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NUCLEAR AND RADIOLOGICAL PREPAREDNESS: THE ACHIEVEMENTS OF THE EUROPEAN RESEARCH PROJECT PREPARE

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The PREPARE project aimed closing gaps identified in nuclear and radiological preparedness in Europe following the first evaluation of the Fukushima disaster. With 46 partners from Europe and Japan, it collected the key players in the area of emergency management and rehabilitation preparedness. Starting from February 2013, the project ended in January 2016. Among others, the project reviewed existing operational procedures for long-lasting releases, cross-border problems in radiation monitoring and food safety and further developed missing functionalities in decision support systems ranging from improved source term estimation and dispersion modelling to the inclusion of hydrological pathways for European water bodies. In addition, a so-called Analytical Platform has been developed to explore the scientific and operational means to improve information collection, information exchange and the evaluation of such types of disasters. The tools developed within the project will be partly integrated into the decision support systems ARGOS and JRODOS.

INTRODUCTION

The PREPARE project (http://www.prepare-eu.org/index.php) has been created to close gaps that have been identified in nuclear and radiological preparedness following the first evaluation of the Fukushima disaster. Among others, the project reviewed the existing emergency preparedness and response (EPR) procedures for dealing with long-lasting releases, cross-border problems in monitoring and food safety and further developed missing functionalities in decision support systems ranging from improved source term estimation and dispersion modelling to the inclusion of hydrological pathways for European water bodies. In addition, as the management of the Fukushima event in Europe was far from optimal, a so-called Analytical Platform (AP) has been developed to explore the scientific and operational means to improve information collection, information exchange and the evaluation of such types of disasters.

This paper summarises the results of the PREPARE project. Detailed results of this project will be published as a special issue of the journal 'Radioprotection' by the end of 2016.

KEY RESULTS

Review the current off-site nuclear emergency planning in European countries

In all countries with nuclear installations, detailed emergency management strategies have been developed in the past. In nearly all cases, such strategies are based on accident scenarios where the duration of the release of radionuclides to the environment is limited to some hours or at maximum a few days. The Fukushima accident has demonstrated the possibility of long-lasting releases of radionuclides from a nuclear power plant (NPP) over several weeks. This made it necessary to test the current off-site nuclear emergency planning in European countries with accident scenarios based on lessons learned from the Fukushima accident and to derive recommendations on how to improve the current planning. The tests should demonstrate whether protective measures foreseen in the current emergency planning could adequately reduce the radiological consequences of NPP accidents with long-lasting severe releases similar to the release from the Fukushima-Daiichi NPP.

The first step was to define hypothetical source terms leading to long-lasting releases of radionuclides which are applicable to nuclear installations in various European countries. In total, 10 source terms have been identified for different reactor types such as pressurised water, boiling water and water-water energy reactors. In the second step, weather data for the release scenarios were derived. As the selected sites were located in four countries, Finland, Germany, Slovakia and Spain, four different weather data sets were used. For each of the 10 source terms, between 46 and 365 weather scenarios were considered. In the final step, the results were compared against the existing national emergency management planning procedures.

Conclusions were derived for the following questions:

(1) Are the current emergency planning zones sufficiently reflecting the potential radiological impact of long-lasting releases?
(2) Is the current concept of emergency planning zones as being implemented in various countries reasonably applicable for long-lasting releases?
(3) Are current intervention criteria appropriate for long-lasting releases?
(4) Will the ICRP criteria of 100 mSv for the residual dose be exceeded?

In most release scenarios, the areas calculated for protective actions did not exceed current planning zones. In the cases where these distances were exceeded, the size of affected population remained quite small. The number of sectors affected increased clearly with the duration of the release. If the release duration was <12 hours, the affected sector was limited to <90 degrees in most cases. For very long-lasting releases, however, the whole circle area (around the release point) could be affected (up to 360 degrees). Related to the discussion about intervention criteria, some issues were identified, among them the point that in case of long-lasting severe releases the following critical situation can occur: the intervention criteria for protective actions are not exceeded in any 7-day-interval (for which some of the reference levels are currently defined in Germany), but the total dose over the release period by far exceeds the reference level. It was also concluded that the current intervention criteria in all countries assured that the residual dose in the first year (ICRP reference level) did not exceed 100 mSv.

How to deal with contaminated goods?

Recommendations related to quality control of contaminated goods were already existing before the Fukushima disaster worldwide (IAEA, Codex Alimentarius) and in Europe (Euratom regulations). However, following the Fukushima accident, the organisations that had to deal with these guidelines realised that they are very generic (based only on criteria in activity concentration) and many adaptations had to be developed for their operational use. To overcome these shortcomings, the PREPARE project aimed to develop strategies, guidance and tools for the management of the contaminated products, taking into account the views of producers, processing and retail industries and consumers. This will help in designing and strengthening the preparedness plans for post-accidental situations at the national and local levels in European countries.

Eleven countries (Belgium, Finland, France, Switzerland, Greece, Ireland, the Netherlands, Norway, Portugal, Spain and UK) through 14 organisations have been involved in the discussion about the management of contaminated foodstuffs and other goods, after a nuclear or radiological event. The majority of countries focused their reflection on foodstuffs (and sometimes feedstuffs). Various methodological approaches were used for the composition of the stakeholder panels and the organisation of the panel meetings.

Some general key messages can be summarised in the following three points not focussing only on contaminated goods or foodstuffs:

- Everything must be done to avoid any accident. Indeed according to the panellists, citizens are victims first, and they are not responsible for the situation arising from the accident. This includes the possible transfer of risks, for instance through the production of wastes or the contamination of the environment should be avoided as far as possible.
- A post-accident situation would be totally new for everyone. This is so unexpected that it will lead to a loss of references and values for all the people. Upstream preparedness—before an accident occurs—is obviously crucial, but nobody will be fully ready if it happens. Only a pre-established distribution of roles of the different stakeholders and agreement on key management issues (e.g. maximum permitted levels, MPLs) at forehand will allow a quick and sensible response.
- The concept of MPLs is useful but questionable. According to the stakeholders, MPLs are needed but their rationale is complex to understand. The definition and values of MPLs must be flexible and need to be adapted to the actual situation. They should be defined as soon as possible based on monitoring results, and should follow a graded improvement process.

Improvement of the decision support systems ARGOS and JRODOS in their atmospheric dispersion and aquatic simulation components

Atmospheric dispersion and deposition

As a consequence from Chernobyl and again following the Fukushima disaster, source term estimation

was identified as critical and extremely difficult to realise at the early stage of an accident. Further to this, the chemical and physical properties of the particles released might often deviate from the simple approach so far realised in the European decision support systems ARGOS and JRODOS. To overcome these shortcomings, the estimation of a potential source term based on a combination of atmospheric dispersion calculations and monitoring data at all distances from the release location as well as the physico-chemical properties of radionuclides emitted to the atmosphere as particles were tackled within PREPARE.

Up to five different particle sizes can now be defined by the user in the dispersion models, with suggested values 0–2, 2–5, 5–10 and 10–20 μm, with their corresponding mass fractions and densities. As limiting condition, the gravitational settling velocity for particles >10 μm dominates the deposition process. This new functionality is available for ARGOS and JRODOS.

Two approaches of source term estimation (or 'source inversion'—SI) algorithms—based on measurements and atmospheric dispersion models were developed within PREPARE and implemented in JRODOS:

- A simple and fast technique that uses very simple dispersion modelling and gamma dose rate measurements in the near vicinity (e.g. at the fence) of a NPP to estimate total released activity of different nuclides.
- A more advanced technique that uses more detailed dispersion modelling and gamma dose rate or other measurements also at farther distances from the NPP (from 1 to 1000 km) to estimate time-dependent activity release rates of different nuclides and the release height.

The algorithm for the simple and fast source term estimation has been implemented as a sequential algorithm operating in cycles of specified time length, during which new meteorological and gamma dose rate measurement data become available and retrieved from the database. The source rate calculated for the specific interval is returned to JRODOS and stored in Projects database. The results of the SI project are available for use by subsequent runs of the Local Scale Model Chain (LSMC) of JRODOS. Tests have been performed with the monitoring configuration around Temelin NPP.

The SI module based on more advanced techniques is triggered upon user's request and the user can set a few basic parameters that influence its results (such as first-guess source term, time discretization of analysed source term, method for errors' calculation, method for handling multiple nuclides, options related to estimation of release height, etc.). Measurements covering the calculation time period are extracted from the database and concern instantaneous gamma dose rates, nuclide-specific instantaneous and/or time integrated concentration measurements, total deposition and wet deposition. As results, the SI module stores in the system database the 'source-receptor' matrix and the time- and height-dependent analysed source term. The user has the possibility to start an LSMC run using the results of the SI module run. Testing of the developed SI algorithm has been performed using artificially generated 'measurements' (i.e. model-calculated values with true source term) obtained for the meteorological and geographical conditions of the well-known European Tracer Experiment (ETEX). Robustness and real-time applicability of the developed algorithm has been demonstrated.

As additional tasks, the computational speed of the advanced particle models in ARGOS and JRODOS was improved—which became necessary for long-lasting source terms—and the European Model for Inhabited Areas (ERMIN) has been modified to deal with particles of different solubility values.

Aquatic modelling

JRODOS is the only decision support system that contains a fully integrated Hydrological Dispersion Module (HDM). Deficits were identified and should be tackled within PREPARE. So far, the HDM was mainly designed as a tool for the prediction of short-term transport and dispersion of radionuclides in river systems. The following new functionalities were added:

- Modelling of radionuclide transport in coastal waters driven by the atmospheric fallout from the dispersion module of JRODOS and/or by direct releases into the marine environment. This approach can be used for the real-time forecasting and for the analyses of long-term contamination of the marine environment including marine biota.
- Modelling of the long-term behaviour of radionuclides in freshwater systems for predicting radiation doses via aquatic exposure pathways and analysing the efficiency of countermeasures to reduce the burden to the public.

The 1D hydraulic model RIVTOX was improved in its computational scheme. The new version is now based on the full Saint-Venant equation allowing simulation also complicated river networks (instead of diffusive wave approximation). In addition, a new sediment-radionuclide transport model was added.

The 3D model THREETOX that is designed for the application in coastal areas or complex and deep lakes was improved with respect to the modelling of the behaviour of radionuclides in sediments. A two-step kinetics was implemented

allowing consideration of short-term and long-term behaviour of radionuclides in the sediments. In addition, the global simulation model MyOcean (http://marine.copernicus.eu/web/2-about-your-copernicus-marine-service.php) can be now used as a boundary condition for the simulation model.

To close a gap in the longer term capabilities of the hydrological model chain of RODOS, the MOIRA simulation system was integrated. MOIRA is a decision support system for characterising the radiological situation and selecting adequate management strategies for different aquatic ecosystems contaminated by radionuclides. It is intended to be used for longer term problems and focuses on caesium and strontium contamination. The system has been validated and was available as stand-alone version.

The box model POSEIDON, designed for the application in lakes, reservoirs and the marine environment, was extended in its food chain modelling by adding benthic organisms to describe the migration of radionuclides from contaminated bottom sediments to marine organisms in the food web. This allows a much better applicability to the marine environment.

Finally, these improved models were tested and validated with data from Fukushima, Spain and Romania.

Communication with the public

Not to lose trust is one of the key objectives of authorities in the aftermath of any disaster. Fukushima as well as Chernobyl demonstrated that this is difficult to achieve. Therefore, the conditions and means for pertinent, reliable and trustworthy information to be made available to the public in due time were investigated and according to its needs in the course of nuclear emergency and post-emergency contexts.

In a first activity, information has been collected from how experts and local actors experienced the Fukushima disaster. Important findings were that the local population faces the maximum level of complexity as their day-to-day life is disrupted and they are confronted to dilemmas: evacuating or living in a contaminated environment; both drastically disrupt the daily life and is a source of stress. Societies and institutions cannot be prepared in the usual meaning of preparedness, reserving resources and setting up routines, and procedures that can temporarily replace jeopardised systems of decision and action in order to facilitate a return to normality. In this respect, the local population has to recreate the conditions by their own to access trustworthy and reliable information, understand the situation at the individual and community level and support reliable decision-making at the individual and community levels.

For professional experts, the situation is also complex as they have to deal with uncertainties and multidimensional issues that might be beyond their expertise fields. The role of experts, however, is not purely technical but also social as they are confronted by a diversity of interactions with other experts (inside and outside institutions), with authorities, local populations and the media. It was concluded that trustworthiness of information is not the level of trust of one actor towards a given source but the result of the interactions between the different experts and information providers. In this respect, the acceptance of an expert by the society is the key for building the condition to disseminate trustworthy information. On the contrary, the expert has also the responsibility to deal with the complexity of a nuclear emergency and post-emergency situation in a way that fits the complexity of societal needs.

Related to media communication, social and traditional media were investigated. Looking at the role of the mass media, a survey in Belgium clearly showed the domination of the traditional media as source of information. Communication with mass media during and after a nuclear emergency presents both a challenge and an opportunity for emergency management. The challenge lies in the different motivations and types of processes applied by mass media and emergency management. The opportunity arises from the power of mass media to reach an audience with information important for compliance with protective actions. Results show that although challenging, nuclear emergency communication can be improved by using mass media and developing skills, training and resources during the preparedness phase of a nuclear emergency cycle.

Organisation of basic training courses and emergency exercises

To guarantee the transfer of knowledge on state-of-the-art EPR in Europe for all interested stakeholders (from scientists to decision-makers), two basic training courses were organised, one related to the early and medium phase of a nuclear accident, the other dedicated to the late phase. Both courses were organised two times and both courses combined a series of presentations with practical exercises and visits. Exercises for the early/medium phase course consisted of a radiological assessment of a hypothetical accident scenario making partly use of the JRODOS decision support system and a full table-top emergency exercise with different role playing, such as radiological impact assessors, decision-makers, first responders implementing decisions on the scene and spokespersons communicating with the press. The late phase course was organised in collaboration with the Institute of Radiology, Belarus offering the unique opportunity to visit the Chernobyl contaminated areas and the local

centres for developing a practical radiological protection culture around Gomel, learning from the inhabitants and local people engaged in the rehabilitation of living conditions. All courses included special lectures on experiences from the Fukushima accident.

In addition, two table-top exercises have been organised with a focus on cross-border consequences. One related to a transport accident at the border between France and Belgium and one on monitoring a large-scale contamination in the aftermath of a hypothetical accident affecting apart from the 'acciland' also neighbouring countries. The transport accident showed potential for improvements of the relations between different national authorities (better knowledge on each other procedures), their technical support and at the local level the need for coordination. For the monitoring table-top exercise, it was recognised that detailed plans and specialised teams are available in most countries (29 participants from 15 different European countries), however, that some aspects are not harmonised transnationally, especially data exchange of measurements outside the early warning network. Also real monitoring strategies are lacking and calibrations can be an issue if many teams are involved. A specific web-based tool coupled to a database was developed for this exercise collecting all data from the different countries. This tool was assessed as very helpful and future exercises on specific issues (such as data exchange, calibration issues, strategies) were identified as important to harmonise European practise in this respect.

The Analytical Platform

The general idea of the AP is to provide an easy to access platform for information exchange in times of a nuclear or radiological crisis, allowing discussions between experts and dissemination of information to the public community. If an alert is issued based on a protocol to be developed as part of the operational procedures, members of different organisations would be attached to the platform and start working.

The core of the AP is the knowledge database with historic events and scenarios and its Case-Based Reasoning (CBR) algorithm to compare them with the ongoing event. The CBR methodology is a process to identify that scenario which fits best to the one under investigation. To facilitate the retrieval mechanism, appropriate similarity functions had to be developed to compare the ongoing event and the one from the knowledge database.

Sixteen historic cases from Windscale fire, Chernobyl and Fukushima accidents and the poisoning of Alexander Litvinenko have been integrated into the database. As the number of these 'real' cases is limited, scenario calculations were performed to feed the database with additional information. Parameters relevant for the scenarios were as follows:

- INES scale—source term (5, 6, 7).
- Start time in four different seasons of the year (spring, summer, autumn and winter).
- Weather (with rain, dry, low wind speed and medium wind speed).
- Population distribution (urban and rural).

This resulted in 96 scenarios. In the longer term, only one weather condition and one population distribution were taken into account for the scenario construction. So far, eight scenarios have been implemented. Information stored is related to countermeasures initiated in the various phases, the area and number of people affected as well as efficiency of strategies in the longer term.

Further components were as follows:

- Virtual meeting room to exchange information by experts.
- Incident manager with timeline of event.
- Web crawler to collect information from the web and social media.
- Ask the expert providing functionality for managing and retrieving documents, including functionality for recommending documents.
- Multicriteria Analysis for evaluation.

Having developed the AP, the next step is to explore its application and usability. To facilitate this, an 'Information, participation and communication' working group was established under NERIS (http://www.eu-neris.net/). Among others, the group intends to establish adequate rules of conduct and the basis for its maintenance.

DISSEMINATION

The final PREPARE dissemination workshop 'Innovative integrative tools and platforms' was held in Bratislava, Slovak Republic in 20–22 January 2016. In total, 112 participants participated at the workshop representing 24 countries: Austria, Belarus, Belgium, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Ireland, Japan, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine and the UK. The workshop language was English.

The PREPARE dissemination workshop allowed to present the results of the PREPARE project and to collect feedback from the participants on the topics of potential future research activities. The knowledge acquired during the project has been disseminated as well as the capability of the new methods and tools.

CONCLUSION

PREPARE has reduced gaps identified after the Fukushima accident by providing the technical

means for a better harmonised response in Europe. This was achieved by fostering the analytic skills at a European level and providing a better guidance of how to communicate with the public and all affected stakeholders. The project has also analysed the existing procedures in emergency management, cross-border monitoring and dealing with contaminated goods. Furthermore, tools applied in emergency preparedness, management and rehabilitation such as the decision support systems ARGOS and JRODOS have been significantly improved by integrating methods to estimate the source term from a nuclear accident and improving terrestrial and aquatic simulation models. Having the NERIS Platform and the ARGOS and RODOS user groups involved in the project, the European dimension was covered.

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