JRODOS EXPERT SYSTEM AND THE CUSTOMISATION TO ROMANIAN CONDITIONS

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The RODOS (*Real Time On-line Decision Support*) system was developed in the EU framework programs aimed to help the decision makers in choosing the right decision to mitigate the consequences in the case of radioactive material release in the environment. In the last years a new version of RODOS, a JAVA based version named JRODOS, has been developed introducing a cross-platform solution capable to run on most operation systems. The JRODOS system has a friendly interface and easy system administration and in addition, three important simulation modules are integrated in JRODOS. These three modules are ICRP (based on recommendation of ICRP 103), ERMIN (*European Inhabited Area Model*) and AGRICP (*Agricultural Countermeasure Program*). JRODOS system is installed and running in Romania and NIPNE (*National Institute of Physics and Nuclear Engineering "Horia Hulubei"*) has the task to test and customize the newer JRODOS releases in the 7-th framework program, in projects NERIS-TP and PREPARE. The RODOS system and its new version JRODOS was used to evaluate consequences and countermeasures for some Probabilistic safety Assessment level 3 or during nuclear emergency exercises organized by IGSU (*General Inspectorate for Emergency Situations*).

Key words: decision support systems, emergency management, radioactive accidental release.

1. GENERAL PRESENTATION

The major objective in the development of RODOS [1, 2] expert system was to harmonize nuclear emergency management in Europe and in the first period, the research was focused in the developing of models suited to early phase of an emergency including atmospheric dispersion and early countermeasure.

In the next period the models are focused in the evaluation of the later phase of the accident and the re-engineering the RODOS system using the Java technology. In the framework of projects NERIS-TP [3] and PREPARE [4] new modules would be separately modeled for the urban and agricultural areas. As a consequence, the European Inhabited Area Model (ERMIN) and the Agricultural Countermeasure Program (AGRICP) were developed. A new expansion of JRODOS was decided in 2011 related to the new ICRP-103 [5] recommendation focused on the development of a new screening model considering all exposure pathways, new supporting tools to help the user to define countermeasure strategies including ERMIN and AGRICP.

The Fukushima accident management in Europe was considered far from being optimal in nuclear and radiological preparedness. As a consequence PREPARE project take into consideration the radioactive contamination of water bodies and catchments including river models like THREETOX, COASTOX or DSS MOIRA (*MOdel-based computerized system for management support to Identify optimal remedial strategies for Restoring radionuclide contaminated Aquatic ecosystems and drainage areas*) and model POSEIDON for the simulation of the behavior of radioactivity in marine organisms along with THREETOX for marine environment (coastal areas and estuaries).

DSS (*Decision Support System*) JRODOS architecture comprises in a Data Base, modules simulating radiological situation, evaluation of countermeasure strategies, simulation of countermeasure strategies and consequences and as main results environmental contamination, potential radiation doses and areas and people affected by countermeasures, health effects, costs and effort.

A new user interface of JRODOS, named RODOS-lite was redesigned based on JAVA programming language. The user-interface is self-explained and realized as separated application being an open interface to the RODOS core. The input data can be inserted *via* dedicated windows for the location of accident, source term, weather data, type of evaluated doses and activities desired to be evaluated and type of short and long countermeasures desired to be assessed. Depending of the location of the release a small image of Google maps or Open Street map can be displayed. A general JRODOS scheme is presented in Figure 1.

The screening model based on ICRP-103 recommendation together with the newer ICRPs, 109 and 111 [6, 7] considers all exposure pathways (inhalation, ingestion, external from plume and deposition). One of the most important findings from the workshop held in Bratislava (2012) [8] were to propose practical implementation of the new ICRP recommendations such as to adopt 1 mSv/year as long term objective and 100 mSv in the first year, a dose limit to be avoided.

Therefore, evaluation of doses in JRODOS is aimed to see if the proposed limit would be exceeded in the first year by application of the countermeasures including food ban. Its flexible coding enables it to cope with differences in site and source term characteristics.

The RODOS system has the possibilities to evaluate not only the nuclear power plant accident but also *Explosion of Radiological Device* (ERD) and *Radiological Accident with Fire* (RAF).

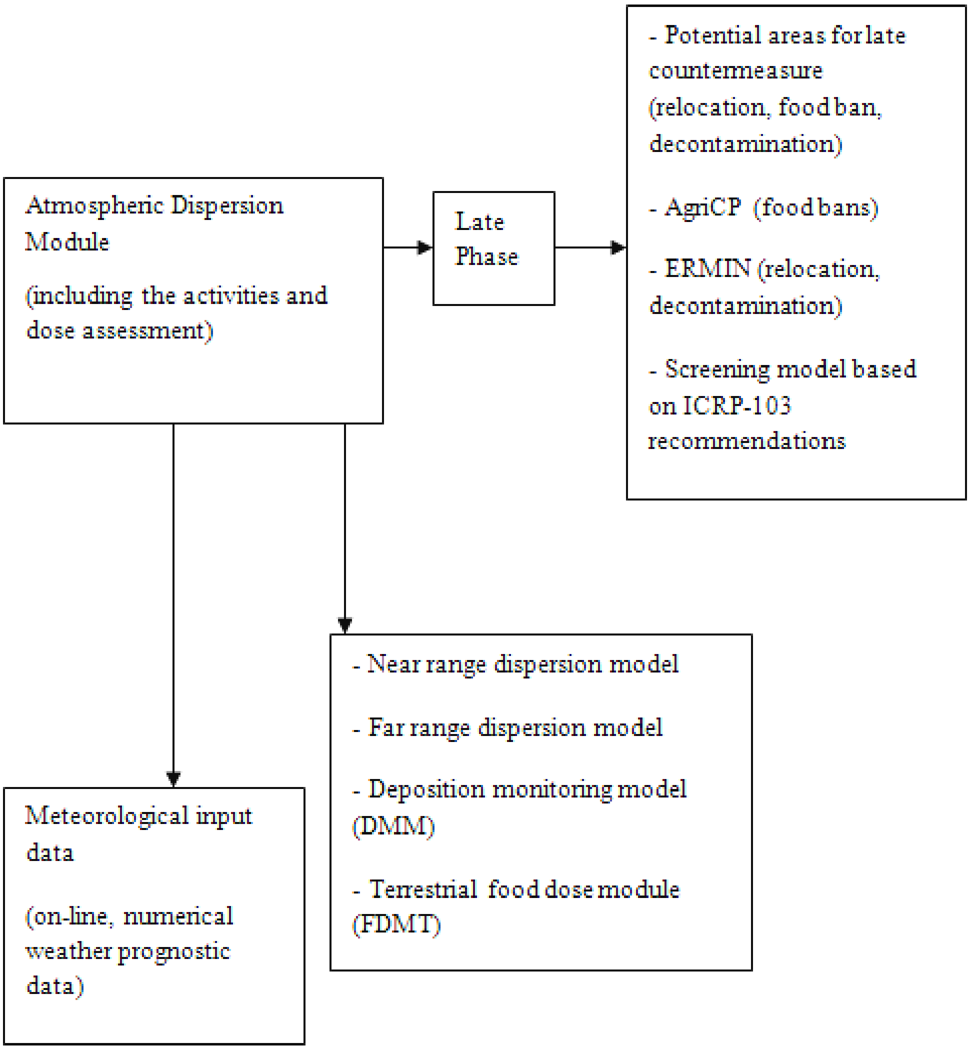

Fig. 1 – General scheme of JRODOS system.

2. JRODOS CUSTOMIZATION TO ROMANIAN CONDITION

One of the important NIPNE team task is the adaptation of the JRODOS system to Magurele site where nuclear activities are carried on. In this case the workstation, where JRODOS system runs, is connected to the local meteorological tower, receiving online meteo data (wind velocity and direction, temperature, rain rate, etc.) 24h per day, first necessary condition to run the system in *Automatic* *mode*. The suitable modifications of JRODOS database were made and a preparation of data software for JRODOS database was projected The second necessary condition for *Automatic mode* evaluation was acquired, by automatic loading 4 times/day of the local and extended 108 hour meteorological forecast, the freely provided by the US – NOAA (*National Oceanic and Atmosphere Administration*) agency. The deposition and the activity assessment for an accidental release exercise of I-131 is presented in Figure 2, when using meteo data provided on-line by meteo tower. By using forecast data, the ground deposition activity can be evaluated for the next *e.g.* 72 hours. Figure 3 presents the assessment for 8 h from the beginning of the release. The evaluation of deposition activity and doses can be extended to the Bulgarian border to assess the cross border effects, if there are.

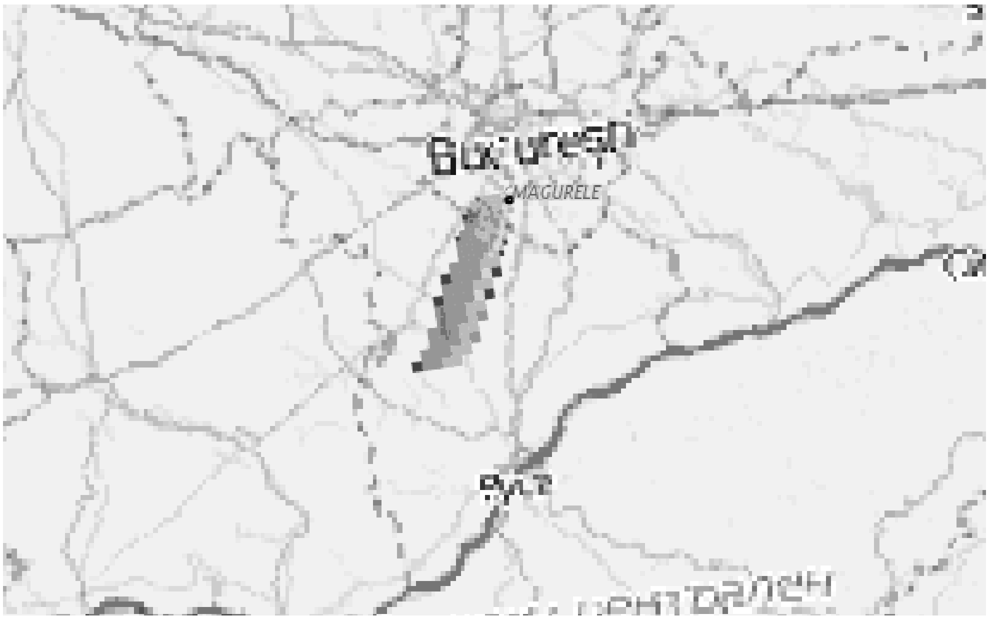

Fig. 2 – Accidental Release Exercise (I-131 release is supposed to be 10^6 times the DRL per day). Ground deposition [Bq/m^2] after 4 hours from the beginning of the release. Meteo data are provided by NIPNE meteo tower.

JRODOS system is a very useful tool in evaluation of different accident scenario consequences during emergency exercises or in PRA studies.

One of the scenarios proposed by IGSU during some emergency exercises is a CANDU NPP Cernavoda accidental release.

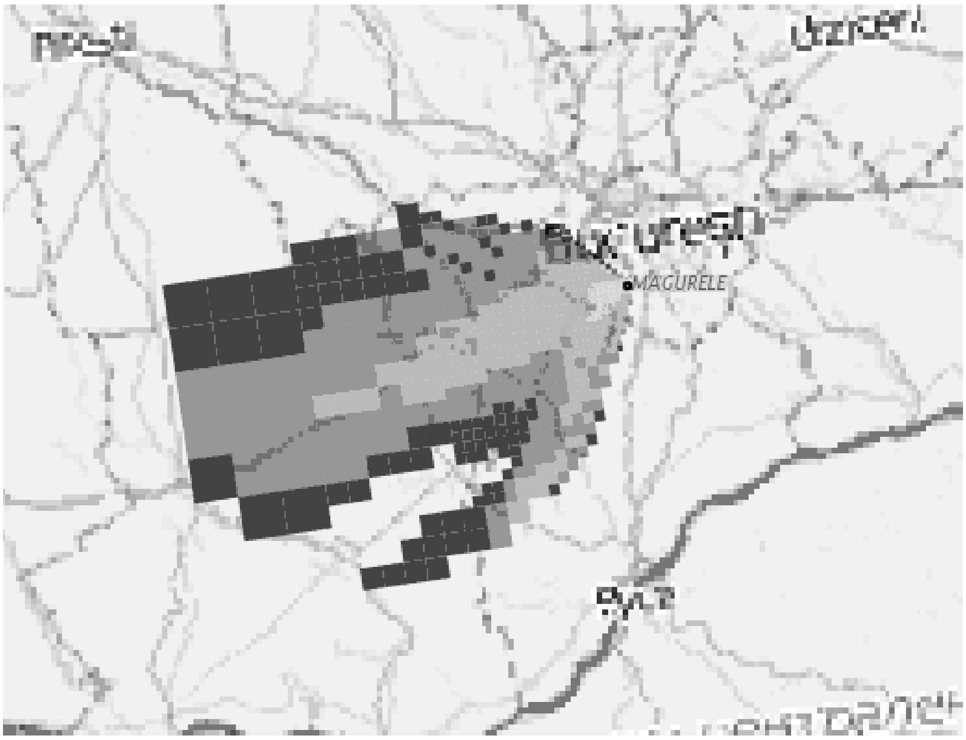

Fig. 3 – The ground deposition after 8 h from the beginning of the release provided by using NOAA forecast data.

The main task of JRODOS is to support decision makers providing them a large scale of information in all ranges and phases of an accident. The JRODOS database includes a set of CANDU-6 source terms based on PSA level 1 and 2 and presented in [9, 10] but the system is able to cope with any delivered scenario. Decision support can be provided at different levels from acquisition and presentation of radiological data and geographical information along with geographical and demographical information to simulation of protective actions and evaluation and ranking of alternative protective action strategies. Figure 4 presents the evaluation of Cs-137 activity distribution based on *Early Core Disassembly with Hydrogen Burn scenario* (ECDHB) and respectively activity distribution of Cs-137 following a fire graphite accident during the decommissioning of VVR-S reactor. The accident scenario consists in early fission product release following the failure of reactor power regulating system and shutdown systems; however the frequency of such as accident is very low ($2.5\ 10^{-8}$ events/year). The release in the environment increases significantly with hydrogen burn and for demonstration of JRODOS capabilities the ECDHB scenario was used.

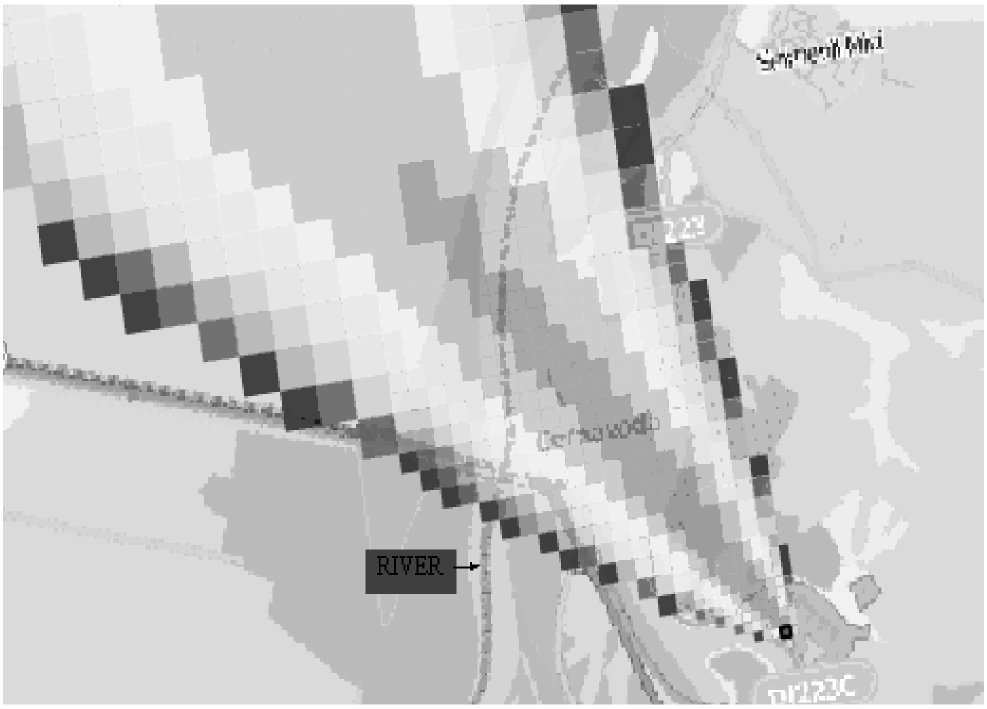

Fig. 4 – Activity distribution map around city of Cernavoda. The CANDU Source Term for exercise simulation is ECDHB, and the wind direction was chosen to Cernavoda.

The assessment of activity distribution of Cs-137 following a fire graphite accident during the decommissioning of VVR-S reactor [11] is presented in Figure 5.

The accident was described as a fire-driven radioactive release to the atmosphere of the material resulting from disassembling reactor's graphite column, on the following pathway, a direct graphite fire flow of combustion products *via* the normal ventilation system of the reactor hall.

The contained fire concept adopted assumes again a graphite scrap bed nearing the condition of a pulverized coal bed – and thus favoring ignition and oxidation of the, otherwise, a material reluctant to ignite – occupying a determined area on the reactor hall. The fire – ignited by an electric arc effect from the fallen electric feeders (a minimum of 400 C is a requisite temperature) is assumed to be self-sustaining, at a burn rate taken at 0.175 mm/min – representing ca. $1/10^{th}$ of the minimal linear burn rate normally adopted for hydrocarbon-fueled fires, which ranges from 1 to 5 mm/h. The case of contained graphite fire a release from reactor building at a 40 m height was considered. The input data are presented in Table 1.

Table 1

Input JRODOS data – for contained graphite fire

Hight of release (on steak)	40 m
Vent area	10.75 sqm
Vertically released volume flux	8.33 m^3/s

Fig. 5 – Fire with graphite from VVR-S reactor during the decommissioning.
Activity distribution of Cs-137.

The repatriation by air of the spent fuel of the VVR-S nuclear research reactor at ‘Horia Hulubei’ National Institute of Physics and Nuclear Engineering, IFIN-HH, Bucharest, currently in decommissioning [12], involved several aspects of the safety assessment. Based on a plausible severe scenario JRODOS system has been used to assess the possible radiological consequences and their territorial distribution. The planned flight route is on a heading to a major airport in the Russian Federation, approximately on the axis Otopeni – Destination point, the plane crash occurred shortly after take-off from the ‘Henri Coanda’ International Airport, with fuel tanks fully loaded, after the impact and the fire ensuing, it was assumed that the radioactive material released was converted into a form that can be entrained in the gas-dynamic flux of the fire fuel either as is, or as airborne ash products. The JRODOS system features possibilities to evaluate explosions of (improvised) radiological devices and radiological accidents involving fire. The activity distribution was supposed to be in plain terrain, in a vicinity of a river. The JRODOS input data are presented in Table 2.

Table 2

Input data for JRODOS. Plane crash during transportation of fuel

mean power	57,4 MW
fire pool area	314 m^2
fire height above ground	1 m
fire duration	450 minutes

Figure 6 presents the activity distribution due to Cs-137 and the values of deposition on the water body and on catchment basins. The evaluation was made supposing a radiological accident with fire. In the above presented exercises the ground deposition occurs near water bodies and especially in the case of a severe accident, the need for a reliable assessment impact of this accident on fresh water environment is very important for evaluation of this impact on population and environment. In the above presented exercises the ground deposition occurs near water bodies and especially in the case of a severe accident, the need for a reliable assessment impact of this accident on fresh water environment is very important for evaluation of this impact on population and environment.

For this reason a DSS dedicated system MOIRA [13, 14, 15] was chosen as the system is designed to address mid- and long-term issues after a post-accidental contamination.

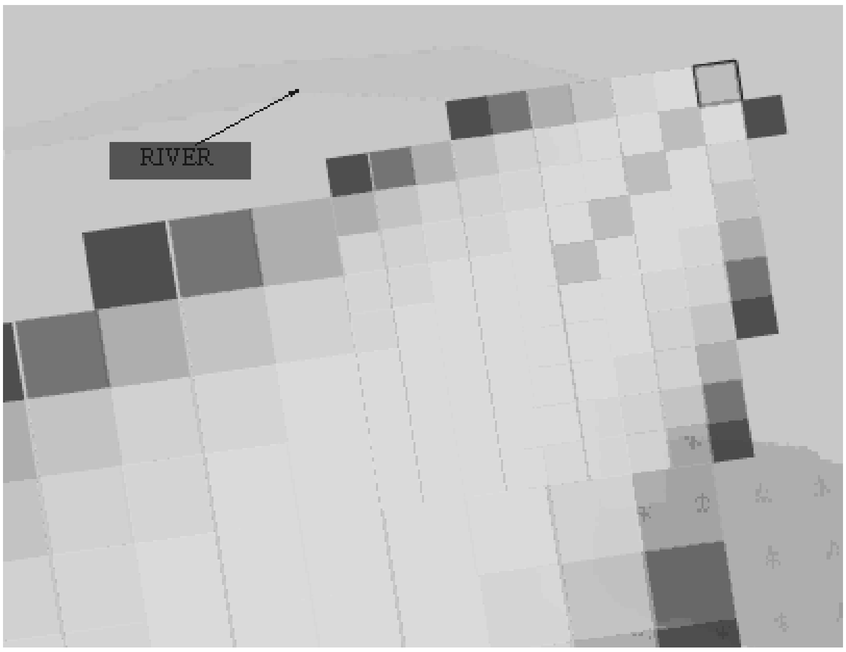

Fig. 6 – Activity distribution of Cs-137(Bq/m^2), an airplane accident scenario during decommissioning of VVR-S LEU fuel.

The computing model for river simulates the time behavior of hydrological quantities and migration parameters of long-lived radionuclides (Cs-137 and Sr-90) and the migration of pollutants to fish species (prey and predator). The model is based on a box-type approach to obtain radionuclide concentration in water. Each elementary box is comprised of water column, sediment layer and right and left sub-catchments of the river. Figure 7 presents the evolution of Cs-137 concentration in the Danube River, following a hypothetical scenario proposed in CONVEX-3 emergency exercise.

In the framework of PREPARE project, one of the important tasks is to integrate MOIRA models in the JRODOS system (RODOS – Hydrological Dispersion Module) for extending long-term evaluation of the radioactive accidental release to aquatic environment. MOIRA DSS is a suitable tool for reconstruction of radiological impact to population following radioactive contamination of water bodies.

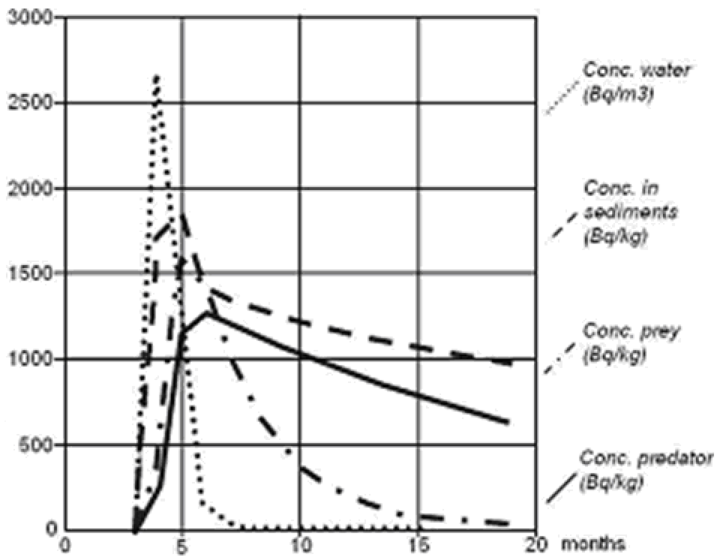

Fig. 7 – Cs-137 concentration in Danube (near the city of Cernavoda) for water, sediments, prey and predatory fish.

3. CONCLUSIONS

The Decision Support System JRODOS is projected and developed in EU R&D Framework Programme to harmonize and ensure an integrated, coherent and consistent response from the European countries in a case of radiological or nuclear accident. JRODOS is designed to present and evaluate the accident consequences in near to far ranges to mitigate countermeasure actions or during exercises and drills initiated by General Inspectorates for Emergency Situation. JRODOS is a useful tool for analysis and prediction of the current radiological situation and the prediction of potential countermeasures. Due to its wide use at European level, JRODOS is a recommended tool for Bulgaria and Romania in harmonization of the nuclear emergency response procedures and evaluation of cross border consequences, one of the main tasks of EMERSYS [16] project.

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REFERENCES

1. W. Raskob, J. Ehrhardt, *The RODOS System: Decision Support for Nuclear Off-site Emergency Management in Europe,* 10th International Congress of the International Radiation Protection Association, May 14–19, Hiroshima, Japan, CD, (2000).
2. W. Raskob, D. Tribushnyi, I. Ievdin, M. Zheleznyak, *JRODOS: Platform for improved long countermeasures modeling and management*, Radioprotection, **46**, no. 6, S731–S736, (2011).
3. ***** Towards a self-sustaining European Technology Platform (NERIS-TP) on preparedness for Nuclear and Radiological Emergency Response and Recovery, Grant Agreement 269718, http://resy5.fzk.de,v (2010).
4. ***** PREPARE, Innovative integrative tools and platforms to be prepared for radiological emergencies and post-accident response in Europe, Grant Agreement-323287,http://cordis.eu, (2011).
5. **** The 2007 Recommendation of the International Commission on Radiological Protection, ICRP103 (2007).
6. ***** Application of the Commission's Recommendations for the Protection of People in Emergency Exposure Situations ICRP109 (2011).
7. J. Lochard, I. Bogdevitch, E. Gallego, P. Hedemann-Jensen, A. McEwan, A. Nisbet, A. Oudiz, T. Schneider, P. Strand, Z. Carr, A. Janssens, T. Lazo, *Application of the Commission's Recommendations to the Protection of People Living in Long-term Contaminated Areas after a Nuclear Accident or a Radiation Emergency,* ICRP111 (2011).
8. W. Raskob, T. Duranova, T. Schneider, R. Mustonen, D. Oughton, *Findings from a workshop on practical implementation of the new ICRP recommendation: a contribution of the NERIS Platform*, technical report, international workshop in Bratislava, February (2012).
9. J.Q. Howienson, H.S. Shapiro, P.J. Allen, J.T. Rogers, P. Mostert, R.W. van Otterloo, *Probabilistic risk assessment study of a CANDU600*, IAEA-SM-296/5, pg. 245–261 (1988).
10. P.J. Allen, J.Q. Howienson, H.S. Shapiro, J.T. Rogers, P. Mostert, R.W. van Otterloo, *Summary of CANDU 6 Probabilistic Safety Assessment Study Results*, Nuclear Safety, **31**, No. 2, 202–214, (1990).
11. D. Vamanu, T. Acasandrei, S.D. Slavnicu, D. Gheorghiu, D. Galeriu, A. Melintescu, *Decommissioning Research Reactor: A case of a Reference Accident Scenario*, Romanian Reports in Physics, **63**, 43–60 (2011).
12. D. Vamanu, D.S. Slavnicu, B.I. Vamanu, V.T. Acasandrei, D. Gheorghiu, *Safety risk in spent nuclear fuel air transportation – A 'Black Swan' anatomy*, Rom. Rep. Phys., **66**, 487–508, 2014.

13. L. Monte, *A generic model for assessing the effects of countermeasures to reduce the radionuclide contamination levels in abiotic components of fresh water systems and complex catchments*, Environment Modelling & Software, **16**, 669–690 (2001).
14. L. Monte, J. Brittain, E. Gallego, L. Hakanson, D. Hofman, A. Jimenez, *MOIRA-PLUS: A decision support system for the management of complex fresh water ecosystems contaminated by radionuclides and heavy metals*, Computers & Geosciences, **35**, 880–896 (2009).
15. L. Monte, *Regional-scale application of the decision support system MOIRA-PLUS: an example of assessment of the radiological impact of the Cernobyl accident on the fresh water ecosystem in Italy*, Journal of Environmental Radioactivity, **102**, 73–83 (2011).
16. **** *EMERSYS, Toward an integrated, joint cross-border detection system and harmonized rapid responses procedures to chemical, biological, radiological and nuclear emergencies*, MTS-ETC Code:774 (2013).