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Article

Implementation in ARGOS of ERMIN and AGRICP

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ABSTRACT **The ERMIN model is a new implement developed to enable estimation of the radiological consequences in inhabited areas of accidents in nuclear installations. Similarly, AGRICP is a model developed to enable estimation of the radiological consequences of contamination of agricultural production areas. This paper provides a short overview of the background of the two models and describes the features enabled through their implementation in the ARGOS decision support system. The integration allows calculation of both dose rates and doses in particular areas, and can be used to evaluate the effectiveness and costs of countermeasure strategies.**

Introduction / background

ERMIN is an acronym for "European Model for INhabited areas" and is a novel model, developed within the EC FP6 EURANOS project, for calculating the radiological consequences within inhabited areas of accidental airborne releases of radioactive material, from nuclear installations (Jones *et al.*, 2006). A series of detailed calculations of doses received over the first two decades after a nuclear power plant accident have demonstrated that a number of different dose contributions may be important to take into account (Andersson and Roed, 2006). When considering contamination in inhabited areas, doses from ingestion will often be of limited relevance, as food is normally produced in other types of areas, but important contributions may, dependent on the exact contamination scenario, include external doses from contamination deposited on soil/grassed areas, trees and other vegetation, paved horizontal surfaces, outdoor building surfaces (external walls, roofs), and indoor building surfaces. Further, doses from contaminant inhalation can be important, particularly in the early phase, where air concentrations from the initial contaminating plume may be high, and later on, from contaminants resuspended in the air. The ERMIN model is the first full dynamic model so far that

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enables detailed estimation of all dose contributions received in inhabited areas in the intermediate and long term phases following an accidental release.

In ERMIN, the initial contamination level on the various surfaces is expressed relative to the level on a mown (shortly cut) grassed reference surface. Both results from the Atmospheric Dispersion Model (ADM) RIMPUFF and from gamma dose rate measurements can be used to generate initial contaminant concentrations on the reference surface in ERMIN. Measurements are processed by the Inhabited Area Measurement Module (IAMM) before they are fed into ERMIN. The deposition velocity of particles, and thereby the initial relative contamination level on a surface, will depend on the aerosol size. ERMIN therefore groups potentially important particulate radionuclides in two aerosol size categories, according to the likely processes of aerosolisation (evaporation/condensation or physical fragmentation caused by the explosion). Also the deposition of elemental iodine gas is modelled differently, due to its high deposition velocity to the different surfaces. For each of the two aerosol groups as well as for elemental iodine, ERMIN is equipped with a data library that, on the basis of measurements made after the Chernobyl accident and other experimental work, provides factors representing the likely initial contamination under different deposition conditions with varying precipitation. The subsequent redistribution of the contaminants deposited in the environment, due to "naturally" occurring processes is in ERMIN for many of the surfaces represented by sets of empirical equations based on a review of time-series observations (*e.g.*, Andersson *et al.*, 2009; Andersson, 2009). Both external doses and inhalation doses from resuspension of deposited radioactive matter are modelled dynamically in ERMIN, both for outdoor and indoor contaminants. For inhalation dose contributions from resuspended matter, dose conversion factors are available from the publications of the ICRP (1995), whereas for external gamma dose contributions, a library of factors obtained through detailed Monte Carlo calculations of photon transport in various types of inhabited environments has been generated. The environments are characterised by the amounts, dimensions and locations of different surfaces, and their material characteristics (material type, density, thickness) (Meckbach *et al.*, 1988; Jones *et al.*, 2006).

ERMIN also allows estimation of the effects of countermeasures on the activities and doses, the amounts of waste arising from the countermeasures and the costs of the countermeasures. It is essentially possible to estimate the implications of implementation of practically any foreseeable combination of the countermeasures described in the EURANOS inhabited areas handbook (Nisbet *et al.*, 2009a), each countermeasure being initiated at any chosen time. It is assumed in ERMIN that the implementation of each countermeasure occurs over a period of time, as would be the case in reality. By comparison with other ERMIN model runs where no countermeasures are assumed to be implemented, saved doses can be estimated, and extra doses to remediation workers can also be estimated by setting appropriate exposure times and locations.

AgriCP is an acronym for "AGRIcultural Countermeasure Program" and is a model designed to estimate the effects of all kinds of agricultural countermeasures directly when simulating the transfer of radionuclides through the food chain. The underlying food chain and dose model is a further development of the FDM model that was in turn based on the ECOSYS model developed as far back as the late 1980's (described in detail by Müller and Pröhl, 1993). The ECOSYS model has however continuously been refined, and also Nordic adaptation efforts are currently being made (Nielsen and Andersson, 2008), to create a foundation that can be used for better integration of the host of recent data obtained on for instance soil-to-crop transfer factors for different types of soil, deposition velocities of different contaminant aerosols to crops, soil contaminant leaching rates, fixation rates, desorption rates and resuspension enrichment factors, animal metabolism parameters, and natural crop contamination weathering parameters. At the same time, this study derives more locality-specific values for Nordic countries for parameters like consumption habits, foodstuff import fractions, seasonal variation in crop growth in different climates (leaf area index) and local animal feeding regimes. The countermeasure data that has been implemented is based on the descriptions in the EURANOS handbook for assisting in the management of contaminated food production systems (Nisbet *et al.*, 2009b).

Methods

In this section, the implementation of ERMIN and AGRICP in ARGOS is described.

ERMIN

In the ARGOS system, the ERMIN and IAMM codes are located in the libraries "libERMIN.DLL" and "libIAMM.DLL", respectively. These libraries have been ported to the Microsoft® Visual Studio 2005 and Intel® Visual Fortran 9.1 compiler for use in a Microsoft® Windows 32-bit environment. When ARGOS starts, these libraries are automatically loaded.

The ERMIN model integration uses a grid to represent the geographical area in which to run the model, called the "Area of Interest" (AOI), being a dynamic subset (sub grid) of a larger "base grid". Within the confines of the base grid, model parameters can be filled describing demographic information (population) as well as defining how the urban environment is composed with regard to building types and amount of vegetation and pavement; this is called an "Environment Breakdown".

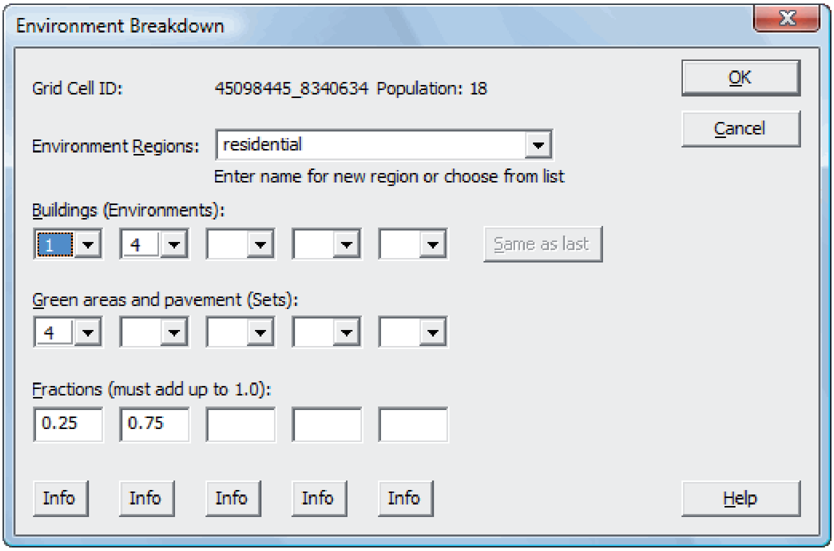

Figure 1 – ***The "Environment Breakdown" screen of ARGOS, where building types and fractions of paved and unpaved horizontal areas can be entered.***

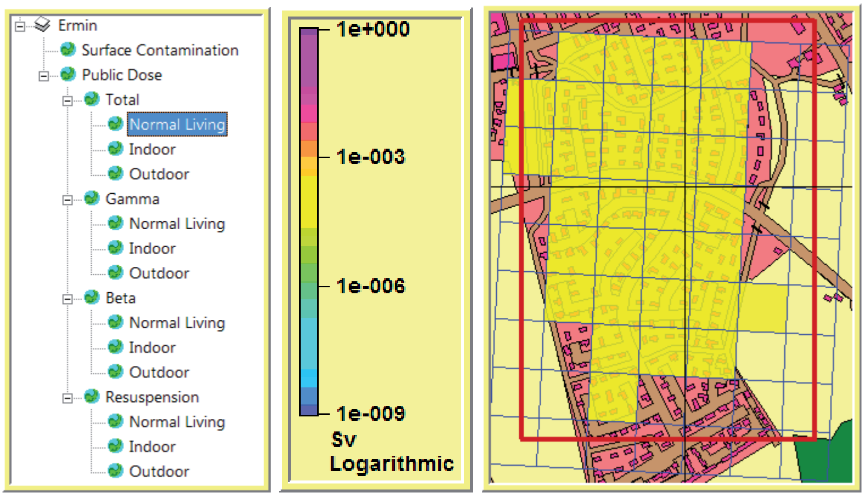

Figure 2 – ***Three parts of the ARGOS User Interface for ERMIN: The ERMIN selection tree on the left, the value colour palette in the middle, and the ERMIN grid cells on the right, with colour coded values for the selected dose.***

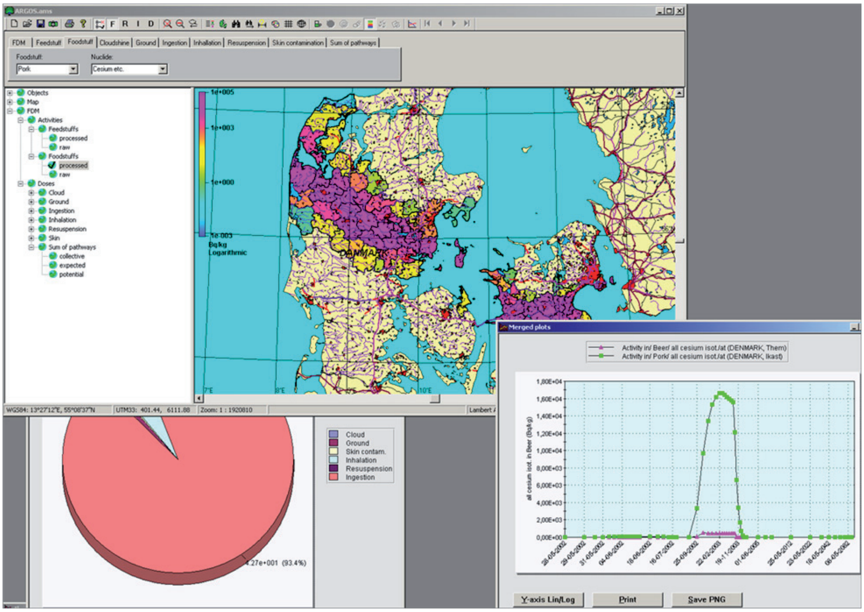

Figure 3 – ***Various possibilities for using AGRICP results: overlay on the map, a Time Dependency Plot for selected municipalities, and a Pie Chart showing dose contribution from different pathways.***

A set of 64 decontamination and remediation techniques is used in the ARGOS DB-editor for building a strategy. These techniques are described in detail in Nisbet *et al.* (2009a). Once defined, the strategy is passed to ERMIN in a function call, then ERMIN calculates and a number of output map files are produced, each giving the values (in the AOI) for a single end-point.

AGRICP

AGRICP, like the previous food chain dose model, FDM, is centered on municipalities, represented by polygons. AGRICP is an external executable that, after being started, will enter a synchronized dialogue with ARGOS, in which an input (represented by a “tasklist”-file) will produce an output (represented by “graphics”-files). This loose coupling allows for a more simple integration, but it has the drawback, that should an error occur in the model, ARGOS cannot initiate an appropriate error handling.

TABLE I.
Overview of the integration features of ERMIN and AGRICP as established in ARGOS.

	ERMIN	AGRICP
Model coupling	Tight integration – if it fails, an error code is passed to ARGOS	Loosely coupled – if it fails, ARGOS has troubles finding out why
Environment	Urban environment – walls, roofs, pavements, roads, parks	Rural environment – fields, soil, plants, roots, leaves, grain, feed, dairy products, meat
Locations	Selected area (AOI)	Municipalities affected by plume or measurements
Entity (dimension)	Grid cells (2520) – local scale	Municipality polygons (2500) – regional scale

Two modes of operation exist: 1) a manual mode, where a single "run" either produces a map layer to be overlaid on the normal ARGOS map or a chart dataset (histogram/pie chart/line chart) to be shown in a separate window; and 2) an automatic mode, where a "screening" function categorises all affected municipalities into groups (portfolios).

A set of 14 predefined countermeasure options have been defined by AGRICP for use by countermeasures in ARGOS. A strategy containing a subset of CM options and their parameters can be passed from ARGOS to AGRICP in an XML-file, and an output file, containing all results of the calculations for the strategy, can be returned.

Results / conclusions

The ERMIN and AGRICP models, for estimation of the radiological consequences of airborne radioactive contamination in respectively inhabited and agricultural areas, have been integrated in the ARGOS decision support system. The integration features have been described above with respect to key screen selections and adaptability features for specific case studies. The two newly integrated models allow radiological estimates in a large number of different grid cells or municipalities, representing either inhabited or agricultural areas. The modules further allow assessing the effectiveness and cost of countermeasures with respect to the target of reducing doses down below an agreed reference level (and further down if cost-effective). In this way the new tools provide valuable and also basic background material for decision makers for initiating but also justifying different countermeasure strategies and determining an optimised solution for the specific case. It should of course be remembered that a wide range of other types of costs and risks (*e.g.*, social) are important in the overall assessment of the contamination situation, and should therefore considered in the decision making process. Radiological risks may in some cases even be insignificant compared with the disruptive effects on society that could be introduced through implementation of a given countermeasure strategy. It should also be noted that although the ERMIN model concept would also in principle be suitable for estimation of the implications of a malevolent use of radioactive material (*e.g.* the explosion of the radiological dispersal device – RDD – which would be likely to occur in a highly populated area, where the scare effect would be greatest), it would for that purpose require the complete re-parameterisation of the model. The reason for this is that the physicochemical properties of aerosols from plausible atmospheric dispersion scenarios of an RDD would generally be completely different from those encountered at greater distances from a nuclear power plant accident. For instance, large and insoluble particles would have a very high deposition velocity to horizontal surfaces and very effectively be removed from impermeable surfaces by wind and weather as well as by forced decontamination.

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