Chapter 21
The Decision Support System RODOS

Abstract The chapter begins with an outline of the historical development from the first UNIX-based RODOS system until the most recent Java-based version JRodos. This is followed by an overview of the models contained in RODOS, and a description of the RODOS Center in Germany, where RODOS operates since 2005 at a central location for use by the federal government and the federal states.

21.1 History

The Chernobyl reactor accident on April 26, 1986, showed how badly European countries were prepared for an emergency like this. Assessments of the radiological situation and decision-making about actions for protecting the public were partly determined by actionism or inadequate, often simply due to a lack of standardized and reliable information. Furthermore, there was no cross-border coordination of emergency measures. These reasons finally led to the development of the decision support system RODOS[1] that combines all relevant data, produces diagnoses and prognoses, and compares the efficiencies of various measures. In addition to the objective of assisting decision makers and consultants in case of an emergency with often tremendous time pressure and great psychological stress, the system also was to be used for training and education in radiological and emergency-related issues.

In 1988, the development started at the former Institute of Neutron Physics and Reactor Engineering of the Karlsruhe Research Center, which is now the Institute of Nuclear Technology and Energy Technology of the Karlsruhe Institute of Technology. Until late 1998, the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety funded the RODOS/RESY subsystem, whose functionality was restricted to emergency measures in the vicinity of nuclear

[1] RODOS: Real-time On-line Decision Support.

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facilities. The first operational version, RODOS/RESY PV3.0, became available in 1997 [1].

Since 1990 and in parallel the development of the comprehensive RODOS real-time on-line decision support system was advancing, promoted by the European Commission. This system contains RODOS/RESY as an integral component and has additionally been designed for large-area consequences and later accident phases [2]. The first fully functional operational version, PV4.0F, was issued in late 2000 [3].

One focal point of the EURANOS[2] project as part of the European Commission's 6th Framework Programme in 2003–2008 [4] consisted in improving RODOS with respect to contents, user-friendliness and facilitated maintenance, including the adaptation to national conditions, and in creating the possibility to operate the system under modern information technology platforms. Suggestions and requests from users became increasingly more important. The new demands resulted first in a novel user interface[3] and then in a complete redesign of the entire operating software,[4] which took shape in 2009 with the first Java-based JRodos version. JRodos [5] was accepted very well in the RODOS community. Since late 2010 it is the basis for all further developments and the final version RODOS PV7.0 for HP-UX and Linux is only maintained. At present, JRodos can run under Microsoft Windows, Linux, and Mac OS.

In Germany, RODOS operates since 2005 at a central location for use by the federal government and the federal states; see chapter "The RODOS Center in Germany." Moreover, it is currently (date 2013) operational in several national emergency centers (Bulgaria, Croatia, Czech Republic, Finland, Poland, Portugal, Slovakia, Slovenia, Spain, Russia); it will soon become operational in the Netherlands, Switzerland, and Ukraine. In addition, institutions like universities and local municipal organizations are applying the system on their own initiative in Europe and overseas. The adaptation of the system to local conditions is described in the chapter on "Adapting to National Conditions".

21.2 Overview of the Models Contained in RODOS

Besides the core models referred to in the text, the system also contains further models for specific applications not described in this article. When in the text explicit reference is made to "JRodos," and not to "RODOS," this means that the mentioned models are contained exclusively in the developing JRodos version and no longer in the HP-UX and Linux versions.

[2] EURANOS: European Approach to Nuclear and Radiological Emergency Management and Rehabilitation Strategies.

[3] cf. [4], pp. 171–179.

[4] cf. [4], pp. 181–189.

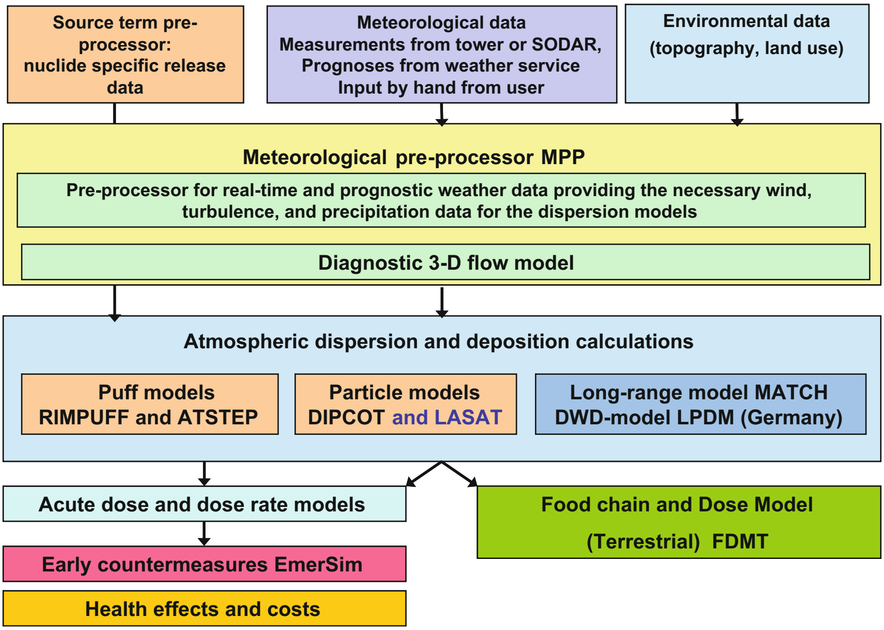

Fig. 21.1 The terrestrial model chain of JRodos

21.2.1 The Terrestrial Model Chain

Figure 21.1 illustrates the components of the terrestrial model chain of JRodos.

21.2.1.1 The Source Term Preprocessor

The source term preprocessor prepares in each calculation time step the amount of released radionuclides for the atmospheric dispersion models. Accepted as input are source term data put in by hand, or measurements from the German remote surveillance systems for nuclear reactors, or archived source terms from the system's data base. The activity release may be specified in terms of nuclide-specific data or aggregated activities of nuclide groups; if necessary this becomes converted into the release rates of individual nuclides required by the models, taking into account the type of reactor and the type of accident.

21.2.1.2 Meteorological Preprocessor and Diffusion Models

The meteorological preprocessor [6] prepares in each calculation time step a three-dimensional wind vector and turbulence field as well as a precipitation field in a format suitable for the atmospheric dispersion and deposition models.

Meteorological input of varying quantity and quality is possible, ranging from meteorological data applying for a given location entered by hand, over data measured at a nuclear power plant by means of a meteorological tower or sound/sonic detecting and ranging (SODAR) equipment, to extensive data fields from numerical weather forecast models. The preprocessor converts the input data into meteorological fields on the entire computation grid, applying a diagnostic (mass-consistent) flow model for refining the resolution and taking into account topographic factors.

The models available for atmospheric dispersion and deposition calculations over a range of up to about a few hundred km are the Gaussian puff models ATSTEP [7] and RIMPUFF [8] as well as the particle models DIPCOT [6] and LASAT [9]. For larger distances, Germany applies the Lagrange particle dispersion model, LPDM [10] of the German Weather Service, and other countries the Eulerian grid model, MATCH [11].

The multitude of diffusion models in RODOS results on the one side from the historic development of the system as a joint European effort, and on the other side from the different levels of performance and ranges of application of the models. The model properties were verified in comparative and validation studies [12]. For the future, it is considered to cover all requirements (especially a sufficiently short computation time) with one single short-range model, if possible.

21.2.1.3 The Model for Early Countermeasures, EmerSim

With the EmerSim model [13], the need and the extent of early countermeasures and the effects of such actions on doses are determined, aiming at the optimization of early countermeasure strategies. A strategy scenario in EmerSim consists of a combination of three specific actions: Staying indoors; evacuation; taking iodine tablets. In a first step, those areas are estimated where the potential doses—that is, the doses without consideration of actions for avoiding or reducing exposure—exceed the respective intervention levels. In a second step, the dose reduction by the actions is simulated in these areas by applying location- and time-dependent shielding factors for the respective actions. The calculations result in time series of modified organ doses for all cells of the calculation grid that can be compared with the potential doses. Comparing the numbers of people in given dose ranges without any action and with different countermeasure strategies provides a measure for the radiological effectiveness, thus helping to discern between the strategies.

EmerSim can be applied in many countries, as the database includes corresponding country-specific intervention levels and dose criteria for early countermeasures.

21.2.1.4 The Terrestrial Food Chain and Dose Model, FDMT

The Terrestrial Food Chain and Dose Model, FDMT, calculates the activity transport through the terrestrial food chains into the human body. It further estimates shorter term and lifetime doses for various age groups that result from food consumption and from all other exposure pathways.

The transport model in FDMT is based on the dynamic model ECOSYS, see chapter “Processes and Models of Activity Propagation in the Human Food Chain”. The results are maps showing the specific activity concentrations in food and feedstuffs at the time of the peak concentration and the development of the concentrations with time. FDMT offers results for 17 vegetable and 16 animal-based human food stuffs as well as for 21 feed stuffs for animals.

An additional module, DepoM, is situated between the atmospheric dispersion and deposition models and FDMT (not shown in Fig. 21.1) and determines contamination of the soil and plant surfaces by dry and wet deposition processes as a function of the season.

21.2.2 The Models for Radiological Consequences in Contaminated Inhabited and Agricultural Areas, ERMIN and AGRICP

One task of the European EURANOS project was the development and implementation of a new kind of flexible and consistent methodology for a dynamic assessment of the radiological consequences in contaminated inhabited and agricultural areas and their mitigation by appropriate actions. This resulted in two models: ERMIN (“EuRopean Model for INhabited Areas”) for inhabited areas and AGRICP (“AGRIcultural Countermeasure Program”) for agricultural areas that became implemented in JRodos and in the ARGOS decision support system [14].

Both models contain dynamic activity transport models as an integral part, thereby differing significantly from previous methodologies that employ pre-calculated—hence static—datasets. Embedding dynamic transport models into the simulation codes enables dynamical calculations and thus achieves unmatched flexibility in the simulation of the effects of late-phase actions on contamination and dose levels and the associated waste and costs. Taking account of measurements and the coupling to data assimilation models is foreseen but not yet realized to a sufficient extent.

The two models and the EURANOS manuals mentioned below are covered in reference [4] in several contributions; therefore, no individual references are given here.

ERMIN contains a transport model describing weathering, retention, and re-suspension processes on inner and outer surfaces, taking into account soil and grassland, trees, other vegetation, horizontal paved surfaces, and outer and inner surfaces of buildings. Basing on the results of a preceding calculation with one of the atmospheric dispersion and deposition models, a start-up step determines time-dependent contamination levels of surfaces and the resulting doses due to external exposure and inhalation without assuming any actions. In a second step, practically any combination of measures described in the “EURANOS Inhabited Area Handbook” can be considered. The effect of the selected actions on the development of the contamination and the doses are then recalculated by the transport model.

AGRICP contains an adapted version of the food chain and dose model described in the chapter “The Terrestrial Food Chain and Dose Model, FDMT”. The agricultural measures that can be considered base on the “EURANOS Handbook for Assisting the Management of Contaminated Food Production Systems”. As ERMIN, also AGRICP calculates dynamically the development of contamination without and with actions and the resulting doses in the respective transport and dose model.

21.2.3 The Hydrological Model Chain

Simulation models for the aquatic pathways are described in [15]; however, the reference is limited to fresh water systems. Generally one can say that any such model needs two components. On the one hand, the hydrological component with the transport and diffusion of radionuclides must be simulated and on the other hand exchange processes among different phases must be taken into account: dissolved radionuclides, those bound to particles, and radionuclides deposited in the sediment (see, e.g. [16]).

The JRodos system contains a complete hydrological model chain [17], whose components are illustrated in Fig. 21.2.

Starting from surface runoff, the RETRACE box model simulates how radionuclides are washed out of the top soil and carried into rivers or lakes. Then, the one-dimensional model RIVTOX computes the distribution and transport in the rivers by means of pre-calculated information about hydrodynamic and sediment-specific characteristics of the rivers [16]. Radionuclide transport on flooded areas, in reservoirs, lakes and coastal waters is described with the two-dimensional model COASTOX, or with the three-dimensional model THREETOX for more complex geometries. For applications to oceans there is the compartment model Poseidon.

The resulting contamination of water and fish is used in the aquatic food chain and dose module, FDMA (Food chain and Dose Module Aquatic), for simulating the radiation exposure of people by intake of contaminated drinking water and fish. Hereby the use of contaminated water for animals as well as irrigating agricultural areas is taken into account.

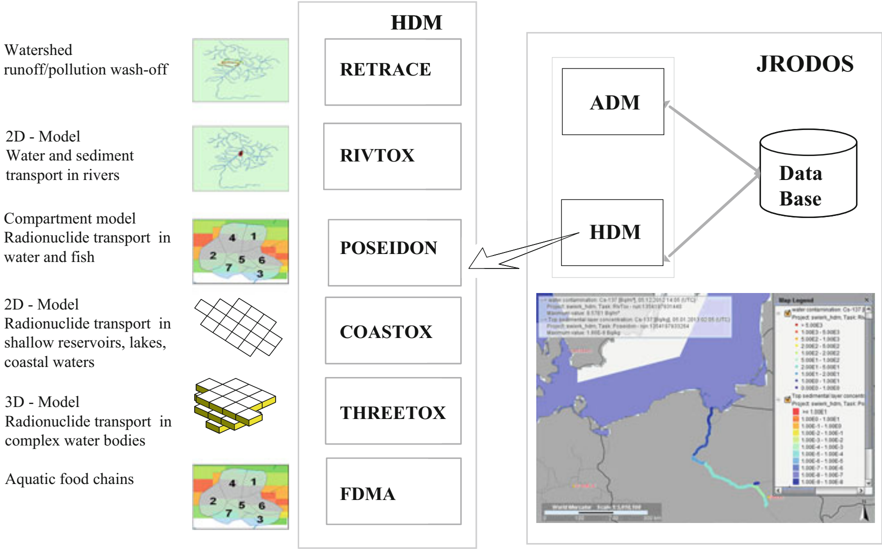

Fig. 21.2 Hydrological model chain in JRodos

21.3 Representation of Location-Dependent Results in RODOS

Location-dependent results in RODOS are calculated in the centre points of the cells of a square Cartesian grid; results that develop with time are available for each time step. The computational grid is centered at the point of the release; and around the latter lie the cells with the finest resolution, where users can choose between various sizes. The cell sizes then increase step by step as a function of the radial distance from the location of the source.

By default, results are represented as color-coded grid cells superimposed on maps. Map-type results can be displayed on the screen and also stored as image or data files.

A visible picture in JRodos is made up of a variety of layers consisting of results and maps that can be combined arbitrarily. On delivery the system contains a default set of maps; in addition, user-customized maps or map layers from the Internet[5] can be used.

Figure 21.3a shows a screen shot of such a map-type result in JRodos with the system's default layers used for the background. The computation grid with the coarser cells as the distance from the source increases can be discerned. The result

[5] At present, "ESRI shapefile" and "geotiff" geographic data formats is supported. Alternatively, one may use geodata from a PostGIS database or from the Web Map Service (WMS) server. The use of Google Maps (hybrid view) or OpenStreetMaps layers is also possible.

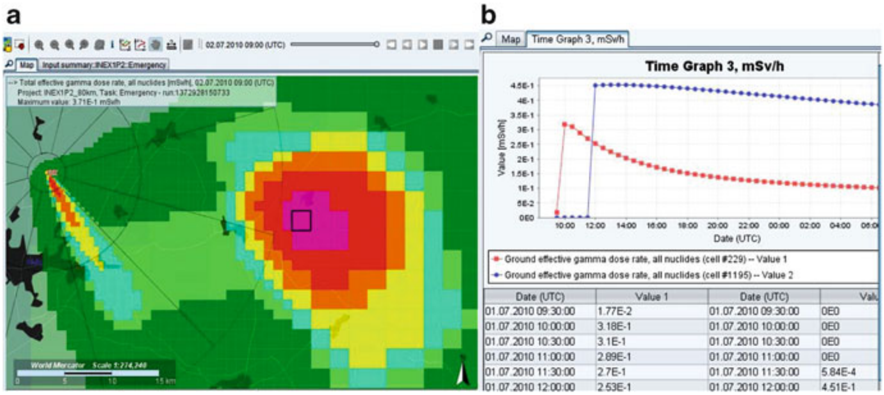

Fig. 21.3 Result representation in JRodos (**a**) map (**b**) time functions at selectable grid points

visible in Fig. 21.3a is the total gamma dose rate at a given time point; the upper menu band contains the time slider for displaying this result for each time step. For time-dependent results, the time function at user-selectable locations can be displayed in graphical form, as shown in Fig. 21.3b, or saved as Microsoft Excel or plain text files.

21.4 The RODOS Center in Germany

21.4.1 Data and User Concept

In 1997 the German Federal Ministry for the Environment took a fundamental decision about setting up a decision support system for radiation protection in Germany with the federal government and the federal states governments at a central location and using RODOS as system—the so-called "RODOS Center." The necessary activities were coordinated and carried out by the Accident Consequence Group at the Institute for Nuclear Technology and Energy Technology of the then Karlsruhe Research Center. After the concept had been worked out [18], the RODOS Center initially was established at the Federal Office for Radiation Protection in Bonn in 2001. In 2003 it was moved to Neuherberg near Munich where it is fully operational since 2005 using the Linux-based RODOS system. After a successful test phase with JRodos under operating conditions transition to the Java-based system is foreseen for the end of 2013.

Figure 21.4 illustrates the conceptual structure and the external data flow of the RODOS Center.

The RODOS Center couples to the German integrated measurement and information system of the federal government (IMIS) and to the remote surveillance systems for nuclear reactors operated by the German federal states (KFÜs), and

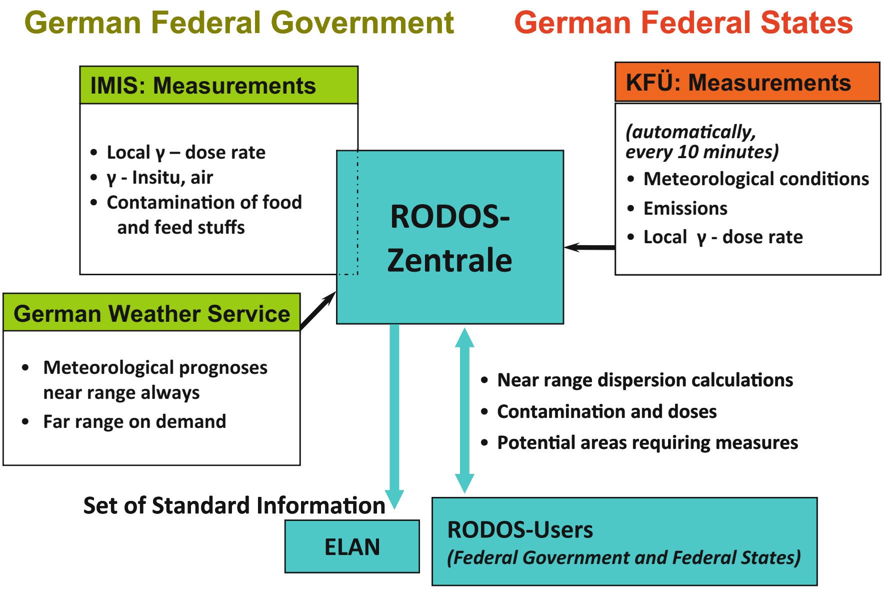

Fig. 21.4 RODOS Center—structure and data flow (source: BfS)

additionally to the German Weather Service (DWD). The KFÜ data come in every 10 min, also in routine operation. In case of a real emergency, measurements from the IMIS system are transmitted automatically in real time. The German Weather Service automatically supplies the latest meteorological forecasts twice a day, and far-range dispersion calculations on demand.

The incoming data together with information from the internal databases of RODOS are used for running diagnoses and prognoses of the radiological situation which is the basis for estimating the potential for protective actions. In addition, health consequences and other quantities are assessed without and with actions being taken into account. All this information assists the decision making team in evaluating potential measures in a way that the most suitable ones can be implemented.

In case of a real emergency, according to German legislation, only a so-called "lead user" has the right to initiate the emergency operation mode of the RODOS Center and to enter a set of standard information into the electronic situation description system (ELAN). In case of a reactor accident in Germany, the lead user is the government of the federal state in which the respective plant is situated. For foreign reactors the lead user is the German Federal Ministry for the Environment, except for some facilities close to the border where special arrangements are in effect. All other users are then entitled either to run interactive calculations with RODOS on their own or let run by the Center (A- and B-users), or to look at results of RODOS calculations released by the lead user for access for this purpose (C-users); different user interfaces are available for this purpose. The RODOS

Center is on alert around the clock which is put to trial once a week. A-users exercise with the system roughly once or twice per week. National exercises are conducted approximately once or twice a year, and there is also participation in international exercises.

21.4.2 Modes of Operation in the RODOS Center

In the pre-release phase, interactive prognosis calculations are carried out on the basis of meteorological forecast data provided by the German Weather Service and assumed source terms.

In the release phase, RODOS performs the following functions:

- Progressing diagnosis calculations are carried out automatically in ten-minutes cycles, based on measurement data from the German KFÜ surveillance system
- Prognoses calculations are issued automatically every 60 min, based on current meteorological forecast data from the Germany Weather Service and assumptions about the source term
- Supplementary interactive calculations are carried out on demand

In the case that new information about the source term is received during an ongoing accident, RODOS repeats the diagnostic calculations from the beginning of the accident until the current "now time", using the new source term together with existing weather data. When this is finished all calculations proceed in real time in the usual way.

The post-release phase is the domain of repeated interactive calculations with RODOS using the results calculated for the release phase, measurements from the IMIS system and from other sources as they become available.

21.5 Adaptation to National Conditions

Comprehensive computer-based decision support systems can provide realistic results only if the data required for the calculation sufficiently reflect the situation in the area under consideration. The default data outfit provided with the standard release of JRodos consists of a geo-referenced database covering the whole world[6] in a relatively coarse resolution, a comprehensive data base about nuclear power plants and other facilities of the nuclear fuel cycle, country-specific intervention levels for emergency measures, and the possibility to switch between several languages.[7]

[6] New feature in 2013; until then the default data base covered Europe only.

[7] Available in 2011 in English, Russian, Ukrainian.

Furthermore, JRodos includes possibilities and tools for facilitating the adaptation to regional or national conditions. The extent of adaptation can be very different, depending on the demands on the system. For instance, when automatic diagnostic calculations belong to the task list, a connection to local measurement systems is necessary. Prognostic calculations require the connection to national weather forecasting data for the near-range, and, if necessary, also for the far range.

In general, local maps can be added in JRodos without major problems. Whether or not the geo-referenced computation data base (elevation, land use, population number, soil type and agricultural production) needs refinement depends on the degree in which local data differ from the data contained in the default database, and also on the availability of region-specific data. It can turn out to be quite difficult to obtain data especially about soil types, agricultural production and consumption habits, as became apparent, for instance, during the customization for Russia.

Incorporating a new language into JRodos is straightforward. However, integrating a new language can be demanding when not only the user interface but also all result trees and manuals are to be translated.

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