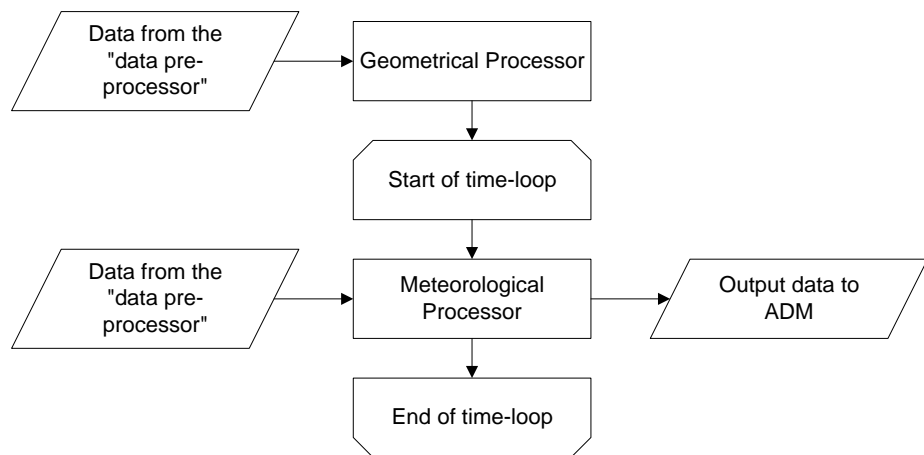


Figure 4.5.1: Flow chart of the function of the RMPP

Computational domain and grid

The RMPP is, as already mentioned, three-dimensional. In the horizontal direction the computational domain is Cartesian with the x-axis aligned to the West-East direction and the y-axis aligned to the South-North direction. The computational grid in the horizontal direction can be defined by the user as uniform or non-uniform. By default it is uniform.

In the vertical direction the computational grid is non-uniform terrain following. The user defines the number of cells and their “undisturbed” (i.e. without topography) dimensions in the vertical. The domain height is constant through the domain, so in each vertical cells-column the same number of computational cells is “squeezed” between the varying topography and the domain top. This is performed in such a way as to conserve the relative size between adjacent in the vertical direction cells, as in the “undisturbed” configuration.

Methods of computations

The RMPP uses two methods for computing the requested output variables:

1. Spatial interpolation in three dimensions
2. Physical or empirical relations

These methods are used according to the availability or not of meteorological information. Variables, for which observations exist, are interpolated to the computational grid points. Variables, for which observations do not exist, are calculated from physical or empirical relations based on the available information.

Input data from meteorological stations and weather forecasting models are treated the same way: measurement locations and grid points of numerical weather prediction models are considered equally as “meteorological stations”. In this document they will all be referred to

to as “stations”. A station can have one or more “observation” levels in height: either measurements or grid points at the same location.

In the case that data from weather forecasting models are used, it is possible that a large number of grid points or stations is located inside the domain. Then the execution time can be substantially increased, given that interpolations would be performed for each cell for all stations. Thus, the concept of a limited number of stations influencing a computational cell has been adopted to speed up the execution time of the RMPP. This means that a maximum of 4 stations has been defined that are allowed to influence a particular computational cell. Obviously, if less than 4 stations are located inside the domain, this number is used as maximum. Only the stations influencing a cell are taken into account during the interpolation procedures when a variable’s value at the cell is computed. By default, the nearest 4 stations (or all the stations if there are less than 4) to a cell are regarded as influencing the cell. However the user can also define a maximum radius of influence where only the stations located in that radius around a cell are taken into account. If for a cell no stations are found within this maximum radius of influence the program stops asking the user to increase the radius.

There is a second step to exclude stations that can influence a cell. This step is based on the topography: if between a cell and a station the ground slope changes sign more than 3 times (by default, this can be set by the user) then it is considered that the station cannot influence the cell. However this criterion is activated only upon specific request by the user, because it is time consuming.

The possible input meteorological variables are distinguished to those for which observations in multiple levels in the vertical for each station can be available, and to those for which only one value per station can be available. The variables for which observations in multiple levels in the vertical for each station can be given are the following:

1. Wind speed and direction
2. Air temperature
3. Specific humidity
4. Pressure

The variables for which only one value per station can be given are the following:

1. precipitation intensity
2. net radiation
3. surface heat flux
4. cloud cover

5. mixing layer height
6. atmospheric stability

The output variables calculated by the RMPP are the following:

1. U-component (west to east) of the wind velocity vector (3-D)
2. V-component (south to north) of the wind velocity vector (3-D)
3. Air temperature (3-D)
4. Specific humidity (3-D)
5. Pressure (3-D)
6. Precipitation intensity (2-D)
7. Cloud cover (2-D)
8. Diffusion coefficient in the x-(west to east)-direction (3-D)
9. Diffusion coefficient in the y-(south to north)-direction (3-D)
10. Diffusion coefficient in the z-(vertical)-direction (3-D)
11. Horizontal wind speed at 10 meters above ground (2-D)
12. Sensible Heat Flux (2-D)
13. Net radiation (2-D)
14. Atmospheric Stability Category (2-D)
15. Atmospheric Stability Class (2-D)
16. Mixing Layer Height (2-D)
17. Monin-Obukhov Length (2-D)
18. Friction Velocity (2-D)
19. Convective Velocity (2-D)
20. Temperature lapse rate (2-D)
21. Brunt Vaisala frequency (2-D)

The wind field produced by the main part of the processor includes only the horizontal components of the wind velocity vector (U and V components). So, in case of a complex terrain application, the calculated wind field needs to be further processed by a wind flow field model to be mass consistent. To partly compensate this, the current version of the RMPP includes a divergence minimising procedure that operates on horizontal levels.

Concerning the interpolation techniques, it is mentioned that for horizontal-wise interpolation, a two-dimensional $1/r^2$ scheme is used. The planes of interpolation for the 3-D input variables (wind velocity components, temperature, humidity and pressure) can be terrain

following or Cartesian depending on the user's option. The heights of the above planes of interpolation are calculated based on the available observation levels for the variable in question. For the 2-D input meteorological variables, the plane of interpolation is terrain following.

In the vertical direction, the interpolation scheme for the wind velocity components is logarithmic in the surface layer, power law up to the mixing height and linear between measured values above power law maximum height. Beyond the highest observation point all the values remain constant. For the rest of the 3-D variables the interpolation in the vertical direction is linear. For the extrapolation of the 3-D input variables temperature, humidity and pressure in the vertical direction specialised functions are used depending on the variable in question.

3.6 Actual status of crop development (WP7)

3.6.1 Problem description and objectives

The radiological consequences of a radioactive contamination of the environment, especially the contamination of food, depend strongly on the stage of crop development at time of a deposition onto the various crops used for food production. The model parameter data base of the food chain modules in RODOS includes data which describe the long term average of the seasonal foliar development of crops, expressed by the leaf area index. But there are considerable year-to-year variations of the actual stage of development, as a consequence of varying weather conditions. This causes considerable uncertainty in the food contamination estimated by the food chain modules within RODOS.

One aim of the research activities in the “RODOS migration” project was to reduce this uncertainty by developing a methodology which makes use of available information at the time of an accident in order to update the model data base of plant development data. Observations of the actual plant development (phenological data), available via internet, as well as meteorological data in combination with models for plant development are used to estimate the current stage of crop development at time of deposition and – as far as justified – at later times, and to update the model parameter data base accordingly.

Actual observations of phenological phases are normally available for very few types of plants only, many of them being wild plants which are of no concern for the food chain calculations. Growth models for plants are also available for a few crops only. Therefore, the possibility had to be included in the developed methodology to deduce information on the development of all those crops considered in the model from the actual stage of development of one or a few plants.

3.6.2 Research performed and progress achieved

According to the needs of the project it was necessary to develop a data base giving correlations between yearly deviations of different phenological phases from their long term mean values. For this purpose, a comprehensive set of phenological data from Germany has been acquired from the German Weather Service (DWD), and has been processed in order to obtain such correlations between different phases. Since the data from DWD were raw, unchecked data, it was necessary to check the data for plausibility, and to sort out data which did not seem reliable. Thus, about 3% of the original data set had to be rejected from further statistical evaluation.

Correlation between the deviations of two phenological phases from their mean date can be high, if their mean dates are close together, but there is nearly no correlation if they occur at quite different times of the

the year. As an example, if emergence of spring wheat occurs a week later than on the average, then there is high probability that emergence of spring barley is also shifted by a few days towards a later time. But it can not be expected that spring wheat's harvest is later than on the average since this depends on the weather situation during the whole summer. But there are also many cases where there is no correlation between shifts of phenological phases which occur nearly at the same time on the average. This happens if the phases depend on different weather items, e.g. one more on temperature, the other more on precipitation.

The modelling of the phenological stages in crop development based on meteorological data is mainly based on air temperature measurements. A literature review revealed, that temperature is the decisive parameter determining the development stage of a crop. It is anticipated, that the on-line meteorological data are stored in the RODOS data base and the model reads in the data from the sowing date to the time of the accident to determine the actual phenological stage of the crop.

Six different sub-models have been developed which can be used for a certain category of crops. This comprises winter wheat, spring wheat, maize, potatoes, rice and grass. However, the data base can be adapted in a way that other crops can be simulated. Example data sets for 6 different crops are provided with the delivery of the module and are subject to national customisation efforts as the starting time and duration of one phenological phase differs from crop variety and climatic zone.

The algorithm for updating the model data base of plant development data has been developed as a sub-module of the EDMOPAR (**E**dit**M**od**P**arameters) module in RODOS. Input to this sub-module is one or more dates of certain phenological phases (e.g. emergence of leaves, begin of flowering or begin of harvest of a certain plant species). As described above, these data are derived either by actual observations or by applying a growth model to measured meteorological data from the past months. The sub-module then compares the actual data with the long-term average of these phenological dates, and using a correlation matrix it determines the probable time shift of plant development (as compared to average conditions which are reflected by the default parameters) for all plants considered in the food chain model. The adjusted plant development data are written into the model parameter files which are used by FDMT and FDMA for estimating the transfer of radionuclides in food chains.

Figure 4.6.1 shows schematically the flow of data in the developed module:

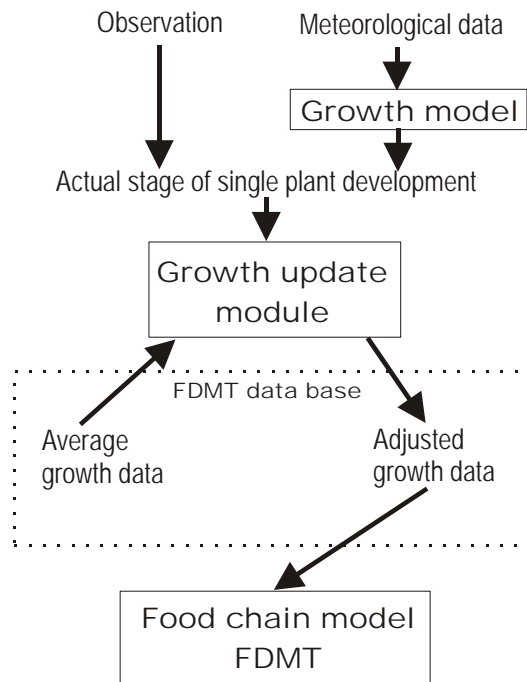


Figure 4.6.1: Data flow in the new RODOS module for updating the crop model parameter data base

A classification of Germany into different radioecological regions has been performed as a by-product of the evaluation of the German phenological data in order to allow a more differentiated adaptation of the model data base. This classification was done on the basis of the long term average of growth and harvest times of a variety of agricultural crops which were available on the basis of 86 so-called natural area groups (NAG). For each of the 64 considered phenological phases the NAGs have been ranked according to their mean date, i.e. the NAG with earliest occurrence has rank 1, the latest has highest rank. Subsequently, for each NAG a mean rank over all 64 phenological phases has been determined, and the NAGs have been sorted according to this mean rank. The last step was to subdivide this sorted list of NAGs into 4 groups, thus defining 4 regions according to the mean dates of crop development. The result is shown in Figure 2. Region 1 is mainly the lower and upper Rhine valley which shows the earliest begin of plant growth in spring. The latest occurrence of phenological phases in springtime is in region 4 which comprises the rim of the Alps as well as several low mountain ranges in the middle part of Germany, and an area at the coast of the North Sea (German Bay). Typically, the start of growth in springtime is shifted by about 5 days from one region to the next.

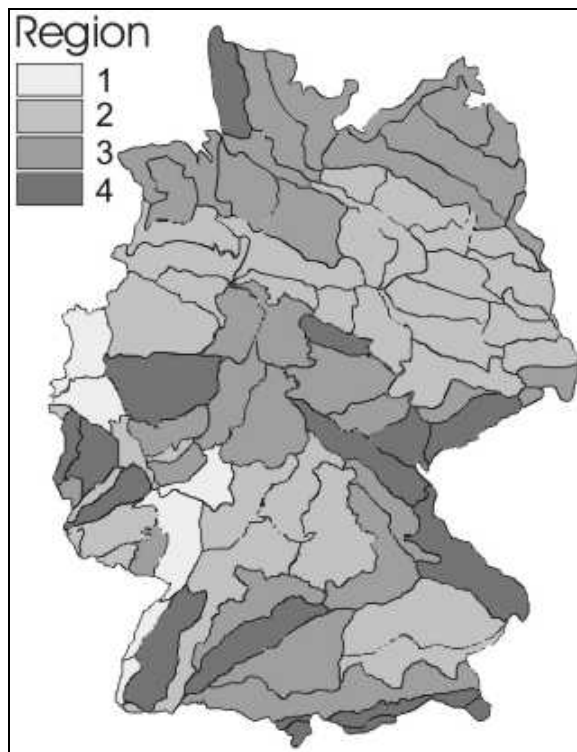


Figure 4.6.2: Sub-division of Germany into 4 “radioecological regions” according to the mean occurrence of phenological phases of various agricultural crops

3.7 Improved modelling for forest contamination (WP8)

3.7.1 Problem description and objectives

The forest food chain and dose model (FDMF40, described in the document RODOS(WG3)-TN(99)-53) was developed by STUK and IPSN, France, under the umbrella of the RODOS project of the 4th Framework Programme. Concurrently with the development of the first version of the forest model the knowledge base of forest remediation was improved, and the chances for extending the model for calculating the radiological effect of various countermeasures related with multiple uses of forests became important. The aim of the current work-package was to improve FDMF for more practical applicability and to extend the model with an assessment of countermeasure implications.

3.7.2 Research performed and progress achieved

The new forest model FDMF allows simulating the fate of radionuclides in the forest ecosystem. It gives the contamination of forest products as a function of time and also shows their spatial distribution on top of geographical maps. Also the radiation doses for different population groups resulting from their use of forests and forest products can be assessed. The modelled dose pathways are ingestion of wild berries, mushrooms and game meat, and external exposure received during the time spent in forests.

The forest model (Fig. 4.7.1) calculates dry and wet deposition of radionuclides to different forest compartments. A dynamic compartment module derives time-dependent distributions of radionuclides in the forest ecosystem. Radiation sources in ground layer and in overstorey give rise to kerma rates. At the reference height, one meter above the ground, the kerma rates are calculated from the time-dependent distributions of radionuclides in the crown, trunk and ground layers. Effective external doses received during stay in forests are estimated to the following population groups: berry and mushroom pickers, hunters, forest workers, vegetarians, and adults and five year old children representing the whole population. For the same groups dietary intakes and ingestion doses are calculated.

The model description RODOS(RA3)-TN(04)-01 and the functional specification document RODOS(RA3)-TN(01)07 describe the current FDMF in detail.

Some changes have been made in the description of the time-behaviour of radionuclides in forests. The compartment structure was changed to accommodate the needs of the newly developed countermeasure

module: the former *trunk* layer was split into *bark* and *wood compartments*, which both receive radionuclides from the new *soil*

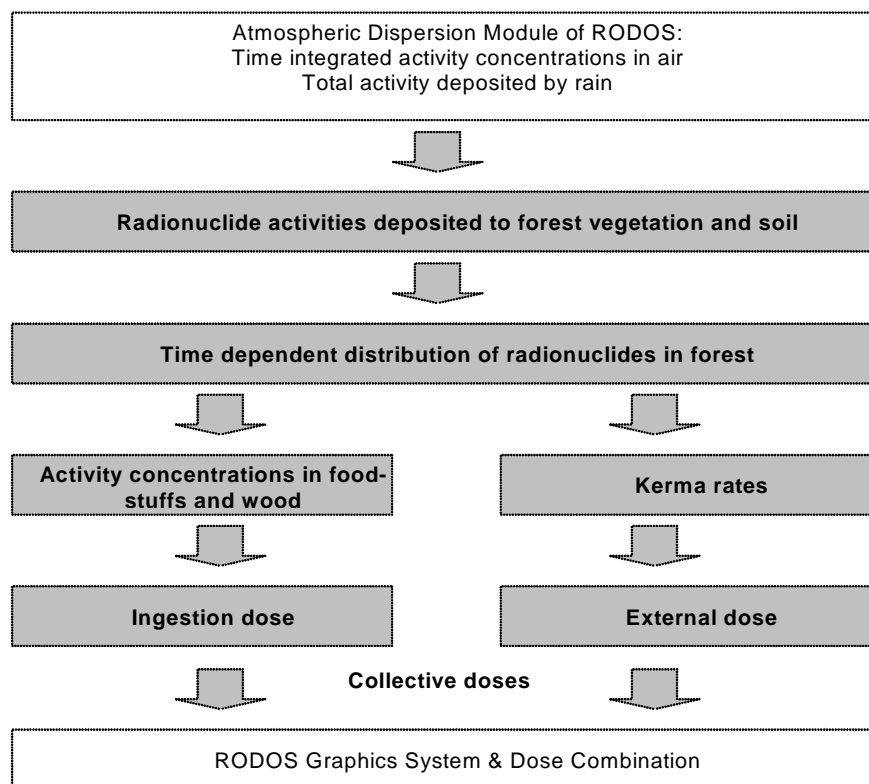


Figure 4.7.1: Flow of calculations and interfaces of the Food chain and Dose Model for Forests, FDMF, in the RODOS system.

available compartment; the *bark* compartment also receives deposited activity directly. Other soil compartments are *topsoil*, which receives radionuclides both directly by atmospheric deposition and as a result of weathering from vegetation, and *fixed soil* containing radionuclides that are not in bio-available chemical form. The sinks of the modelled system are surface runoff, and radioactive decay (Figure 4.7.2).

Model database

The model database can include several forest types, for each radioecological region, which identify the respective parameter set for model calculations. The user can specify one forest type for a calculation run. Independent of the forest type, the user can choose one type among categories of mushrooms, defined on the basis of uptake of radiocaesium from soil. In the parameter database also berries and game animals are categorised by species, or, if relevant, by the uptake of

of radiocaesium from soil to these food products.

The vertical distribution of radiocaesium in soil on different forest sites was reassessed to derive the parameter value for the time-dependent depth distribution which is used in the kerma rate calculation. The time spent in forests, a parameter needed in the external dose calculation, was estimated for the whole adult population and for the subgroups based on a new survey on outdoor activities. Different population groups were found to stay in forests longer than suggested in the previous version of the database.

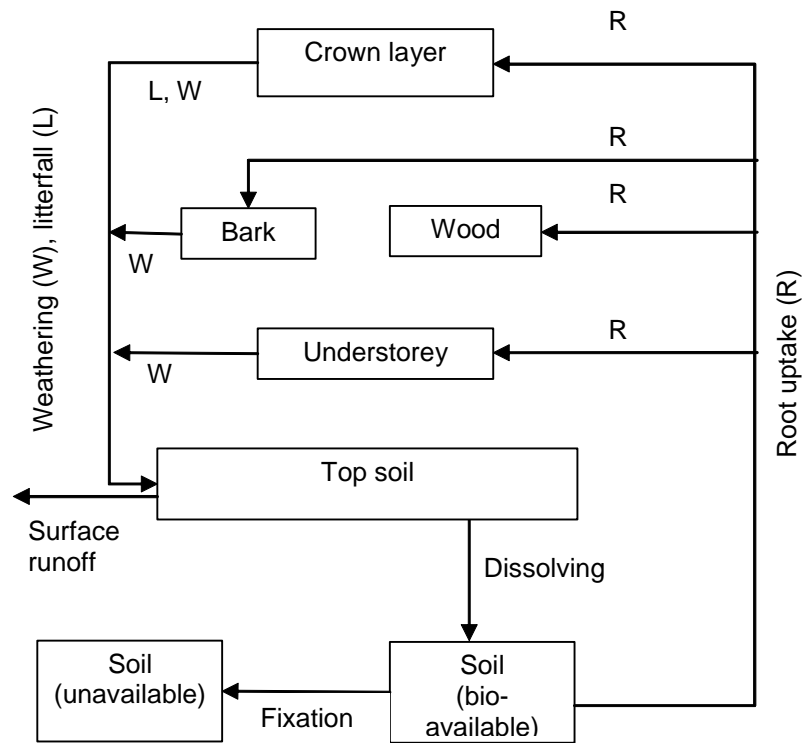


Figure 4.7.2: Compartments and transfer processes in the FDMF.

Late countermeasure model for forests (LCMforest)

The main objective of the countermeasure module LCMforest is to provide the radiation protection community with a tool that allows the assessment, evaluation and planning of countermeasure strategies. The user can choose between different countermeasure options, specify the intervention area and the timing, and receives an evaluation of the performance of the strategy in terms of averted dose and costs.

In the early phase of a large-scale fallout situation both, access to forests and use of wild food products, may need temporal restrictions. Considering the contamination dynamics of trees and giving an intervention value for activity concentration in wood, the timing of

felling operations can be modified and thereby harvesting of otherwise unacceptably contaminated timber can be avoided. The availability of acceptable timber can be improved with practicable remedial measures which are activated at different times after the contaminating deposition. For access restrictions and for actions related with wild foods, user-defined intervention criteria will set the timing.

The countermeasure assessment model LCMforest provides the user with a tool for assessing either the dose saving potential of different countermeasures or the availability of acceptable timber. Only such countermeasures have been modelled that are not in conflict with the principles of sustainable forestry. Simple restrictive measures, as banning or dietary advice, have been cost-effective and feasible in many post-Chernobyl circumstances. Twelve countermeasure options are available in LCMforest:

- access restriction
- ban mushrooms
- ban berries
- ban game meat
- intensify processing of mushrooms
- intensify processing of berries
- intensify processing of game meat
- intensify processing or ban mushrooms
- intensify processing or ban berries
- intensify processing or ban game meat
- apply soil improvement measures, and
- time felling.

Banning after assessment of the radiological effect of intensified processing, if the need for intervention still remains, gives a meaningful option for seriously contaminated areas. The model shows the area where banning is needed anyway, and such areas can be excluded from application of processing of certain type of wild food.

Each countermeasure available in LCMforest has an application area and time, derived by using intervention levels. Banning, for example, is assessed in those areas and for that time period in which intervention levels are exceeded, as demonstrated by the maps in Figure 4.7.3.

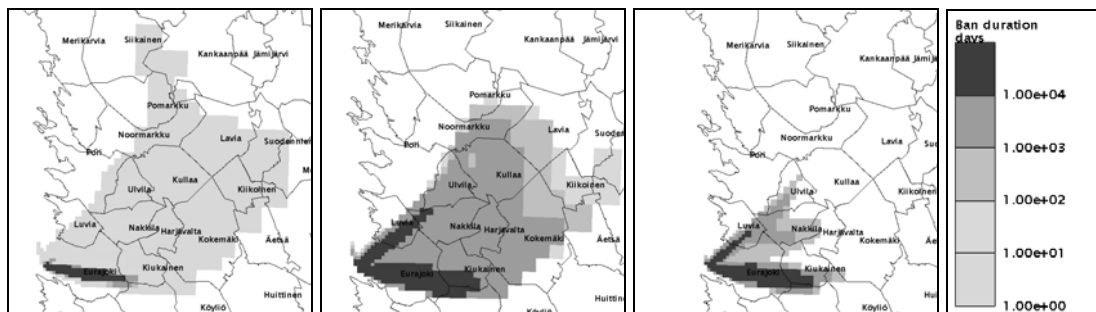


Figure 4.7.3: Ban duration in days for berries (left), game meat (middle), and mushrooms (right) after a hypothetical radioactive contamination by isotopes of caesium, iodine and strontium. Action levels for activity concentration in wild foods, used as input to mark the intervention area and duration were 2000 Bq kg^{-1} for ^{131}I and for ^{137}Cs plus other nuclides with gamma emission, with $T_{1/2} > 10 \text{ d}$, 1250 Bq kg^{-1} (from EU Council regulation 3954/87).

Description of the model (RODOS(RA3)-TN(04)01) and its functional specification document RODOS(RA3)-TN(01)06 are available. Model outputs of both FDMF and LCMforest are maps, tables and time plots.

Whenever possible, costs are attributed to countermeasures. Costs of banning are assessed equal to costs for wild foods that would be consumed normally. Costs for delayed or early felling of trees are given as net present values of delivery price of harvested timber per unit area of forest. For management of forest soils costs are mainly for work, use of machines and fertilisers. Costs for intensive processing of wild foods take into account additional work and energy. The information on costs in multiple use forestry was obtained from Finnish Forest statistics made available in 2001.

Testing of the forest models

Preliminary tests were made and the validity of the results checked for FDMF and LCMforest. Results of an international validation exercise carried out in IAEA's BIOMASS programme have been provided to the authors and were compared with the results of FDMF. The validation of FDMF will continue beyond the project period, and also additional data sets that are acceptable for validation are searched.

Adaptation of FDMF and LCMforest for areas not currently covered

To provide European-wide coverage the models FDMF and LCMforest can be adapted to new radioecological regions by extending the parameter database, in the same manner as in other food dose models of RODOS. The user has to adapt the database, *i.e.* include parameters for a new area before using the model for this area.

Currently there are two radioecological regions defined: Central Europe and Finland, often representative for forested areas in the same latitudes elsewhere in Northern Europe. There are three forest types in each

each region defined in the parameter database. Dominating tree species and their age or development stage characterise a forest type. Several species of berries and game animals provide options for these food types, and mushrooms are categorised into groups with similar uptake of radioactive caesium from soil. For extension of the model database to a new region the user can choose an appropriate number of categories or species of wild food products. For each new region, at least one forest type and a type of each wild food must be defined. The parameter values for Central Europe can also be adjusted for a site included in this region.

The processes of surface runoff and soil fixation, which are not often significant for northern forests in areas of flat topography or sub-arctic climate, are included in the model for potential need elsewhere. Forest biomass can vary substantially with climate and fertility of soils. Adaptation to local conditions is important especially for the assessments of the radioactivity of timber. Local growth conditions and differences in uptake of radionuclides by plants are also reflected in contamination of wild foods. Therefore the actual circumstances on the site and the local use of forests need to be considered in adaptation of the database to a new region.

3.8 Shielding grid for the radioecological module (WP9)

3.8.1 Problem description and objectives

The RODOS Food Chain and Dose Module for Terrestrial pathways (FDMT) considers the influence of different environments (open air, buildings) on the external radiation exposure as well on inhalation doses in a relatively crude way. It uses location factors for low, medium, and high shielding house types; for each location for which doses are calculated the prevailing house type is derived from the population density

For some areas in Europe, especially in the vicinity of nuclear power plants, more specific information on the shielding properties of the buildings is available from respective studies. Therefore, the FDMT module has been enhanced in order to make use of such information as far as it is available.

3.8.2 Research performed and progress achieved

Available information on location specific shielding properties of houses, expressed by location factors (which describe the dose modification by shielding) can be stored in a so-called shielding grid, i.e. location factors for different exposure pathways can be part of the RODOS geographical data base.

The shielding grid enables to use specific information on shielding properties of houses and on deposition properties of the outdoor environment if it is available for the area considered. The highest possible spatial resolution of the shielding grid is the RODOS calculation grid.

Representative location factors (averaged over time and over the local population) for all 5 radiation exposure pathways

- groundshine short term
- groundshine long term
- cloudshine
- inhalation short term
- inhalation long term

can be stored, as far as available, in the RODOS geographical data base and are retrieved by FDMT for all locations of the calculation grid. In areas where no specific information on location factors is available, the data base returns values indicating lack of data. In this case, FDMT applies the same method as in the previous versions, i.e. it uses the region dependent location factors for low, medium and high shielding buildings.

Applying time averaged location factors instead of individual location factors for staying indoors and outdoors has the advantage that any model approach can be used to generate these factors. Especially for staying outdoors the location specific properties (which can yield an outdoor location factor different from unity) can better be taken into consideration. This is of importance if a grid cell consists of a mixture of different environments, e.g. street canyons and parks in a city.

In addition to the location factors, the occupancy factor (fraction of time spent indoors) can be given for each location (grid point) in the geographical data base. It is used only if there are no data on location factors for an area. In areas where the data base returns an occupancy factor indicating lack of data, the region specific occupancy factor as used in the previous versions is applied to calculate the average location factor.

3.9 Validation of the RODOS system (WP10)

3.9.1 Problem description and objectives

The main objective of this work package is to test and validate the complete model chain of the RODOS system as far as possible on real scenarios. This should include atmospheric dispersion, deposition, foodchain modelling up to dose modelling and finally the application of countermeasures. Not only a single model will contribute but a chain of models has to be used to complete a given scenario. In addition, the preparation of the data bases will provide insights about the minimum information required and whether the default data set can be applied under special conditions. As result, information on the accuracy of the prediction for a given situation and potential error bounds are anticipated.

Selected Scenarios

In a first step, several potential scenarios have been analysed and two of them, distributed within the BIOMASS (BIOSphere Modelling and ASSessment) exercise have been used.

The first scenario, an acute release of I-131 from the 60 m stack of a nuclear chemical separations plant at the Hanford Site, started at the beginning of 2 September 1963. The main release lasted for several days. The scenario allows for testing atmospheric dispersion via foodchain to dose modelling. Countermeasures, however, were not initiated. Main emphasis is directed to the performance of the initial calculations of the atmospheric dispersion module ALSMC

The second scenario is based on measurements of Cs-137 contamination following the Chernobyl accident. The test area is located in the western part of Russia, in the Novozybkov district of the Bryansk Region (coordinates 52° 30'-40' N, 31° 50'-32° E). Starting point are measured ground contamination, total deposition and vertical profiles of Cs-137 concentration in soil. In addition, information on protective actions taken over a period of several years is available. Endpoints are the contamination in feed- and foodstuffs over a period of 10 years with and without agricultural countermeasures. As also countermeasure practices are provided, the foodchain and dose modules together with the longer-term countermeasure module have been mainly applied for this scenario. In addition it was possible to test the customisation to national conditions performed in FP4 in which data for the foodchain and longer-term countermeasure modules for Russia and Ukraine were collected.

3.9.2 Research performed and results achieved

Hanford Site

Information on the source term was collected from measurements initiated as soon as the release was detected. Additional environmental samplings were also performed together with the standard surveillance programme. Measurements of wind velocity and temperature are made routinely at the site meteorology tower. Similar data from additional weather stations within a few hundred kilometres are also available.

The following endpoints could be tested:

- daily air concentrations of I-131
- average time-integrated air concentrations
- average deposition
- total inventory over the region
- time-integrated concentrations in milk
- average time-integrated concentrations in specified vegetation
- thyroid burden of two specified children

One of the most interesting tests was to use a selected number of meteorological stations for the transport and dispersion calculations. Three cases, one with the information from the Hanford tower at 10m height (HAN01), one with information of the Hanford tower at 60 m height (HAN02) and one with all wind stations (HANwind) have been investigated in detail. The scenario with one station and wind at ground level performed worst, with one station and wind at elevated level performed second and that with all stations performed best. Isolines of the time integrated air concentration for the three cases are shown in Figure 4.9.1.

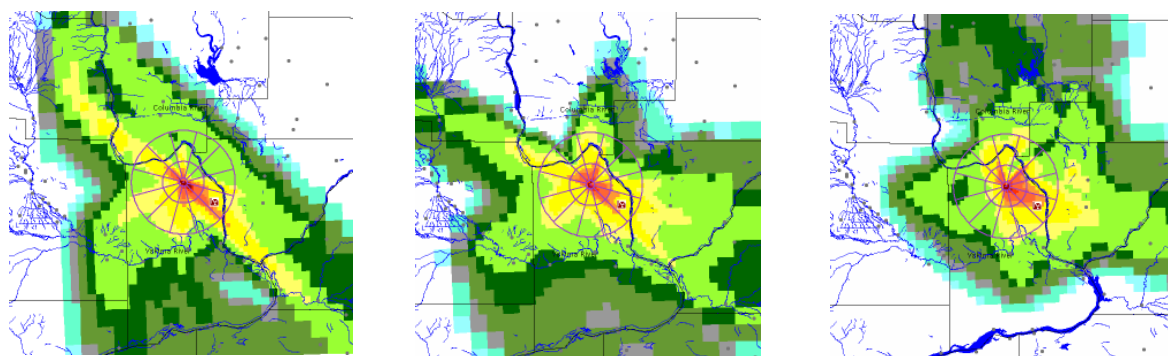


Figure 4.9.1: Time integrated air concentration of I-131 for the three cases. Left HAN01, middle HAN02, right HANwind (same legend)

For most locations the concentration of the complete wind field set differed from the measurements by about a factor of 2 to 3. Only in two cases, the discrepancy was around 10, a result which requires further investigation. The single stations showed either good (factor 2-4) or bad (up to a factor 10 and more) agreement. The reason for the rather good performance of the case with all wind field stations can be seen in the changing weather conditions and the influence of the topography with clearly changing wind directions and velocities over the whole area. These changes are not necessarily reflected at the central station; in particular the variation in the wind direction could not be reproduced by the meteorological pre-processor when based on one single station.

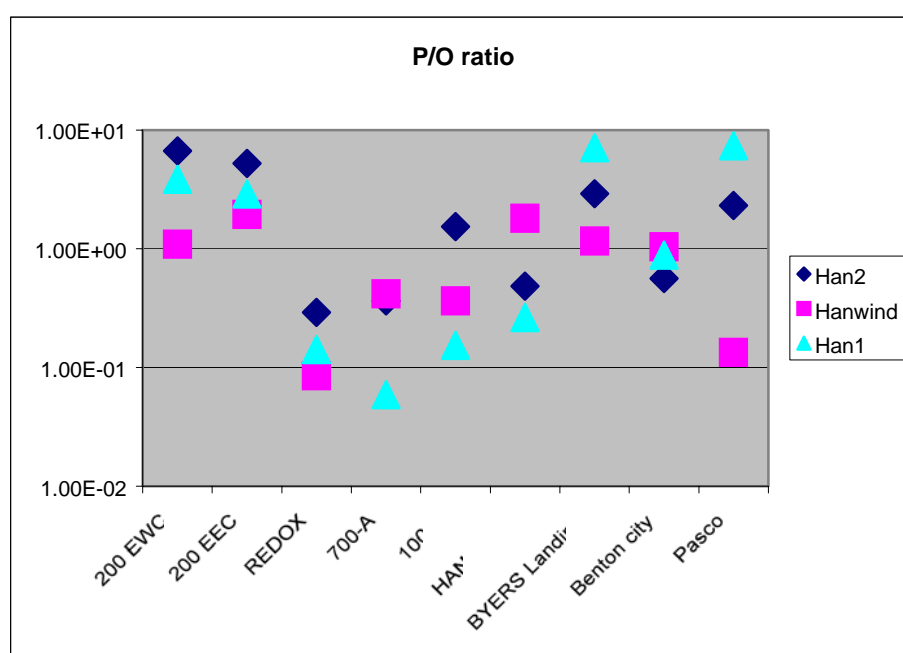


Figure 4.9.2: Ratio of predictions (P) and measured (O) air concentrations for three wind field realisations

Concentrations in vegetations were measured at several farms. Normalising the air concentrations of the predictions to the measured values, the deposition routines performed well, however, at the lower end of the measured values. There were two locations reported with a deposition velocity of about 0.05 m/s whereas the others and also those predicted by RODOS are around 0.01 – 0.02 m/s; such values have been reported in the past assuming a release of iodine in elementary form. It could not be clarified whether the measurements are correct and whether these very high deposition velocities are a result of the site characteristics. Nevertheless, this fact may give some indication of the uncertainties possible in such situations.

Iodine concentrations in pasture grass and milk were available mainly for the eastern and southern part of the Hanford site. As the iodine concentrations in both air and grass are only available for three locations, the evaluation concentrated thereon. Simulated concentrations in milk are lower by about a factor of 2-3 for Farm A and Pasco compared to the measurements. However, taking into account the lower iodine concentration in grass estimated by RODOS, the results for milk compare quite well. This is different for Ringold. With a comparable initial iodine concentration in milk, the model overestimates the measured values by about a factor of 5 in the beginning of September whereas at the end of September the difference decreased to about a factor of 2.

Thyroid doses for two children could not be compared in detail, as RODOS does not provide the information on the iodine burden of the thyroid. However, comparing the dose value calculated with the Becquerel measured show a reasonable agreement.

Bryansk Region

Starting point for this scenario was the initial soil contamination provided for several villages, however, the contamination in food products had to be compared against an average value with and without countermeasures. Therefore, the average contamination of 795 kBq/m² was selected for all foodchain calculations. Contaminations in feed and food products were provided over 10 years for:

- Hay
- Leafy vegetables
- Wheat
- Potatoes
- Pork
- Milk
- Beef
- Mushrooms (not considered in the calculations)

Calculations were performed for the default database of FDMT and for a customised one. Data for the customisation procedure were taken from the radioecological region of northern Ukraine. This area was selected as it shows similar soil characteristics as the region around Bryansk

Results for the different feed- and foodstuffs show all similar patterns. In the first year, RODOS overestimated the concentration by at least a factor of 10, in some cases by a factor of 100. In the following years, when only root uptake is relevant, the results with the adapted data base show a good agreement within a factor of two to three with the measurements. Exemplarily, results are shown and discussed for hay.

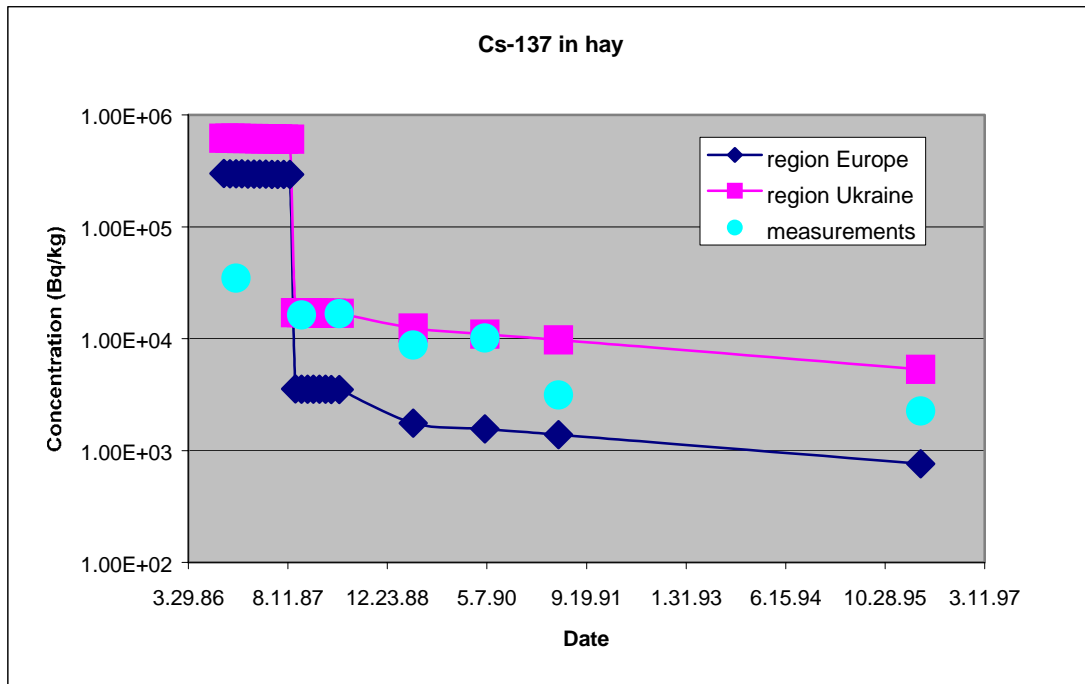


Figure 4.9.3: Cs-137 contamination in hay

Contamination in hay results from two processes. In the first year, direct deposition dominates, whereas in the second year, the root uptake is the single source of contamination. This is reflected in the decrease in the contamination after the winter feeding period in the beginning of the year 1987. The reduction in the contamination is expected to be about one order of magnitude and such a value can be found in many text books and is reproduced by FDMT. The measurements, however, show only a reduction by a factor of two. As deposition to soil and grass should be similar from theory, the initial measured values seem to be much too low as soil contamination reported is much higher as the contamination of plants. One possibility to explain the rather low measured concentration in the first year might be the application of countermeasures to areas with high contamination. Both, the experience from other deposition events and from the theory of atmospheric transport and deposition suggest this effect to explain the low measurements. As countermeasures are not simulated in RODOS when calculating concentrations in feed- and foodstuffs, this effect cannot be seen in the model calculations and thus the discrepancy in the first year is rather high.

In the second year, the root uptake was clearly underestimated by the standard parameter set of FDMT, whereas the Ukrainian data reproduce the uptake quite well over the 10 years period. This adapted data set contains a 10 times higher root uptake than in the default set.

The reduction factors for countermeasures reported fit well with those implemented in RODOS. This is no surprise, as the data base of LCMT was partly derived from Chernobyl experience.

Conclusions

RODOS performed quite well in the two test scenarios. The results highlighted the importance of input data for atmospheric transport and dispersion calculations and also the need to customise the database of the foodchain and dose module. The scenarios also provided some advice on how to further develop the system. Some quantities, which can be easily measured, in particular, concentrations in feed- and foodstuffs with applied countermeasures, will be realised in one of the next RODOS versions as these quantities are vital for any further validation of the system with the application of countermeasures.

3.10 Pre-processor for non-standard dose rate measurements (WP11)

3.10.1 Problem description and objectives

In case of a nuclear emergency, measured data can only be used for improving the knowledge about the radiological situation if it is clearly defined what has been measured. Therefore, measurements of gamma dose rates (GDR) should be taken in a standardised environment since otherwise they can differ for more than an order of magnitude for different measurement places even under identical radiological conditions (same activity in air, same deposited activity on a standardised surface, e.g. lawn). This effect is due to variations in the vicinity of the measurement device, e.g. the existence of trees, sealed areas, buildings, etc. In practice, it is not possible to take all GDR measurements in a standardised environment which is often a big lawn (several ten meters around the probe) without any trees, buildings etc. Without consideration of the real measurement conditions such measurements cannot provide a realistic picture of the radiological situation, and they cannot be used for reasonable data assimilation.

3.10.2 Research performed and progress achieved

It was the objective of this work package to develop a pre-processor for the RODOS system which checks the quality of the GDR measurements on the basis of available information about the environment of the measuring site. For this purpose, data from literature as well as own calculations have been used to provide a module which can be used for a fast assessment of bias and uncertainty of GDR measurements. The applied methodology is mainly based on publications by Zähringer et al. (details see RODOS(RA3)-TN(03)02).

For checking the effect of a non-standard environment on the GDR, the environment of a measuring site is subdivided into 4 concentric rings (0 m – 3 m, 3 m – 7 m, 7 m – 20 m, 20 m – 100 m). Input to this module is

- the contribution of 9 surface types to the total area of each ring,
- the deposition type (dry, wet, mixed, or unknown), and
- the season of the year (this is used for a rough estimation of the contribution of trees).

A simple and robust approach is chosen for bias and uncertainty assessment for the problem of estimating the contamination of a reference surface from dose rate measurements, since this approach should be applicable within RODOS. It involves quantifying bias and uncertainty for each of the main parameters in the dose conversion calculation and then combining them to obtain an overall bias and uncertainty of the resulting reference surface contamination.

The approach is based on the assumption that errors from individual sources can be described separately by uncertainty distributions. Error sources in this context are all parameters which can either influence bias or uncertainty of the results for reference surface contamination. For each site-specific parameter i which is considered as an error source, a bias factor B_i is quantified as the ratio of the parameter to that corresponding to ideal site conditions. The factors B_i are assessed from the evaluation of relevant data combined with expert judgement. The overall bias B from all sources can then be calculated from the B_i from all sources according to the equations for conversion of dose rate into surface contamination. The overall bias B is the factor by which one would divide the surface contamination derived from a GDR measurement to obtain an unbiased estimate of the true contamination of the reference surface at the given site.

Additionally, 95% uncertainty intervals $[K_{1,i} - K_{2,i}]$ are quantified for each error source. The uncertainty interval is determined such that the probability is judged to be 95% that the true value of each bias factor B_i is within the chosen interval. The uncertainty intervals are assessed from data about uncertainty and variability of relevant radioecological parameters (e.g., stage of plant development) combined with subjective judgement of the authors. The total uncertainty interval of the resulting surface contamination is estimated roughly with the following approach: both the lower limits $K_{1,i}$ and the upper limits $K_{2,i}$ are combined in exactly the same way as the bias factors B_i to result in the total lower and upper limit K_1 and K_2 . Obviously, this approach leads to an upper estimate of the total uncertainty interval, but the big advantage over other error propagation techniques is the easy realisation.

The resulting bias factor and the uncertainty interval can be applied before the GDR data is used as input into the system and – in particular – transferred to data assimilation modules.

The pre-processor has been developed as a subroutine which can be called from any module of RODOS. For testing and demonstration purposes a standalone program has been written which

- reads in data about measuring sites from a file,
- calls the pre-processor subroutine from where it gets back the according correction factors and uncertainty ranges, and
- displays the result on the screen.

The approach for assessing bias and uncertainty of ground contamination as derived from GDR measurements is applied as an example to one of the measuring sites of the German environmental radioactivity monitoring network IMIS. A sketch of the measuring site is shown in Figure 4.10.1.

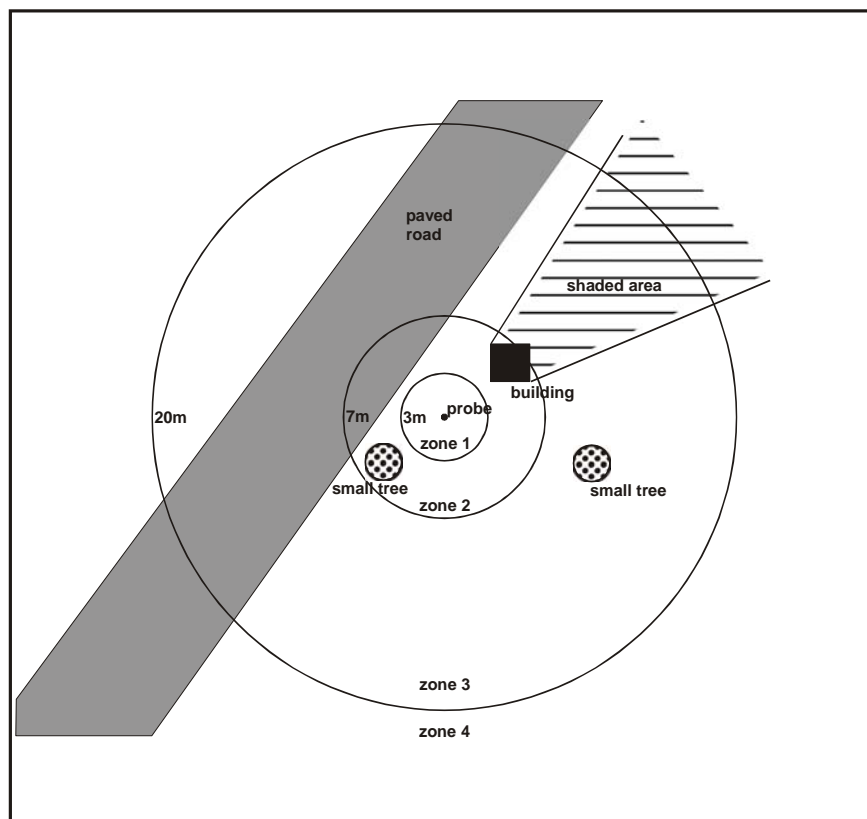


Figure 4.10.1: Sketch of the vicinity of a dose rate probe of the German monitoring network IMIS. The sketch is centred around the probe, the area is divided into 4 concentric ring zones extending from 0-3 m, 3-7 m, 7-20 m and 20-100 m. Structures and surfaces which differ from those of an ideal measuring site are indicated in the sketch.

Input to the module for checking bias and uncertainty of the GDR is essentially the information given in Table 4.10.1. These data describe the environment shown in Figure 4.10.1 .

surface type	shading	ring 1 (0-3 m)	ring 2 (3-7 m)	ring 3 (7-20 m)	ring 4 (20-100 m)
1: lawn	visible	100	67	63	84
	shaded	0	0	10	10
2: deciduous trees	visible	0	7	1	0
	shaded	0	0	0	0
3: paved	visible	0	20	25	6
	shaded	0	0	0	0
4: building (base area)	visible	0	6	1	0
	shaded	0	0	0	0

Table 4.10.1: Relative contribution of each area source (identified by surface types) to the total area of each ring zone.

In this example in ring 1 (which consists of lawn only) the dose rate remains unchanged compared to an ideal measurement site. In ring 2 the tree leads to an increased dose rate (relative to an ideal site) due to the increased deposition to the leaves and also the increased conversion factor for the tree. This increase is much higher than the decrease of the dose rate due to the lower deposition on the road and the reduced conversion factor caused by the shielding of the house. In ring 3 the reducing effect of the road and the building are larger than the increasing effect of the tree, so that the total dose rate is smaller than that for an ideal site. The situation is the same for ring 4. In total the increased dose rate for ring 2 is slightly overbalanced by the reduced dose rates for ring 3 and 4, and a slightly reduced total dose rate results for this site: the bias factor determined by the pre-processor is 0.89 which means that the dose rate is 11% lower than on an ideal site. The estimated uncertainty bounds of the bias factor are 0.73 to 1.31.

3.11 Unplanned work performed in the interest of the users community

3.11.1 Problem description and objectives

RoDBMS – the new RODOS data base management system

A precondition for operating the RODOS system on Hewlett-Packard workstations and servers is the availability of the HP ALLBASE data base software. Following the announcement of HP to no longer maintain ALLBASE after the end of 2004, FZK started in spring 2002 to design and code a RODOS specific data base system (RoDBMS). It will replace ALLBASE and – as it is owned by the RODOS project and developed in the RODOS software package, it can be distributed to all users without any licensing problems or additional costs.

RtGraph- the real-time graphics package of RODOS

The graphical software package RtGraph offers a variety of tools and functions for accessing, evaluating, converting, exporting, and visualising the RODOS real-time data and prognostic data. It was considered to operate in the X-Window environment.

The existing RtGraph had to be redesigned and extended by new software tools using Web technologies (Java, XML, HTML, scripting languages, etc) to provide the dynamic generation of Web-based documents for RODOS real-time data and prognostic data.

Restart capability of RODOS

One important aspect of the work programme is to assure the operability of the system under all conditions. With the implementation of the long lasting releases (WP3), the failure-free operation of RODOS in particular in the automatic mode becomes a critical element of the general operability. It has to be assured, that any interruption of this mode has limited consequences and can be cured easily.

Revised source term input facilities

During the 1st emergency exercise of the DSSNET, the users experienced a number of difficulties with the source term input capabilities of the RODOS system, which were to a large extent due to missing training, but also from missing functionality in the system. One of the key problems was the impossibility to change the type of source term input during the course of the accident progression. In a real accident situation, the source term information is likely to come in different parameterisations in the different stages of the accident and so this is a problem. Therefore, it was decided to generate a more flexible source term software, which can process different kinds of source term input in order to supply the atmospheric dispersion modules with the required standardised source term information.

Plant and site data of European nuclear power plants

During the 1st DSSNET meeting it was proposed to incorporate in the RODOS system the list of all European NPPs and other nuclear facilities together with the data needed by the system for performing site specific calculations. FZK sent out a questionnaire to all DSSNET members asking for the necessary data. In addition, the nuclide specific inventory for different burn-up states, at least for equilibrium, and typical plant specific source terms – if available - should be provided.

Based on the responses, FZK has compiled the received information in the report “Collection of site specific data of European nuclear power plants as input to RODOS” (DSSNET(WP3)-TN(01)-02). Under this contract, the available site and plant data have been incorporated into the data base of RODOS PV5.0.

European geographical data base

There has been an expressed interest from the RODOS users’ community over the past years to have a consistent geographical data base in RODOS covering the whole of Europe. After many contacts with commercial companies, FZK has finally succeeded to obtain access to such a data base for an acceptable price, however with the condition, that it has to be converted into the RODOS specific RIF format before its distribution to the RODOS community. FZK purchased the complete data set with a resolution down to 1:400'000 from the DDS company in Karlsruhe, Germany, before the end of 2001.

3.11.2 Research performed and progress achieved

RoDBMS – the new RODOS data base management system

In order to replace the HP based ALLBASE data base software, the PostgreSQL DBMS was chosen to become the software framework of RoDBMS. PostgreSQL is an Open Source software, distributed under the BSD license, which is as flexible as the more common GNU General Public License. Currently, PostgreSQL is utilised in countless applications all over the world, it is a sophisticated product and it offers an exemplary application support.

In a first step the new DBMS was checked for supporting the previously used ALLBASE features, like transaction management, table locking strategies, multi data base connectivity, error handling, storing binary data sets, and retrieving data base catalogue information. PostgreSQL was found appropriate.

In a second step the existing RODOS software had to be adapted to the new DBMS. Related software modules are the data base generator utility, the data manager, the various data editors, and the real-time

software (data converter, data supplier, data dump). Adaptation is now complete.

The third step comprised benchmark tests both in the interactive and automatic mode of RODOS. Differences in run-time between ALLBASE and PostgreSQL are minimal and negligible. Further extensive tests on the wide functionality of RODOS will be made. The RoDBMS is considered to run operationally by mid 2004.

RtGraph- the real-time graphics package of RODOS

The RtGraph - software for analysing and visualising data stored in the real-time database of RODOS was designed and developed for graphically presenting

- radiological and meteorological data from local and country-wide monitoring networks connected to RODOS;
- global numerical weather prognosis stored in WMO GRIB format files;
- local numerical weather prognosis stored in LSMC ASCII text format;
- results of comparisons of monitoring data and model results of RODOS.

The RtGraph software uses the Web technologies (Java, JavaScript, HTML/XML, SOAP) to provide the dynamic generation of Web-based documents for RODOS real-time data. The software concept follows the “document based approach” for document management and production using XML/HTML.

The generation of documents increases confidence of the users (national emergency management teams) in the system as they can use the generated documents within the decision-making process (they can save the documents within their location and easily view the document on any computer with a standard HTML browser). This aspect is also important for the RODOS inspection certification for its application as decision support system in national emergency centres.

The visualisation system is robust, as it uses standard HTML browsers which display already generated documents. The generated HTML/XML documents allow an easy share of the latest results between users via the network. The generation of documents in standard formats allows an easy transfer (export) of the system results to Geographical Information Systems (GIS) for further processing. The generated documents can also be used for visualisation in any MS-Office document.

RtGraph allows the use of a set of customisable parameters for generating documents. All customisable parameters for the document are stored in special templates. RtGraph executes during operation the

template and saves the results in its own disk cache; it analyses and generates new documents from new data very fast on the base of the cached templates. This approach allows the generation of the documents in real-time. RtGraph constructs also dynamically hierarchies of generated documents on the basis of different attributes (date and time, type of measurement, covered geographical area, etc) and it stores the hierarchy in sets of linked HTML pages. Some of the RtGraph components have to be developed and improved in future on the basis of users experience with the current version of RtGraph (the main items for further development are multi-language support, generation of documents in interactive mode, interactive requests to the real-time database for generating time series).

The RtGraph software has been integrated in RODOS. Developed as set of independent components, RtGraph has been tested in emulation mode and later connected to depot and by-pass data of RODOS real-time database; the installation procedures for RtGraph have been developed and tested.

A documentation for adaptation of the software to local conditions by RODOS users is available; the documentation includes a tutorial with examples for customisation of RtGraph for analysing and visualising global numerical weather prognosis for Europe, local numerical weather prognosis for FZK as test site, and data from the German monitoring system IMIS.

Revised source term input facilities

The work started at FZK in the second half of 2001. The user driven changes of the source term input windows have been completed and integrated in RODOS PV6.0. The features of the new source term input capabilities are described under WP3 in Chap. 4.3.

Plant and site data of European nuclear power plants

Based on the responses, FZK has compiled the received information in the report “Collection of site specific data of European nuclear power plants as input to RODOS” (DSSNET(WP3)-TN(01)-02). Under this contract, the available site and plant data have been incorporated into the data base of RODOS PV5.0.

European geographical data base

The collected data can be subdivided into background data necessary for visualization and statistical data important to operate the simulation models of the system. Background data comprise the following features:

Geographical data (from AND)

- Waterbodies (i.e. rivers, lakes, ocean)
- Political borders (up to province borders)

- Cities (areal and point objects) corresponding to AND Level 1-3)
- Roads (highways included based on AND Level 1, 2)

Topographical data (from Globe, 1 x 1 km resolution)

Land use (from Global Land Cover Facility)

Soil type (from ESRI)

Collection of statistical data was difficult and only production data from the SAVE-IT project on level NUTS 3 were implemented. These data cover about half of the feed- and foodstuffs available in the RODOS system:

- milk (cow, sheep, goat)
- beef (bull), lamb, pork, chicken, eggs
- potatoes, leafy vegetables, root vegetables, fruits, maize bulbs

Population data were collected from various sources (ESRI, geographical publishing house). The data was processed and converted into the RODOS internal graphical format (RIF). The data set is made available on the RODOS Homepage and can be downloaded on request. Documentation of the data set and how to tailor the data for an installation in one particular country is available as RODOS report (RODOS(RA1)-TN(02)-03). Additional data for specific countries with finer resolution can be requested in addition, as they were not part of the overall data set due to size and memory constraints.

Restart capability of RODOS

Malfunctions or crashes of a computer system cannot be fully excluded, in particular in case of complex calculations in connection with on-line data from external resources. Therefore, a possibility was created in the RODOS system to restart the “automatic mode” in the time interval before the interruption occurred. To that purpose, the system makes use of all relevant data stored in the previous time interval. This option is extremely important in case of long lasting releases as it prevents that the RODOS calculations have to be repeated from the beginning of the release, as it was necessary in RODOS version PV4.0.

Preparation and test of RODOS version PV5.0 (WP12)

3.11.3 Problem description and objectives

The aim of this work package was to integrate all newly developed RODOS modules into the two versions PV5.0 and PV6.0, and to develop test procedures to assure a stable operational status of the system when being delivered to the users.

3.11.4 Research performed and progress achieved

Testing of RODOS

The extensions of RODOS and the new functionalities included in the versions PV5.0 and PV6.0 as described in the previous sections required modifications to nearly all modules implemented in RODOS and the interfaces between them. Additionally changes were made to the user interfaces, the geographical and production data base, the graphics software package and the operating system. The extended or even new functionalities of RODOS require the development of new and adequate test procedures which must reflect these features. That means that the test cases of version PV4.0 could still be used, but they cannot be applied for testing the new parts. The test procedures had to be extended to cover the wider range of applications of the system.

Irrespective of the fact that many tests of single modules are performed during the development phase already, systematic testing of the complete system under a wide range of scenarios has to be performed after the installation of a final draft version of RODOS PV5.0 or PV6.0, respectively. Thus, the testing of the system consists not only of the testing of single modules or packages, but especially the interactions between the models and the behaviour of the complete system as a whole under various more or less complex conditions have to be tested.

The testing of the complete RODOS system can be subdivided into two parts:

- The testing of the so-called *system software*, i.e. the user interface, the graphics package and the operating system, is rather straight-forward. The function of a certain button on the screen is well-defined and it is mostly easy to see whether pressing the button leads to the right behaviour of the system or not. The correct performance is independent of the program which is running.
- The testing of the so-called *external programs*, i.e. the models included in RODOS (e.g. for atmospheric dispersion, doses, countermeasures) is much more complicate as a formally correct run of the program says nothing about the correctness of the results.

For the following reasons the situation here is highly difficult:

- As the models are not only extended, but also some changes are made to the modelling itself, there are no "correct" result values available, i.e. using a test case of version PV4.0 will no longer lead to the identical results.
- The higher the flexibility in the user input, the greater is the spectrum of possible scenarios which have to be tested.
- It cannot be automatically assumed that the features of version PV4.0 still work correctly after the extensive restructuring of the programs.
- Each model can produce hundreds of single endpoints which have all to be checked.

Thus, for testing all features of the external programs, a lot of scenarios had to be performed for the interactive and the automatic mode separately, e.g. combinations of more or less long lasting releases with more or less long prognosis periods. Of course, it is unrealistic to assume that all possible combinations of meteorology, nuclides, source term modes, prognosis periods etc could be tested. So, a limited set of test scenarios covering a rather wide range of applications had to be developed which is adequate to detect errors in (nearly) all parts of the system even under extreme conditions and which finally raises the quality and reliability of the code.

The test procedures for the system and the application software have been updated to account for the new functionality of RODOS PV5.0 and PV6.0 as provided by the modules developed under this project. Extensive test have been performed to ensure that

- the user interface interacts correctly with the system and the application software,
- the new or revised software components still produce the same results under "standard conditions",
- the new functions of the system and application software works as expected,
- the data flow between the new or revised software components and the overall RODOS system works error free.

No test procedures exist yet for the data assimilation modules and the hydrological model chain.

RODOS version PV5.0

The following software components developed by the partners of the “RODOS migration” project have been integrated in RODOS version PV5.0:

- Web-based interface for users of Category C (FZK)
- New meteorological pre-processor (NCSR, FZK)
- Revised source term interface for long term releases (FZK)
- Revised ATSTEP for long term releases (FZK)
- New DepoM module for calculating plant specific deposition (GSF)

- Revised FDMT for long term releases (GSF)
- Revised LCMT for long term releases (NRPB)
- Data base for all NPPs in Europe, including plant specific inventories and source terms as far as available (FZK)
- European geographical data base (FZK)

In addition, the following software components developed under the “DAONEM” project have been integrated in RODOS version PV5.0:

- Atmospheric Dispersion Updating Module ADUM together with RIMPUFF
- Deposition Monitoring Module DeMM (GSF and University of Innsbruck)
- Food chain Monitoring Module FoMM (GSF and University of Innsbruck)

Furthermore, the hydrological model chain as provided by IMMS CC, Kiev, has been implemented within the RODOS environment of version PV5.0. It consists of the

- Run-off model RETRACE
- River model RIVTOX
- Lake model LAKECO
- 2-D model COASTOX
- 3-D model THREETOX

RODOS version PV6.0

In RODOS PV 6.0, the following software modules developed by the partners of the “RODOS migration” project were updated or newly integrated (bug fixes or model maintenance not listed)

- Web-based interface for users of Category B and C (FZK)

- Updated system software with restart functionalities (FZK)
- Export functions (FZK)
- Revised source term interface with dynamic input windows (FZK)
- Revised FDMT with extended interface to LCMT (GSF)
- Revised LCMT with user defined areas and doses to workers (NRPB)
- EDMOPAR for the update of the crop status (GSF, FZK)
- FDMF with countermeasures for the semi-natural environment (STUK)

In addition, the following software components developed under the “DAONEM” and the “EVATECH” projects have been integrated in RODOS version PV6.0:

- Atmospheric Dispersion Updating Module ADUM together with RIMPUFF (SCK-CEN, RISO, FZK)
- ESY software with modified RODOS-ESY (Manchester) and WebHipse as new web based evaluation software ESY (UniKarl)
- Revised Deposition Monitoring Module DeMM (GSF and University of Innsbruck)
- Revised Food Monitoring Module FoMM (GSF).

4 Assessment of results and conclusions

4.1 Functional analysis of the main deliverables of the project

The main deliverables of the project are the new releases RODOS version PV5.0 (May 2002) and PV6.0 (March 2004) of the RODOS system. The modelling capabilities and validity of RODOS PV5.0 have been significantly improved with the integration of a more flexible meteorological pre-processor and the extended applicability to radiological accidents with releases lasting up to 47 days. This has been further enhanced with new modules allowing for assimilating measurement data in near range atmospheric dispersion and food chain calculations (performed under DAONEM) and with the implementation of the whole hydrological model chain prepared under FP4, an additional activity not covered by the work programme of this contract.

In RODOS version PV6.0, progress has been manifested with an improved forest foodchain and dose modelling including counter-measures, and with the development of methods for updating the foodchain modules to take into account the actual status of the crop development. A shielding grid enables the customisation of dose calculations to the shielding characteristics of inhabited areas. Pre-processing tools allow for the correction of non-standard dose rate measurements. None of the existing decision support systems in Europe provides these new features, which will significantly improve the accuracy of the system's diagnostic and prognostic capabilities and the applicability of the system as a whole.

With the new Web-based user interface, the concept of the interaction between the RODOS system and its operators and users has been made available by accessing the commonly used platform independent Web-technology. Networked remote users with access rights can easily connect with centrally installed RODOS systems with a browser (e.g. Netscape, Internet Explorer) installed on a normal PC. As Category C users, they can receive RODOS results in standardised form as made available by the central installation. Category B users can define and undertake RODOS runs via easy understandable dynamic input windows. The results are then obtained as for C-users. Through this new interface, the interaction with the RODOS system has been considerably simplified with the consequence of the acceptance of the system by a much larger user community.

4.2 Value analysis

The progress made could only be achieved with the manpower and money invested. The development teams have a significant amount of experience with the software concept and structure of RODOS and they are familiar with the models and data bases incorporated. This leads to

leads to effective use of the manpower and money invested. The development of the new meteorological pre-processor and the extension of the release duration required significant restructuring, remodelling and re-coding of the existing software modules including the user interfaces. The new Web-interface made it necessary to go beyond the available Web-techniques and tools and to develop new software elements to realise the requested functions. New commercial software developments made it necessary to revise the initial concept, the main cause for the delayed preparation of the interface for Category B users. With the validation studies performed, an often requested demonstration of the system's performance and results compared to the measurements during and after "real accidents" is now available.

Under the circumstances described, the progress achieved is considered to be cost-effective; with the resources invested, the results would have never been obtained by a commercial software company.

4.3 Protection of the results

The RODOS system, which integrates all the software components developed in the past and, in particular, under this contract is distributed to the users in executable form only. The source codes are only maintained by the developers and FZK, who is responsible for the control of the whole system. In addition, all institutions operating the RODOS system have signed a software agreement which protects the interests of the RODOS Consortium.

4.4 Targeted audience/recipients for dissemination

The versions PV5.0 and PV6.0 of the RODOS system and all complementary patches have been and will be distributed by FZK free of charge to all institutions where previous versions have been installed and who have an expressed interest to update the RODOS software. Currently, about 17 institutions have installed the system for (test-) operational use in their national emergency centres and 10 research institutes use the system for RTD purposes; furthermore, it will be delivered in future to new user institutions in East and West Europe. The software itself is free of cost, however any installation and/or customisation work to be performed by members of the RODOS Consortium will be charged on a full cost basis.

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