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# Radiological Assessment and Optimization

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WITHIN THE NUCLEAR-FISSION SAFETY domain, there are still ample needs for R&D work to optimize the radiological protection of the population and the environment.

Radiological optimization is one of the basic principles in each radiation-protection system. It is a basic requirement in the safety standards for radiation protection in the EC and has been laid down in the legislation of many European countries, including Belgium. However, its implementation and practical application still pose many problems, which SCK•CEN contributes to overcome through this project.

Radiological assessments constitute an important part of radiological optimization. Areas needing such evaluations include accidental releases and environmental site contaminations, and land disposal of radioactive waste. In case of an accidental release into the atmosphere, expected radiological consequences to the population have to be assessed both in the early phase, as soon as possible, and in the late phase, to introduce appropriate countermeasures or remedial actions. Techniques are under development to assimilate early off-site monitoring data to obtain a comprehensive picture of the main contamination and dose fields.

## Objectives

- to implement the ALARA principle in activities with radiological consequences;
- to develop methodologies for radiological optimization in decision-aiding;
- to optimize radiological assessment models by validation and intercomparison;
- to improve methods to assess in real time the radiological hazards in the environment in case of an accident;
- to develop methods and programmes to assist decision-makers during a nuclear emergency;
- to support the policy of radioactive waste management authorities in the field of radiation protection;
- to investigate (with a view to the application) existing software programs in the domain of multicriteria analysis;
- to organize courses on off-site emergency response to nuclear accidents.

**Programme** Within the framework of the fourth EC Radiation Protection Research Programme (DG XII), SCK•CEN co-ordinates the project RESTRAT (REstoration STRATegies for radioactive-contaminated sites and their close surroundings) and participates in the development of RODOS (Real-time On-line DecisiOn Support system), a comprehensive decision-support system for nuclear accidents in Europe.

RESTRAT chiefly aims to develop a generic methodology for ranking restoration techniques as a function of site characteristics in a radiological optimization framework. It uses five contaminated sites as example cases: the Drigg disposal site (United Kingdom), the Ravenglass estuary (United Kingdom), the Ranstad tailing site (Sweden), the lake Tranebärssjön at Ranstad (Sweden), and the river Molse Nete (Belgium).

RODOS aims to assimilate and analyse continuously data and information (for example, plant, meteorological, and monitoring data) during the progression of an accident. It predicts the actual and future environmental contamination fields, establishes a ranked list of feasible countermeasures, based on preselected criteria, and indicates the advantages and drawbacks of each countermeasure, as guidance for decision-advisors and decision-makers. SCK•CEN's contribution is related to the quasi real-time assessment of the radiological situation in the environment during the early phase, based on the comparison of model predictions with limited environmental-monitoring data sets in the near field (less than 30 km).

Our department also carries out, on behalf of the EC (DG XI), a study contract called CARE (investigation of possible basis for a Common Approach with regard to the REstoration of areas affected by lasting radiation exposure as a result of past or old practice or work activity). The contract foresees four major tasks: the identification of areas concerned, the assessment of radiological impacts for normal evolution and accidental scenarios, the identifica-

tion, characterization, and selection of restoration options, and the derivation of intervention criteria. SCK•CEN contributes to Tasks 1 and 3 (physical restoration options).

In the field of impact assessment of radioactive contaminations or releases of radioactive substances in the environment, our department optimizes models for evaluating biospheric concentrations and doses to man. To keep in touch with the international developments in that field and to upgrade our assessment models, we are participating in international validation studies (see BIOMASS in "Environmental Restoration," page 24).

On behalf of Belgian nuclear operators and in consultancy with the responsible authorities for the national emergency plan, SCK•CEN is continuously involved in the definition of improved methodologies and new software tools to assess the radiological consequences in case of accidental releases.

Radiological optimization studies are also required for the restoration of radioactively contaminated sites (see "Environmental Restoration," page 24) and shallow-land burial of radioactive waste, as a support to the policy of the competent authorities (decision-aiding).

Regarding the behaviour of radiocaesium in soils (natural, seminatural, and agricultural ecosystems), a PhD thesis aims to develop a dynamic multisite, multireaction retention model based on the fundamental physicochemical caesium sorption properties on clay minerals. This model will predict the time evolution of the bioavailable fraction of the radiopollutant present in the soil compartment as a function of the soil characteristics.

The development of group support systems is a new important item in our programme.

**Restoration strategies** In the framework of RESTRAT, SCK•CEN co-ordinates the tasks in the various working packages:

- example case studies;
- physicochemical phenomena governing the behaviour of radioactive substances;
- documentation on restoration techniques;
- elaboration of a risk-assessment model;
- selection of restoration options;
- elaboration of a manual.

In addition, we have been mostly involved in documenting physical restoration techniques and describing and characterizing the example case of the river Molse Nete.

The physical restoration techniques were classified in four categories: physical removal of sources; physical separation of contaminated fractions (soil washing, flotation, filtration); containment (capping, subsurface barriers, wet covering, dry barriers); physical immobilization (cement-based immobilization, grouting). Their relevant characteristics—applicability, performance, costs, and side-effects—were determined and quantified.

The example site of the river Molse Nete has been described in geographical, geological, hydrological, pedological, meteorological, and demographical terms. The relevant physicochemical parameters have been identified and quantified. The radioactive source term and environmental contamination of the area were documented.

As far as SCK•CEN's involvement is concerned, the characterization of the Molse Nete site will be finalized in 1998, a list of applicable restoration techniques for the example sites drawn up, and their characteristics quantified. Also the elaboration of the manual will be tackled.

**Real-time assessments** Within the framework of the RODOS project, we translated into a stand-alone PC programme a global methodology to assimilate early environmental data in order to assess in quasi real-time the main environmental contamination fields following a release at a nuclear power plant. The methodology, already described in SCK•CEN's 1996 Scientific Report, is based on the comparison between off-site near-range monitoring data and the corresponding model predictions, and gives an estimate of the source term. This source term is subsequently used in a dose/dispersion model to yield rapidly a global spatiotemporal picture of the contamination fields. Taking into account the likeliness of

obtaining off-site measurements in real time in sufficient amount, the use of simultaneous short-term averaged gamma dose rates from automatic real-time fence monitoring systems forms the kernel of the method.

Because gamma dose rates are only liable to give information about the global source term without differentiating into its composing radionuclides, we examined whether the use of in situ gamma spectrometry to monitor a radioactive plume could generate the required complementary information. In situ gamma measurements tracked the routine release of $^{41}Ar$ from SCK•CEN's BR1 reactor as a tracer. Using the measurements and on-site weather mast data in conjunction with developed methods, the calculated source term estimations globally gave satisfactory results, considering the requirements of an accidental situation. Although more research is necessary to consider the full complexity of a real accident, monitoring the cloud using in situ gamma spectrometry is thus liable to generate truly useful information for use during the early phase of a nuclear emergency.

In 1997, the RODOS prototype version PRTY 2.0 has been installed at SCK•CEN.

In the future, we will refine the methodology developed so far within the RODOS project to consider the complexity of real accidental situations. We will implement the stand-alone module into RODOS and give some attention to the type of uncertainty which could be estimated and transmitted to decision-makers during the acute phase of a nuclear emergency.

**Common approach to restoration** The contribution of SCK•CEN to the CARE study has been mainly the identification of the areas of concern. We gave an overview of industrial activities involving the extraction and processing of materials which may contain enhanced levels of naturally occurring radioactive materials. The different liabilities were subdivided in nine categories: uranium mining and milling, metal mining and smelting, application of natural radionuclides of radium and thorium, phosphate industry, coal mining and power generation from coal, oil and gas drilling, rare-earth and titanium oxide industry, zirconium and ceramics industry, and disposal of building materials. Existing information on the process, scale of the industry and levels of naturally occurring radioactive materials in feed materials and waste and by-products was collated and issues of past and old practices were emphasized. The radiological impact (releases and pathways), mainly of radionuclides of the $^{238}U$ and $^{232}Th$ decay series, was considered. The occurrence in European countries was inventorized.

Specific sites were selected and fully described for the first five categories: Sillamae (Estonia) for uranium mining and milling; Mansfeld (Germany) for metal mining and smelting; London (United Kingdom) for application of radium and thorium; Freital (Germany) for coal mining and power generation from coal; Tessenderlo (Belgium) for the phosphate industry.

Radiological impact assessments are being performed for these sites for the undisturbed case and after remediation, and the results generalized to the categories (Westlakes). They will be used for the development of cleanup criteria (Risø).

As main task for 1998, SCK•CEN will draft the final report, intended to be submitted to and discussed within the Article 31 group.

**Modelling of radiocaesium behaviour in soils** During 1997, the dynamic three-site model developed in 1996 was improved; it now takes into account radiocaesium retention onto clay minerals on a long-term basis (six months). On the basis of experimental results obtained under well-controlled laboratory conditions (see "Radioecology," page 17), we added a process characterizing very rapid sorption and retention of radiocaesium on highly specific sites and adjusted the kinetic constant describing the interactions between the different pools of sorption on a long-term basis, this for the four clay minerals studied in 1996 (illite, bentonite, biotite, and vermiculite).

The model, tested on three other 2:1 clay minerals (beidellites), allowed qualitative ranking

of the different kinetic constants involved and the establishment of ranges of variation for these parameters. The results were in very good agreement with the clay structure of the investigated materials.

We also focused our attention on the effect of competition occurring when different clay minerals (illite, vermiculite, and biotite) are mixed in different proportions (50–50% and 30–70%). The competition effect between the different pools of sorption was clearly pointed out by the values of the parameters provided by the modelling.

Furthermore, we studied the effect of the pH on radiocaesium retention. The results show clearly that, at lower pH, desorption of radiocaesium occurs from the specific and highly specific sites.

Finally, we analysed the effect of inert material for radiocaesium sorption and retention, by mixing quartz to illite in different proportions. The sorption and desorption processes were slowed down as a function of the quartz content. These results show the need to improve the model for such interactions.

**Nuclear emergency plan** Within the framework of the Belgian nuclear emergency plan, SCK•CEN started to develop the PC model *Noodplan Doel V2.0* on behalf of the Doel nuclear power plant. The model follows up a radioactive release based on real-time stack monitoring and meteorological data. It is able to differentiate between the total dose expected from the release and the dose still avertable by forthcoming intervention. This PC model will be finalized in 1998. We started negotiating the construction of a similar programme for the Belgian *Institut des radioéléments* (IRE).

**Group support systems** As regards the development of group support systems, one of our sientific researchers paid a six-month visit to the Collaborative Systems Laboratory at the New Jersey Institute of Technology. He studied the technology and the theory of group support systems, and in particular analysed their decision analytic opportunities. Applications are being developed for the "Decision Analysis and Modelling" and "Emergency Room" subprojects of the new Emergency Planning and Policy Support project NORD at the Radiation Protection department.

**Training** In the framework of the European Radiation Protection Education and Training (ERPET) programme of the EC Radiation Protection Research programme (DG XI), we organized a seventh training course on off-site emergency planning and response to nuclear accidents at SCK•CEN in July. Under the auspices of the same programme, SCK•CEN was invited to Ljubljana (Slovenia) by the Jožef Stefan Institute to give a similar course for an audience from South-East Europe in September. An eighth training course and a similar one in Romania are foreseen for 1998.

## Partners, sponsors, and customers

**Scientific partners** Forschungszentrum Karlsruhe (FZK) — National Radiological Protection Board (NRPB) — Risø National Laboratories — University of Leeds — University of Manchester — University of Warwick — Electricité de France (EdF) — KEMA Nuclear — Centre d'études sur l'évaluation de la protection dans le domaine nucléaire (CEPN) — Scientific Production Association Typhoon (SPA Typhoon) — EC Joint Research Centre (JRC) — Jožef Stefan Institute — Université catholique de Louvain (UCL) — Universiteit Gent (UG) — Westlakes Scientific Consulting (WSC) — Studsvik Eco&Safety — Forschungszentrum Rossendorf (FZR)

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