7.21 SAFE-AIR VIEW: A DECISION SUPPORT SYSTEM FOR NUCLEAR EMERGENCIES

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INTRODUCTION

The Joint Research Centre in Ispra (JRC), Italy, is one of the research institutions of the European Commission. Its mission is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policy, independent of special interests, whether private or national.

Within its mission, the JRC Ispra has long been running nuclear installations for research purposes. The nuclear licences for such installations, issued and verified by the Italian control authorities, require also the management of any nuclear accident originating in its facilities.

At JRC Ispra it has been implemented, by the Unit for Safety, Security and Radiological Protection (SSRP), a programme for the surveillance of radioactivity levels in the environment in nuclear emergency conditions. Such a programme requires also the organisation of nuclear emergency exercises on a regular basis, which are aimed at two main tasks: testing the capabilities and efficiency of tools and personnel for the management of accidental situations within the JRC premises; provide immediate countermeasures and a valid support to decision makers in charge for the implementation of intervention actions outside the JRC premises.

The SSRP Unit has long used reference technical documents *Cuoco A. et. al.* (1965), *Clarke R.H.* (1979), to predict the patterns of radioactive contamination within the environmental compartments (ground, airborne, food, etc) and the consequent dose absorbed by the target population, in case of release of radioactivity by a nuclear installation. The technical documents refer to mathematical models and provide calculation tools for the performance of such prediction. The results of these calculations are then compared to the reference dose and radioactive concentrations limits issued by the Italian authorities *Pucciarelli* (1998) for the possible implementation of intervention actions (sheltering, evacuation, food ban, etc).

The mentioned mathematical models are based on conservative assumptions and general purposes standard data sets about the site characteristics where the nuclear accidents occurs (flat terrain, elevated release, Gaussian plume, constant wind directions, particular wash out coefficients, population habits and age distribution, boundary conditions, etc.). The information provided by these models in terms of radioactivity concentration in the environmental compartments are therefore a first gross but cautious indication, leading generally to an overestimation of the hazard.

In the course of the years many things have been changing and improving. The reference scenarios of nuclear accidents at JRC Ispra have been changing with the research programs (ranging from one scenario of a single radioisotope release by the stack of an operating research reactor, to over twenty scenarios involving various release heights, isotopes and boundary conditions in the decommissioning of nuclear facilities, production of radioactive waste, etc). The site characteristics of the region around the JRC site have been changing (population and buildings distribution and growth, life and diet habits, etc.). New mathematical models, other than the Gaussian ones, have been developed and are executables on PCs, able to take into account specific local conditions, as the real geo-morphological site characteristics (presence of several lakes, hills and mountains, etc). The radiation protection standards have provided new dose limits for new population age classes. The requirements in communication strategies ask for visible answers and rapidity of information exchange.

It was therefore necessary to implement a PC based software for the prediction of the radiological impact on the environment and on the population around the JRC Ispra site caused by any accident occurring at any nuclear facilities within the site. For this reason the SSRP Unit has developed with other partners a specific decision PC based support tool, whose characteristics are described in this paper. The developed SW is the first implementation of GIS technology applied to an existing MS-DOS™ mode validated model for wind field definition, calculation of atmospheric dispersion and concentration of pollutants at receptors. The software has been designed as to be able to superimpose, for each point in an area of 50 km radius from the JRC Ispra, layers of information coming from customisable databases. The result is a friendly-user Windows™ based software, able to quickly calculate and display values of ground and air radioactive contamination around JRC Ispra, following an accidental release of radioactive substances from within a JRC Ispra nuclear installation.

MATERIALS AND METHODS

The new SW requisites were planned to have the possibility to:

- calculate in every single moment the ground and airborne particulate contamination in an area within a radius of 50 km from the source point and for a virtually infinite time from the beginning of the release;
- create scenarios for point sources, extended sources, stacks, or combinations of these;
- convert the contamination into dose to the population, through customisable conversion factors and according to the type of radio nuclides released;
- take into account all the meteorological conditions and measurements (temperatures at various heights, wind speed and direction, relative humidity, atmospheric pressure, solar irradiation, precipitation);
- have a model, already developed for the scope and recognised by national control authorities, which provides the simulation of the geo-morphological and social conditions in the area surrounding the JRC Ispra (seasonal roughness, buildings and dwellings distribution, hills, lakes, population and its habits) as much as possible coherent with the real conditions and to be implemented according to the foreseen accident scenarios;
- be compatible with PCs and Windows(R) platforms, have a user-friendly interface, provide output on screen, file and printer.

The new SW, named SAFE_AIR VIEW, is based on the integration of GIS technology with the model SAFE_AIR *Canepa et al.* (2000), *Canepa and Ratto* (2003), an advanced mathematical model for the definition of wind fields, simulation of atmospheric dispersion of contaminants, calculation of contaminant concentrations at sparse or dense receptors.

The SAFE_AIR code is included in the Model Database of the European Topic Centre on Air Quality of the European Environmental Agency (EEA). It has also been inserted in the list of

the air pollution models to be used for air quality purposes issued by the Italian Agency for Environmental Protection and for Technical Support (APAT).
The SAFE_AIR code is itself the combination of two sub-codes: WINDS (Wind-field Interpolation by Non-Divergent Schemes) and P6 (Program Plotting Paths of Pollutant Puff and Plumes). These two codes lack of graphic interface, require input as text files and give text outputs that can be handled with commercial SW.

The WINDS model is a diagnostic tool for the calculation of three-dimensional wind fields in complex terrain, based on mass conservation hypotheses. The WINDS input data about wind are very flexible, e.g.: uniform geostrophic wind; wind data from fixed meteorological stations on Earth and/or from vertical profiles, as meteorological towers, SODAR, LAM; use of the internal boundary layer theory *Castino and Tombrou* (1997).
Furthermore, in order to obtain accurate results, other data input like orography and seasonal roughness have to be furnished.

P6 is a pseudo-Lagrangian multi-source model that makes use of both Gaussian plume segments and puffs to simulate airborne pollutant dispersion: in such a way it allows to deal with numerical simulation of both non-stationary and inhomogeneous conditions. Every plume element develops according to different conditions found along its trajectory. The resulting ‘chain’ of elements gives a better description of pollutant dispersion than a ‘rigid’ plume, as in traditional Gaussian models, but the simplicity of the Gaussian formulation is maintained. In order to obtain accurate results, particular care has to be given to data input, like 3D wind field (from the WINDS model), orography, and time resolution.
The “simulation time” is the time, typically of the order of few hours, during which the diffusion phenomenon, which is numerically simulated, is assumed to last. The “simulation time” can be divided into an arbitrary number of “meteorological time step”, each of them with a typical duration of 30-60 minutes (with a 15 minutes minimum physical limit). During each “meteorological time step”, the meteorological and emission conditions are updated, in order to describe non-stationary conditions. In this way the P6 model allows the management of temporal steps of quasi-instantaneous emissions of contaminants.
The model sequence fixes a stationary period, calculates the meteorological step, calculates the emission step and evaluates the total simulation time. In each step of the entire simulation it is possible to change the meteorological conditions and the emission data.

The GIS environment allows a direct interaction with the territory elements in which the simulation takes place, using real data represented in geo-referenced cartography. The super-imposition of multiple layers allows the contemporary visualisation of multiple information (thematisms). Therefore, a strong initial effort has been put in the preparation of the cartography sets (as ESRI shape-files), which has then revealed to be time saving during the simulations. Other than a complete coherence with real data, the GIS offers the possibility to easily implement the official cartography with user’s data as well as to create new ones by means of a GIS package.

The advantages of a system as that described above are many: no need of interaction with the text mode input files (though this feature still remains); all the input data and scenarios are kept in an easily accessible, customisable and organised database; the wind field, as well as the contamination patterns in the airborne particulate and on the ground, can be visualised and customised by means of advanced graphic tools (it is possible to see the contaminant cloud moving as time passes); the graphic outputs can be exported to be used with other programs.

The specific layers of information that are handled by SAFE_AIR VIEW are:

- use of soil (agriculture, industry, dwellings, etc)
- administrative areas
- age classes for population
- orography obtained by refined high resolution DEMs
- roughness as a function of the soil use, with correction factors provided by literature
- various map formats (binary, ASCII, Raster)
- maps reduction to 5 different resolutions (50, 100, 250, 500, 1000 metres) for different run-times
- official Regional technical cartography 1:10000 for zooming purposes
- geo-referenced buildings and installations at JRC Ispra
- distribution on the territory of meteorological stations, emission sources, receptors

A practical consequence, under the radiation protection point of view, of the flexibility of such a system is given, for example, by the possibility for the user to customise the age classes in which the population may be divided. In fact, the conversion factors, which provide the dose to the population versus the radio nuclides intake, are age-dependent. The radiological protection standards, set out after long years of research in radiation dosimetry, have been improving from a simple classification into infants (< 1 year old), children (5 to 7 years old) and adults (> 17 years old), into a more detailed classification: < 1, 1-2, 2-7, 7-12, 12-17, > 17 years old, with new pertinent conversion factors.

RESULTS

The software, named “Safe_Air View”, is an easy Windows™ type and intelligent interface, where most of the features can be customized and recorded (accident scenarios, radio nuclides databases, dose conversion factors, crops and population distribution, source terms, meteorological profiles, maps and others). The interface drives the model by a continuous and sequential input-output process, performing a semi-real time simulation. Redundant checks during each step prevent errors in the model runs. Output graphs and tables can be exported or plotted. The GIS environment offers the possibility to relate radionuclide concentrations with population distribution and other geo-referenced maps of contamination, in a geographic view.

CONCLUSIONS

The Safe_Air View software is a valid decision aid tool for the JRC Ispra off-site nuclear emergency planning and management.

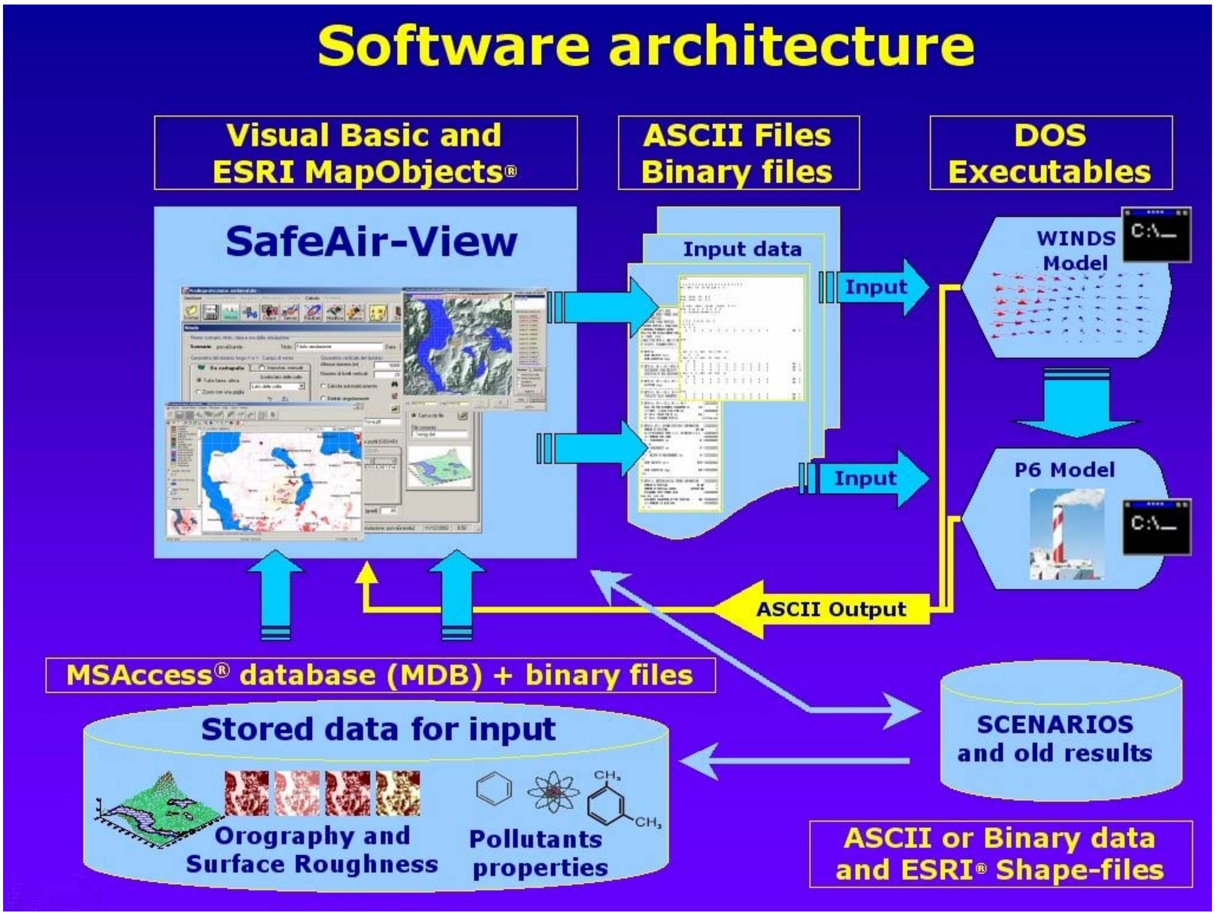

Figure 1. Software architecture of SafeAir-View

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