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Emergency Management and Radiation Monitoring in Nuclear and Radiological Accidents.
Summary Report on the NKS Project EMARAD

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Abstract

In order to manage various nuclear or radiological emergencies the authorities must have pre-prepared plans. The purpose of the NKS project EMARAD (Emergency Management and Radiation Monitoring in Nuclear and Radiological Accidents) was to produce and gather various data and information that could be useful in drawing up emergency plans and radiation monitoring strategies. One of the specific objectives of the project was to establish a www site that would contain various radiation-threat and radiation-monitoring related data and documents and that could be accessed by all Nordic countries. Other important objectives were discussing various factors affecting measurements in an emergency, efficient use of communication technology and disseminating relevant information on such topics as urban dispersion and illicit use of radiation.

The web server is hosted by the Radiation and Nuclear Safety Authority (STUK) of Finland. The data stored include pre-calculated consequence data for nuclear power plant accidents as well as documents and presentations describing e.g. general features of monitoring strategies, the testing of the British urban dispersion model UDM and the scenarios and aspects related to malicious use of radiation sources and radioactive material. As regards the last item mentioned, a special workshop dealing with the subject was arranged in Sweden in 2005 within the framework of the project.

This report describes the EMARAD project and the work performed and results obtained. The report is complemented by another EMARAD publication "Proceedings of the NKS/EMARAD Mini-seminar on Malicious Use of Radioactive Material, held at Hotel Park Inn, Solna Centrum, Stockholm, on May 24-25, 2005".

Key words

Emergency preparedness; Radiation monitoring strategy; Emergency measurements; NPP accident consequences; Illicit use of radiation; Urban dispersion; Web-based library; Communication

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Preface and summary

The management of various nuclear or radiological emergencies requires that the authorities have pre-prepared plans and various background material at their disposal. The purpose of the NKS project EMARAD (Emergency Management and Radiation Monitoring in Nuclear and Radiological Accidents, 2002–2005) was to produce and gather data and information foreseen to be useful in preparing emergency procedures and radiation monitoring strategies.

The participating institutes and experts in the project were:

Denmark:	Risø National Laboratory (Kasper Andersson, Jørn Roed, Søren Thykier-Nielsen)
Finland:	Radiation and Nuclear Safety Authority STUK (coordinating organisation; Riitta Hänninen, Tarja Ilander, Eila Kostiainen, Juhani Lahtinen, Kaj Vesterbacka) VTT Technical Research Centre of Finland (Jukka Rossi, Seppo Vuori)
Iceland:	Icelandic Radiation Protection Institute (Kjartan Gudnason, Sigurdur Emil Pálsson)
Norway:	Norwegian Radiation Protection Authority NRPA (Inger Margrethe Eikelmann)
Sweden:	Swedish Radiation Protection Authority SSI (Robert Finck); University of Lund (Christer Samuelsson)

During the course of the work, two project meetings were held: in September 2002 in Sweden near Stockholm and in February 2003 in Finland at STUK in Helsinki.

The deliverables of the project are:

- A website hosted by STUK containing most of the data and reports produced in the project.
- Downloadable NPP accident consequence data calculated for ten power plants located in or close to the Nordic countries. The total number of scenarios is 32 (one to eight per power plant).
- A number of special application programs that can be used to process the downloaded NPP accident consequence data.
- A selection of downloadable demos, brief working documents and presentations addressing the testing of the British UDM model as well as aspects related to malicious use of radiation.
- A working document on the general factors affecting radiation monitoring strategies.
- A separate publication on communication and emergency preparedness (being prepared), this was also a topic at the NKS-B CommTech seminars. Presentations from the seminars can be found at the NKS web site.
- A separate NKS publication “Proceedings of the NKS/EMARAD Mini-seminar on Malicious Use of Radioactive Material, held at Hotel Park Inn, Solna Centrum, Stockholm, on May 24-25, 2005”.

The data stored on the web server can be used in training and in preparing exercises, as well as for pre-studies.

Some results of the work carried out within the framework of the project have been published in scientific reports and journals or presented in various conferences.

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1 Introduction

An essential prerequisite for the proper management of a radiation emergency is that there are response plans and procedures prepared in advance. To draw up such plans and to enhance the Nordic harmonisation of e.g. measurement activities in emergencies there must exist a selection of reference and support material (data, documents, demos and presentations) accessible to all competent authorities.

The purpose of the NKS project EMARAD (Emergency Management and Radiation Monitoring in Nuclear and Radiological Accidents, 2002–2005) was to respond to the needs mentioned. The participating organisations represented all five Nordic countries: Risø National Laboratory from Denmark, Radiation and Nuclear Safety Authority (STUK) and VTT Technical Research Centre from Finland, Icelandic Radiation Protection Institute from Iceland, Norwegian Radiation Protection Authority (NRPA) from Norway, and Swedish Radiation Protection Authority (SSI) and University of Lund from Sweden.

The deliverables of the project can be listed as:

- A website hosted by STUK and intended to store most of the data and documents produced in the project.
- Downloadable NPP accident consequence data calculated for ten power plants located in or close to the Nordic countries. The total number of scenarios is 32 (one to eight per power plant). The scenarios were calculated by VTT with the code VALMA using meteorological data provided by the Finnish Meteorological Institute (FMI).
- A selection of special application programs that can be used to process the downloaded NPP accident consequence data. The programs were created by STUK.
- Various downloadable demos, brief working reports and presentations addressing the testing of the British UDM model (Urban Dispersion Model) and various aspects of malicious use of radiation. This support material was provided by Risø National Laboratory and SSI. In addition, a separate mini-seminar, hosted by SSI and University of Lund, with the title "NKS/EMARAD Mini-seminar on Malicious Use of Radioactive Material" was arranged in Sweden in 2005. There will be a separate publication describing the seminar and conclusions made.
- A working document on the general factors affecting radiation monitoring strategies. The document was compiled and mostly written by STUK.

During the course of the work, two project meetings were held: the first in September 2002 in Sweden near Stockholm and the second in February 2003 in Finland at STUK.

Some results of the work performed within the framework of the project have been published in scientific reports and journals or presented in conferences.

This report is organised as follows. The website is briefly introduced in chapter 2, and chapter 3 gives a description of the stored NPP accident consequence data and the use of them. Chapter 4 is dedicated to urban dispersion and chapter 5 to malicious use of radioactive sources and material. Monitoring strategies are treated briefly in chapter 6. Chapter 7 presents the conclusions.

2 EMARAD website

The web server is located at STUK’s headquarters. It was opened to the project participants in the beginning of December 2002. The server is currently a Compaq Proliant ML370 G2 computer (two processors 1400 MHz, 1 GB RAM, 72 GB hard disk space) with the Windows 2000 Server operating system and MySQL data base system. The system is configured in a way that allows logging in with a user ID and password.

The primary purpose of the www site is to serve as data storage and to provide users with means to display and download the data, reports, demos and special application programs. In addition, the NPP accident consequence data can be to a certain extent modified through the user interface.

The tailored server software consists of a simple www-presentation system (home page of the site shown in Fig. 1) and a few special programs written in PHP4, Java and FORTRAN.

Figure 1. Home page of the EMARAD site.

3 NPP accident consequence data

3.1 Calculations

The calculations (see Tables 1–3) were performed by VTT with the computer code VALMA (Ilvonen 2002). The meteorological data were provided by FMI. They consisted of SILAM particle trajectory files based on retrieved HIRLAM archive data (Sofiev et al. 2006, HIRLAM 2006). Depending on the scenario, the dispersion of release clouds was followed up to 50–67 hours. FMI also prepared written weather descriptions.

Table 1. Nuclear power plants considered in calculations and corresponding scenario-related data.

Site and type of reactor	**Date and time of trajectory data**	**Source term category** (Table 2)	**Duration of release** (h)	**Release height** (m)	**Max. time for dose calculations**
Barsebäck, Sweden (BWR)	18.6.2002 06...12 UTC	A	3	0-100	50 y
Forsmark, Sweden (BWR)	15.6.1998 06...18 UTC	B B B B B	3 3 12 12 3[a]	25-35 240-260 25-35 240-260 30[a]	50 y 48 h 48 h 48 h 48 h
	20.8.1998 06...18 UTC	B B B B	3 3 12 12	25-35 240-260 25-35 240-260	48 h 48 h 48 h 48 h
Ignalina, Lithuania (RBMK)	25.5.2003 00...12 UTC	C C	3 12	20-30 20-30	48 h 50 y
Kola, Russia (PWR)	24.5.1998 06...18 UTC	B B B B	3 3 12 12	25-35 240-260 20-40 240-260	50 y 48 h 48 h 48 h
	26.8.1998 06...18 UTC	B B B B	3 3 12 12	20-40 240-260 20-40 240-260	50 y 48 h 48 h 48 h
Loviisa, Finland (PWR)	25.11.2003 06...13 UTC	C C	3 7	0-30 0-30	50 y 48 h
Olkiluoto, Finland (BWR)	15.10.2002 12...15 UTC	B A	3 3	10-30 0-2000	48 h 50 y
Oskarshamn, Sweden (PWR)	8.7.2002 06...12 UTC	A	3	0-100	50 y
Ringhals, Sweden (PWR)	30.6.2002 06...12 UTC	A	3	0-100	50 y
Sosnovyy Bor, Russia (RBMK)	29.7.1998 06...18 UTC	C C C C	3 3 12 12	20-40 200-300 20-50 200-300	50 y 48 h 48 h 48 h
Tornless Point, United Kingdom (AGR)	19.6.2002 00...12 UTC and 06...12 UTC 25.6.2002 06...12 UTC	A A A	12 6 6	0-20 0-100 0-100	50 y 50 y 50 y

[a] A test calculation: grid size of 1*1 km and time step of 3.6 minutes (in other calculations the grid was substantially larger – approximately 10 km × 20 km – and time-step 15 minutes). The results of this calculation are not included in the data normally accessible to all users.

The nuclide inventories of the reactors were based on the data given in the threat-analysis report of STUK (Toivonen et al. 1993) in which the Loviisa, Olkiluoto and Sosnovyy Bor reactor inventories were used as reference inventories and scaled for other similar type of reactors. An exception is here the Torness Point AGR-reactor: its inventory was assumed to be that of a BWR reactor with the same power. Radioactive chain decay during the time between the shutdown and the starting time of each trajectory was taken into account in the calculations. No delay was assumed to exist between the shutdown and start of the release.

Table 2. Source term characteristics.

Source term category (see Table 1)	**Release nuclides as fractions of inventory**
A	Noble gases: 1 Iodine, caesium and tellurium: 0.1 Other nuclides: 0.01
B	Noble gases: 1 Iodine: 0.1 Other nuclides: 0.01
C	Noble gases: 1 Iodine, caesium, rubidium, tellurium and antimony: 0.1 Other nuclides: 0.01

The VALMA model can calculate up to 31 dose and concentration quantities. The first eleven quantities are always the same but the last 20 quantities can be specified by the user. An example of the output quantities is given in Table 3.

As can be seen in the last column of Table 1, the quantities were calculated either for a 48-hour (typically 37 points of time) or a 50-year (47 points) period. In the latter case migration and weathering effects were included but only[1] in the values of fallout gamma dose rate and fallout gamma dose (the quantities 6 and 7 in Table 3) by using the ROSA code (Rossi and Vuori 1993) that includes the well-known Gale migration model.

The grid-cell based output file of VALMA comprises the source term information and a series of records that contain the min and max longitude and latitude coordinates (in degrees) of the grid cell in question followed by up to 31 quantity values corresponding to a specific point of time. On the www server the original large output files have been divided into smaller time-labelled files in order to make it simpler to handle the data. All results and information related to the NPP accident consequence calculations can be downloaded from the server in the original format (one large output file and a separate weather description file) or as zipped archive files (the source term file, weather description file and a number of distinct data files each representing the situation at a specific point of time).

[1] Initially the aim was to adopt the migration model directly to the VALMA nuclide-decay-chain model but this proved too laborious to be realized within the project.

Table 3. Example of VALMA's output quantities.
In most calculations the output quantities were the same as below.

1	Total dose (external + inhalation)
2	Total external dose rate (cloud + fallout, all nuclides)
3	Total external dose (cloud + fallout, all nuclides)
4	Cloud gamma dose rate
5	Cloud gamma dose
6	Fallout gamma dose rate
7	Fallout gamma dose
8	d/dt_inhal of effective inhalation dose (50 years)
9	Effective inhalation dose (50 years)
10	d/dt_inhal of inhalation dose to thyroid (50 years)
11	Inhalation dose to thyroid (50 years)
12	Concentration of I-131
13	Time-integrated concentration of I-131
14	Deposition of I-131
15	Time-integrated deposition of I-131
16	Concentration of CS-137
17	Time-integrated concentration of CS-137
18	Deposition of CS-137
19	Time-integrated deposition of CS-137
20	Concentration of SR-90
21	Time-integrated concentration of SR-90
22	Deposition of SR-90
23	Time-integrated deposition of SR-90
24	Concentration of CO-60
25	Time-integrated concentration of CO-60
26	Deposition of CO-60
27	Time-integrated deposition of CO-60
28	Concentration of KR-85M
29	Time-integrated concentration of KR-85M
30	Deposition of KR-85M
31	Time-integrated deposition of KR-85M

The MySQL data base of the server does not contain the scenario-calculation data but only the information on where the specific calculation results are stored.

3.2 Displaying and modifying consequence data patterns on-line

The www server displays the pre-calculated NPP-accident consequence patterns on-line as thematic maps (Fig. 2). The user interface allows users also to scale the patterns; naturally, the quantities that can be scaled depend on the original calculated data. Users can also move the displayed patterns along latitudes and/or longitudes (translocation, see Fig. 3). These moved patterns are stored in users' home directories.

The digital maps (both normal maps with state borders and topographic maps) available on the server show Europe, Eastern Europe, Scandinavia, Denmark, Finland, Iceland or Kola peninsula and its surroundings. Because no commercial software or maps are used, the maps cannot be zoomed or panned, and only the locations of nuclear power plants are marked on them. Placing the cursor on top of a power plant symbol shows plant-related info, and placing it on top of the displayed data pattern shows the value of the displayed quantity in that specific grid cell as well as the cell coordinates.

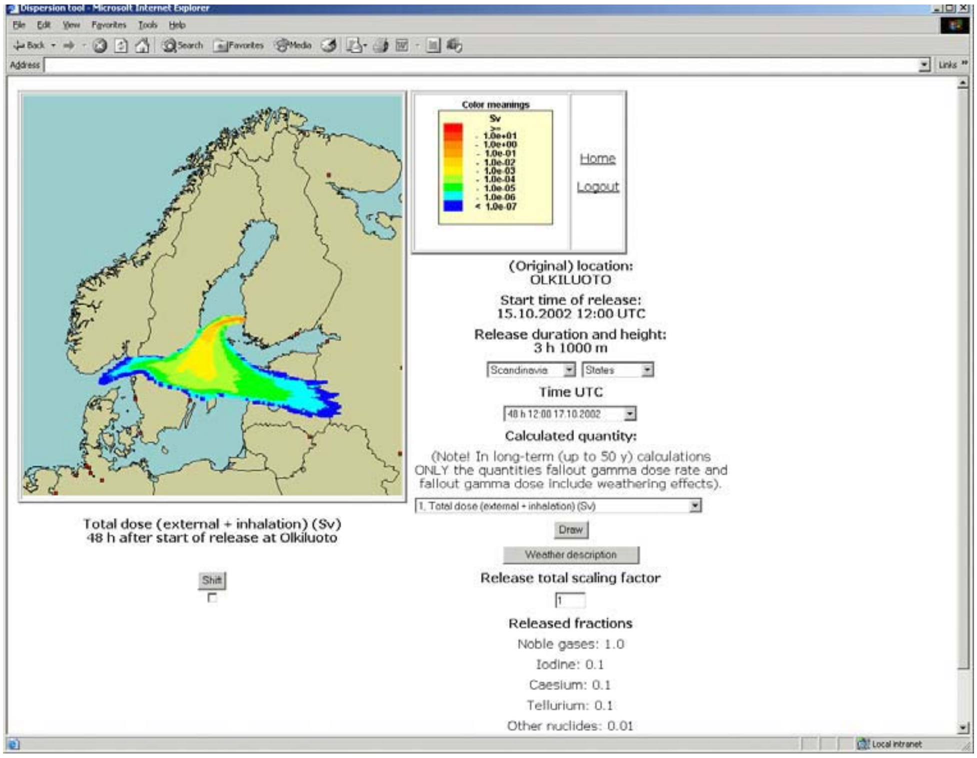

Figure 2. Example of a displayed hypothetical dose pattern and the related info on the screen.

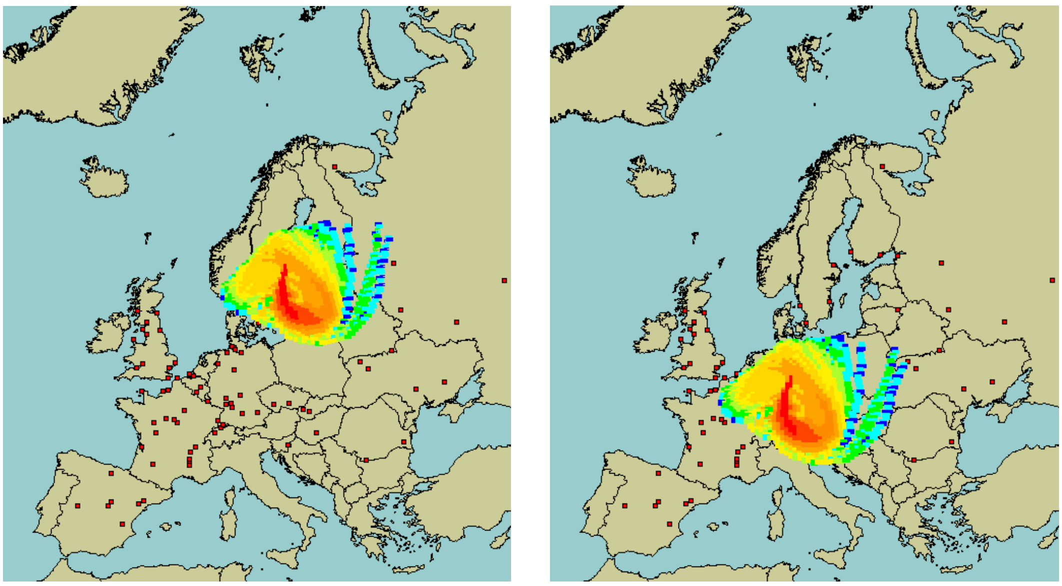

Figure 3. Example of moving a hypothetical dose pattern from the original location (Forsmark, left) to a location in northern Germany (right).
The procedure applied in moving grid cells along the longitude lines is mathematically a simple one. Thus moving a shifted pattern back to its original location does not produce a pattern that would look exactly the same as the original pattern.

3.3 Specific application programs for processing downloaded consequence pattern data

There are seven application programs in zip files that can be downloaded from the EMARAD web server to be applied to processing downloaded (zipped) NPP-accident-scenario consequence data. The source code is included in the download packages. The programs are:

- Emarad_calculate_area
  - Calculates total areas of consequence patterns given in the data files.
- Emarad_find_pattern
  - Searcher for those grid cells in data files that satisfy given dose quantity conditions.
- Emarad_move_pattern
  - 'Moves' the pattern to another location, i.e. changes grid cell coordinates in the pattern-data files (i.e. does the same function as shown in Fig. 3).
- Emarad_point_data
  - Creates data files for distinct locality points.
- Emarad_point_and_time
  - Puts all pre-calculated one-locality-point data (with the time information given directly in the records; see Emarad_time_stamp below) in a single file in time-ascending order. The output file can be input to Excel to produce e.g. trend curves.
- Emarad_scale_data
  - Scales desired dose-quantity values with factors given by user.
- Emarad_time_stamp
  - Adds time information to all data records (as the first numeric value of the records).

All programs are FORTRAN (Compaq Visual Fortran Professional Edition 6.6.0) console applications without any graphical Windows user interfaces. They are invoked with a command of the form program_name filepath, where program_name is the name of the program to be executed and filepath is the file path of the program's initialization file. The exact contents of the initialization files depend on the program. The programs use also many other input files and produce various output files. In most cases the data output files of a specific program serve as input files of another program.

The programs are coded in the old-fashioned way of making FORTRAN programs. That is, all data formats are very important. If a wrong format is used, the results will be unpredictable or there may emerge severe run-time errors.

On the EMARAD server there is a downloadable guide "Emarad application programs: User guide" that describes the programs and their use in detail.

4 Dispersion in urban areas

4.1 Urban dispersion model UDM

Widely used Gaussian plume and puff models perform poorly in urban areas because of the increased turbulence around the large number of obstacles. Therefore special urban dispersion models like UDM (Urban Dispersion Model; Hall et al. 2002) are needed. This is even more important since the new radiation threats include such scenarios as explosions of radiological dispersion devices ("dirty bombs") in urban surroundings.

The urban-dispersion-related work within the EMARAD project dealt mostly with the testing of the UDM model, which is created by the Defence Sciences and Technology Laboratory at Porton Down, England. It is a simple model designed to treat the dispersion at short ranges in urban surroundings where the surface obstructions within the urban canopy (mainly buildings) modify the dispersion patterns. UDM is intended to deal with the sources at the ground level and distances between 100 m and 10 km, beyond which the dispersing plumes tend to fill the whole boundary layer and the characteristics of the surface become less important. The model can be used for both continuous and short-term releases. Its structure is such that the different dispersion regimes (within which different types of models should be used) are separated. Because of the fundamentally different approaches that need to be applied within the regimes there are no appropriate single models or types of models; the UDM, however, provides modelling procedures for all different regimes (and sub-regimes).

4.2 Example calculations and demonstrations

The model was tested using both artificial and realistic urban conditions (with non-radioactive sources). The related working reports stored on the server are:

- S. Thykier-Nielsen, J. Roed and I.H. Griffiths: Simulation of dispersion in combinations of flat, complex and urban terrain. 2004.
- S. Thykier-Nielsen: Realistic urban scenarios for Copenhagen. 2004.
- S. Thykier-Nielsen: Simulation of dispersion in urban areas: Experience gained during the EMARAD project 2002 to 2005. 2005.

Apart from the documents mentioned, there are a couple of related other presentations and documents downloadable from the server. Figure 4 shows a snapshot taken from a video demonstrating urban dispersion.

In all test cases a simple meteorological situation was assumed, all parameters – wind speed, wind direction and atmospheric stability – being constant but varying from one scenario to another. Usually a ground or near-ground source was assumed. In one case a moving source simulating a leaking tank lorry was used.

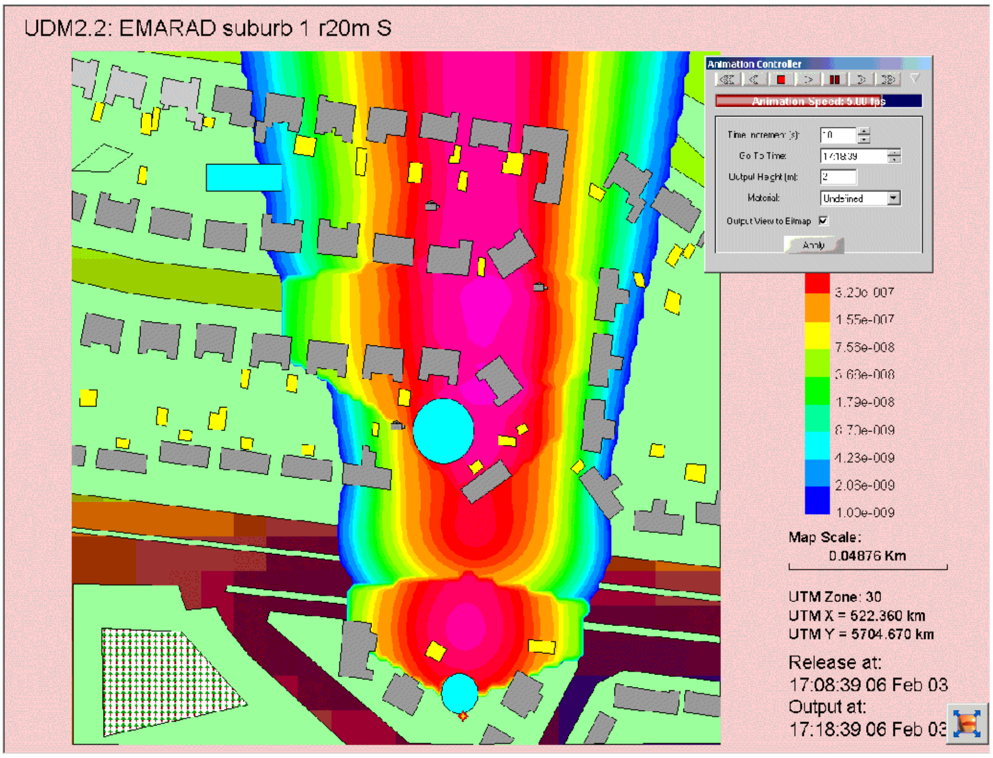

Figure 4. Snapshot taken from a video demonstrating the testing of the UDM model.

The conclusions concerning meteorological conditions were that unstable conditions and large wind speeds reduce the influence of buildings. However, the concentration patterns are very complex and even minor changes in atmospheric conditions may cause large changes in the dispersion pattern. As regards the scenarios in the Copenhagen area, the simulations showed that the actual site of the source is of large significance. When applying UDM for a source in a narrow street, artificial sources were found to be generated downwind, which as such is a typical behaviour of the UDM-type of models. Furthermore, the puffs in UDM are not horizontally isotropic because the complexity of the urban environment causes them to be shaped by the buildings (i.e. usually all the three puff sigma parameters are different).

It is clear that if the results of an urban dispersion model are to be integrated in a decision support system ultimate care must be taken. Evaluations of the effect of perturbations in the meteorological parameters should be made before defining the critical (hazard) areas. In general, the calculation results should be seen as giving an indication of the areas where high concentrations are likely to be found and as an estimate of the order of magnitude of the concentrations.

UDM is now linked to ARGOS-CN, the coming version of ARGOS, dealing especially with releases of nuclear and chemical material in urban areas. ARGOS-CN will be released in spring 2006. Furthermore, as the license of UDM, for political reasons, expires in 2007, a new Nordic urban dispersion model will be developed. The Nordic urban model will mainly be developed as co-operation between Risø and FOI (Sweden). The Nordic model is due mid 2007.

5 Malicious use of radiation

As already referred to previously, during the past few years the spectrum of radiation-related threats has been partly widened: illicite and malevolent use of radiation and radioactive sources has gained more and more emphasis. Consequently, the authorities have been forced to change their priorities at least slightly and to gather relevant information on the new scenarios. For this reason, the EMARAD project hosted also comprised activities related to malicious use of radiation.

A special seminar ”Mini-seminar on Malicious Use of Radioactive Material” was arranged in Solna near Stockholm in May 2005. Participants from the Nordic Radiation Protection Authorities and Research Institutes presented knowledge and presumptions of the prerequisites for a potential perpetrator to stage a radiological attack using radioactive material. Presentations concidered possible radioactive material that could come to use and discussed the possibility for a perpetrator to handle the material. Findings from border monitoring systems, atmospheric dispersion modelling, dose calculation and medical aspects of radiological dispersion devices were outlined. The special problems of emergency planning and response to malicious threats were discussed using four case studies. These were a lost or stolen dangerous source, a found unidentified radiation source, a suspected radioactive explosive device and radioactive material dispersed by an explosion or a fire.

The most dangerous threat would be a theft of fissile material and its use in an improvised nuclear device or the use of a complete nuclear weapon. Another possibility would be that terrorists could use radioisotopes and disperse them by conventional explosives or fire. Radioisotopes cannot produce the large-scale devastation that a nuclear device can do, but radioisotopes in the hands of a terrorist would still bring fear to society and cause social and economic disruption.

It is not a straightforward task to stage a radiological attack. The seminar concluded that a perpetrator would need at least some basic knowledge in radiation physics, get hold of suitable radioactive material and have enough financial resources to realise the plans. There must be a motive for a perpetrator to carry out this more complex operation instead of using “conventional methods” with explosives that are much easier to get hold of. The complexness may be the reason why radiological terrorism has not yet occurred. But it cannot be excluded that a radiological terrorist attack will occur some time in the future.

The problem for the rescue authorities is that the first responders generally have no experience of this situation in real life as “every-day accidents” involving radioactive material almost never happen. Special training is needed to cope with a malicious event. In the long term, it is a challenge for the society and authorities to maintain enough knowledge and skill to handle a possible future nuclear or radiological terrorist attack.

There will be a separate NKS publication “Proceedings of the NKS/EMARAD Mini-seminar on Malicious Use of Radioactive Material, held at Hotel Park Inn, Solna, Stockholm, on May 24-25, 2005” that includes the presentations and conclusions of the mini-seminar.

Apart from the seminar, also other closely-related work was carried out in the EMARAD project. The following three separate working documents or presentations were produced (they can be downloaded from the web server):

- R. R. Finck and C. Samuelsson: Malicious use of radioactive material. 2005.
- J. Roed and K.G. Andersson: The implication of airborne contamination created by an action of terror in an urban environment. 2004.
- K.G. Andersson: On factors influencing doses from deposition on humans of contaminants dispersed by 'dirty bombs'. 2005.

The first study named above aimed at addressing the problems in modelling the consequences of dirty bombs, anthrax and other pollutant spread airborne in an urban environment. The basic formulas for the relationship between indoor and outdoor contamination are given in the report together with an example table containing values of some basic parameters in case of radioactive particles originating from a major nuclear power plant accident (note that a significant part of the contamination from a dirty bomb would be associated with much larger particles than those dealt with in the report).

The second document discusses the possible impacts of a dirty bomb detonation in terms of doses from contaminant deposition to humans. The particles released from a dirty bomb incident would likely be considerably larger than, for instance, those observed over great distances after a major nuclear power plant accident. This means that the indoor deposition rate of contaminant particles would be high, and the filtration of the contaminated air by passing through the building structure would become significant. Both of these factors will in most cases (unless windows, doors and other air ducts are left open) result in a comparatively low indoor-to-outdoor contaminant aerosol concentration ratio. The influences of a number of factors on the deposition to humans are discussed. Electrophoresis (the influence on particle deposition of differences between electric voltage potentials in the various environmental surfaces, including humans) was not found to have significant effect for the rather large particle sizes probably to be of relevance in case of dirty bombs. However, the deposition of the particles on skin was clearly very strongly affected by the skin surface moisture. The largest particles arising from a dirty bomb would likely have extremely short clearance half-lives on skin, but since the deposition velocity would be very high, a significant dose contribution from the largest particles cannot be ruled out on the basis of the available information. A calculation example involving ^{90}Sr indicated that the dose from contamination on skin after a dirty bomb detonation may be three times as high as that from outdoor contaminated surfaces under the same circumstances. If the source applied in the bomb is as powerful as 1000 TBq, as some 'orphaned' sources are, the skin beta doses could well be in the Sievert-range, depending on the exact dispersion conditions.

The major result of the work is the demonstration that dirty bombs can lead to significant doses from contamination on humans, and these doses therefore need to be considered adequately in various dose models for decision support.

The issues related to doses from ‘dirty bomb’ explosions are further dealt with in (Andersson 2005).

6 On radiation monitoring strategies

In a nuclear or radiological emergency, all radiation measurements must be performed efficiently and the results interpreted correctly in order to provide the decision-makers with adequate data needed in analysing the situation and deciding on countermeasures. Managing measurements in different situations in a proper way requires the existence of pre-prepared emergency monitoring strategies. Preparing a comprehensive yet versatile strategy is not an easy task to perform because there are lots of different factors that have to be taken into account. These factors can be categorised as belonging to one of the two groups: the static group and the dynamic group. The factors in the static group are those whose status or related contents are known or available before any nuclear or radiological emergency arises where as dynamic factors are those whose contents will become clear only at the beginning (or during the course) of an accident or a specific event. Such factors as population distribution, geography and topography, fixed potential sources, routine monitoring arrangements and resources allocated to emergency monitoring represent the static group while the scenario (source term, source location) and prevailing environmental conditions are items of the dynamic group.

The general conditions and emphases laid on the different factors may vary substantially from one country to another. Correspondingly, there are also differences in the radiation monitoring arrangements and monitoring strategies chosen by individual countries, which fact is also manifested among the Nordic and Baltic Sea countries (NKS 2001).

In order to help individual countries to establish national emergency monitoring strategies and to support harmonisation of measurement activities, international organisations have published general guidelines for emergency response and radiation measurements (see e.g. IAEA 1999, OECD 2000), and the Sixth Framework Programme of the European Union includes several sub-projects that address some issues of radiation monitoring strategies (EC 2004). In addition, there are many other international publications, guides and scientific papers that partly deal with items having interfaces with emergency monitoring strategies. NKS, too, has been active in this respect.

One possible way of producing a strategy is to identify the factors mentioned above, prepare a list of simple questions based on them (such as “What are the potential threats?” and “Where and in what kind of environmental conditions are the measurements performed?”) and then answer these questions in a strategy report.

As concerns the strategy-related work within the EMARAD project, the main emphasis was put on identifying and discussing the various factors influencing practical strategies. The results of the work are presented in detail in the working report “Emergency monitoring strategy and radiation measurements” (prepared by J. Lahtinen, 2006). Here only a brief summary is given.

A monitoring strategy should be versatile and realistic and it should have provisions for various back-up arrangements needed in case of problems with the primary measuring equipment or expert personnel. A strategy, however, must not give the impression that it is universal and covers all possible situations. There may be accidents or events not included (even) in a well-defined, comprehensive strategy plan. Thus, a strategy should not kill the creativity of the emergency authorities or the use of the common sense.

In an ideal case, an emergency monitoring strategy could be defined on the basis of the following items and aspects:

- The strategy has interfaces with various societal and economic factors and takes into account all stakeholders.
- Likely threats have been identified and their consequences analysed in advance. In addition, necessary extra resources have been allocated.
- There exists a well-functioning infrastructure (measurement systems, personnel), including an early-warning system, for carrying out routine monitoring activities.
- The relations between fixed and mobile monitoring systems are defined and their main uses understood.
- General dependence of radiation measurements on the accident characteristics, source term, season, environmental conditions, measurement location and measurement method are recognised and all possible difficulties concerning the uncertainty and interpretation of results are understood.
- There are fast and reliable means of data communication.
- There exists a system for preparing situation analyses. Related problems, such as combining results from fixed networks and mobile measurements have been identified.
- There are interfaces between measurement results and different forecast or decision support systems that both enable the correction of predictions on the basis of monitoring data (e.g. data assimilation) and support the management of measurement activities on the basis of predictions.
- There are realistic yet flexible plans for sampling and laboratory measurements.
- Specific needs of mobile monitoring teams are looked after (accommodation, team shifts etc.).
- There are proven back-up systems and procedures at all levels.
- Possibilities offered by international assistance and co-operation are recognized.

In many countries the actual situation tends to be worse, however. In that case the only possibility is to create a strategy which is consistent with the framework set by the existing reality and then use the above list as “a reminder of how it should be”.

The applicability of any emergency monitoring strategy must be tested regularly in different kinds of exercises (table-top exercises, drills, field exercises). A strategy should also be updated whenever appropriate. The need of update could be generated, for example, by the identification of a new threat scenario or by the acquirement of a new type of measuring equipment.

Some of the strategy-related conclusions drawn and ideas generated during the work of the EMARAD project have been published in scientific journals (e.g. Lahtinen 2004, Lahtinen et al. 2006).

7 On use of communication technology for emerency preparedness

In recent years communication technology has played an ever increasing role in nuclear and radiological emergency preparedness. The reaction time requested by modern societies is getting shorter and shorter. The modern media is able to set up live satellite based news broadcasts from almost any place on the earth. The authorities must be able to respond and provide assessments and guidance as quickly as possible. Another complicating factor is that the experts in this highly specialised field are rather few and it can be important to be able to contact a given expert and enable him/her to work wherever he/she might be located. Communication technology plays a key role here.

More and more measurement and decision support systems are being automated, but a common interface for the different systems (and in different countries) is still to be defined. Different communication protocols are in use, each may have its own advantage, but how should one be chosen for common use?

Even the choice of how web technology is used is not as simple as it would seem at first sight. Many web sites may appear to the ordinary user to be advanced and serving their purpose well. Yet when one tries to print the information the right hand side of the displayed text may be missing. In reality there have been substantial improvements in standardization of web technology, but most web sites are still based on older standards and technically outdated (Zeldman, 2003). As a consequence their performance is very browser specific and usually formatting code is mixed with the actual contents. For emergency preparedness this means that far more stringent requirements need to be placed on the communication channels than would be the case if new standards were properly used (high bandwidth may be required were very low bandwidth might have been sufficient). This also means fewer opportunities for using mobile devices (e.g. telephone with web browsers) that are becoming more integrated into emergency response systems.

Communication technology is a rapidly expanding field, with no one expert having a complete overview. This makes it difficult for potential users to identify the pitfalls and the possibilities the new technique may offer.

7.1 Aim with EMARAD work on communication technology

The aim with the EMARAD work on communication technology was to have a forum for exchange of ideas and descriptions of experience between the Nordic authorities dealing with radiological and nuclear emergency preparedness. The aim was not to develop any new systems, but to make as efficient use as possible of the existing technologies and be aware of the possibilities that emerging technologies might offer. This lead to the NKS-B CommTech seminars.

The original idea behind the first CommTech seminar was to bring together key users from the Nordic nuclear and radiological emergency response authorities on one hand and leading experts in different fields of communication technology on the other. The hope was that this could encourage a dialogue that would then continue and make it easier for these authorities to co-operate and use communication technology more effectively. This idea was first discussed at a meeting of representatives from the Nordic authorities dealing with radiological and nuclear emergency preparedness (the NEP group). The group suggested that this should be organised as an NKS seminar and asked Sigurður Emil Pálsson to organise it, since he had previously been active in presenting issues concerning the use of communication technology at NEP meetings (e.g. integration of web and mobile phone technologies).

7.2 The NKS-B/CommTech seminars 2003 and 2005

The first CommTech seminar was held at STUK, Finland, in the spring of 2003 with 25 participants. The seminar lead to exchange of views and discussions, but it was also clear that some of the leading Nordic experts had not been involved and some of the relevant international work had not been presented. Since the first seminar was less expensive to conduct than expected and the NEP group considered a follow-up to be worthwhile, then permission was sought from the NKS Board to use part of the remaining funding to organize a new seminar, taking into account weaknesses identified at the first seminar and subsequent technological developments. It proved difficult to find a time suitable for all key participants until May 2005. Then the second seminar was held at SSI, Sweden, with 19 participants.

Presentations from the seminars can be accessed from the NKS web site (under NKS-B, results, CommTech) as well as some other material (e.g. code) and on the new NKS DVD. A report is also being compiled.

The dialogue on use of communication technology for emergency preparedness has strengthened in the Nordic countries. It has become a regular item on the agenda of NEP meetings and the XML format has now come into widespread use internationally. There has been an active exchange of ideas and experiences between the Nordic authorities and they have now taken an active role in international work on the utilization of communication technology (e.g. within the IAEA as providing members to the working group on communication). The NKS-B/CommTech work has now come to an end, but hopefully it has contributed to build up awareness, Nordic co-operation and competence in this field.

8 Conclusions

The purpose of the NKS project EMARAD was to provide the Nordic radiation monitoring authorities with a tool that would help them to prepare emergency plans and monitoring strategies.

The deliverables of the project can be summarised as:

- A website storing the data and documents produced in the project.
- Downloadable NPP accident consequence data calculated for ten power plants located in or close to the Nordic countries. The total number of scenarios is 32 (one to eight per power plant).
- A selection of special application programs that can be used to process the downloaded NPP accident consequence data.
  - J. Lahtinen: Emarad application programs: User guide. 2006.
- Various downloadable demos, working documents and presentations addressing the testing of the British UDM model (Urban Dispersion Model), urban dispersion in general and various aspects of malicious use of radiation.
  - S. Thykier-Nielsen, J. Roed and I.H. Griffiths: Simulation of dispersion in combinations of flat, complex and urban terrain. 2004.
  - S. Thykier-Nielsen: Realistic urban scenarios for Copenhagen. 2004.
  - S. Thykier-Nielsen: Simulation of dispersion in urban areas: Experience gained during the EMARAD project 2002 to 2005. 2005.
  - J. Roed and K.G. Andersson: The implication of airborne contamination created by an action of terror in an urban environment. 2004.
  - K.G. Andersson: On factors influencing doses from deposition on humans of contaminants dispersed by 'dirty bombs'. 2005.
  - R. R. Finck and C. Samuelsson: Malicious use of radioactive material.
  - Five demo presentations on urban dispersion prepared by Risø.
- Dialogue on the effective use of communication technology amongst the Nordic authorities dealing with radiological and nuclear emergency preparedness (NEP group). This was done via the CommTech seminars and presentations at NEP meetings. Presentations from the seminars can be found at the NKS web site and in a report being compiled.
- A special working document on the general factors affecting radiation monitoring strategies.
  - J. Lahtinen: Emergency monitoring strategy and radiation measurements. 2006.

In addition to the above, there is a separate NKS publication "Proceedings of the NKS/EMARAD Mini-seminar on Malicious Use of Radioactive Material, held at Hotel Park Inn, Solna Centrum, Stockholm, on May 24-25, 2005".

To conclude, the project produced both reference data and background information that help the authorities in their efforts to prepare emergency plans and monitoring strategies. The data stored on the web server can be used in emergency exercises and in training, too. As a whole the project also contributed to the exchange of information and ideas between the participating organisations and thus enhanced the mutual co-operation.

Some results of the work carried out within the framework of the project have been published in scientific reports and journals or presented in conferences.

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11 Disclaimer

The views expressed in this document remain the responsibility of the author(s) and do not necessarily reflect those of the NKS.

In particular, neither NKS nor any other organization or body supporting the NKS activities can be held responsible for the material presented in this report or stored on the EMARAD web server.

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Abstract

In order to manage various nuclear or radiological emergencies the authorities must have pre-prepared plans. The purpose of the NKS project EMARAD (Emergency Management and Radiation Monitoring in Nuclear and Radiological Accidents) was to produce and gather various data and information that could be useful in drawing up emergency plans and radiation monitoring strategies. One of the specific objectives of the project was to establish a www site that would contain various radiation-threat and radiation-monitoring related data and documents and that could be accessed by all Nordic countries. Other important objectives were discussing various factors affecting measurements in an emergency, efficient use of communication technology and disseminating relevant information on such topics as urban dispersion and illicit use of radiation.

The web server is hosted by the Radiation and Nuclear Safety Authority (STUK) of Finland. The data stored include pre-calculated consequence data for nuclear power plant accidents as well as documents and presentations describing e.g. general features of monitoring strategies, the testing of the British urban dispersion model UDM and the scenarios and aspects related to malicious use of radiation sources and radioactive material. As regards the last item mentioned, a special workshop dealing with the subject was arranged in Sweden in 2005 within the framework of the project.

This report describes the EMARAD project and the work performed and results obtained. The report is complemented by another EMARAD publication "Proceedings of the NKS/EMARAD Mini-seminar on Malicious Use of Radioactive Material, held at Hotel Park Inn, Solna Centrum, Stockholm, on May 24-25, 2005".

Key words: Emergency preparedness; Radiation monitoring strategy; Emergency measurements; NPP accident consequences; Illicit use of radiation; Urban dispersion; Web-based library; Communication

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