TRAINING IN MANAGEMENT AND ANALYSIS OF SEVERE ACCIDENTS

ORGANISED BY FRANCE

IN THE FRAME OF THE

INTERNATIONAL ATOMIC ENERGY AGENCY

TECHNICAL COOPERATION PROGRAM

(HUN/9/013)

BUDAPEST

13 - 24 JANUARY 1992

4.2. - THE MANAGEMENT OF NUCLEAR EMERGENCIES

Reabilitation of Soils and Surfaces after an Accident

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PRESENTATION OF THE RESSAC RESEARCH PROGRAM

(REhabilitation of Soils and Surfaces after an ACcident)

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ABSTRACT

If, despite all the precautions taken in nuclear power plants, a severe accident were to occur in France involving extensive release of radioactive materials to the environment, existing emergency plans would be implemented enabling urgent decisions to be made with regard to the immediate protection of the population: confinement indoors, evacuation, distribution of stable iodine, etc. But, at a later stage, mean and long term actions would have to be carried out to decontaminate the polluted areas and limit subsequent contamination of the food chain, with a view to enabling the populations concerned to return to normal life. These actions would concern, in decreasing order of priority and using the WHO and IAEA definitions, the near field, closest to the accident site, and the far field, subjected to the direct impact of fallout. They should be aimed at reducing external exposure due to deposition and internal exposure by inhalation of radioactive products re-suspended in the atmosphere and by ingestion of products for human consumption. In the context of IPSN research and development programs on severe accidents, the RESSAC program was defined in 1985 for the purpose of studying methods and means of rehabilitating the near field and controlling problems related to the far field. Elaboration of the program is presently proceeding at the Nuclear Research Center of CADARACHE, focussed on the following main topics: assessment of what happens to the radionuclides deposited on the soil and vegetation, determination of priorities and how to intervene, management of the waste produced.

1. INTRODUCTION

Despite all the precautions taken at the design, construction and operating stages of nuclear power plants, the possibility of severe accidents occurring with significant release of radioactive products to the environment cannot be entirely excluded. In France, it was consequently deemed necessary to define emergency plans to protect the population from the consequences of such accident situations. For the actual accident development stage and the short term after the accident, these plans are presently operational: on-site emergency plan (PUI), specific to each nuclear plant and implemented under the authority of the plant manager, and external emergency plan (PPI), applicable to the immediate environment of each nuclear site and implemented under the authority of the administrator ("préfet") of the department concerned. As regards the long term after the accident, the French public authorities are presently elaborating the post-accident plan of action (PPA), aimed at enabling a return to normal life in the affected areas by reducing external exposure due to deposition of radioactive products and internal exposure due to the re-suspension of radioactive products and by limiting subsequent contamination of the food chain.

Elaboration of the post-accident plan of action is based on a set of technical data pertaining notably to the methods and means to be implemented to achieve the ends defined above. The purpose of the RESSAC research program is to provide this input data.

The present stage of the RESSAC research program, currently proceeding at the nuclear research center at Cadarache, was defined in 1985. Certain aspects are co-financed by the Commission of the European Communities (CEC). For this stage, we postulated deposition of radioactive products following a severe accident on an EDF PWR (PWR reference source term S3 /1/). However, it should be noted that this in no way curtails the overall applicability of the results, since most of the nuclides studied would also be released during a severe accident on another type of nuclear plant. For this stage, the soils selected for the experiments are natural soils considered to be representative of the near field environment of PWR plant sites in France.

In accordance with the goals defined above, the main questions to which the RESSAC program should provide answers are as follows:

- assessment of the developments to be subsequently undergone by the radionuclides deposited on the soil and vegetation,
- determination of intervention priorities, according for instance to land-use and groundwater vulnerability.
- selection of intervention means, according to the field of application (cultivated land, forests, access ways, etc.) and equipment availability,
- management of waste produced.

We shall discuss further on the research actions undertaken to answer these questions. But beforehand, we shall briefly describe how it is intended to utilize the RESSAC program results, since on this will depend the required nature and form of the results.

2. CONTEXT IN WHICH RESSAC RESULTS WILL BE USED

In the event of a nuclear crisis, the Institute of Nuclear Safety and Protection provides technical assistance to the competent safety authority during the accident stage (scope of the on-site emergency plan and the external emergency plan) and more generally, to the public authorities as a whole during the post-accident stage (scope of the post-accident plan of action) in particular, by coordinating the on-site intervention resources devised by the Atomic Energy Commission. These various assignments are carried out through a technical crisis center, CTC, located at the Nuclear Research Center at Fontenay-aux-Roses.

During the accident stage, the final objective is to supply a forecast of radioactive release into the environment, sufficiently early to enable efficient application of counter-measures designed to protect populations [2]. For this purpose, the CTC have at their disposal various high-performance communication, documentation, assessment and forecast resources. For example, a high-speed, accurate tool for forecast and assessment of radiological consequences was installed in the CTC - the CONRAD code [3] - based on a dedicated data processing system. This also enables display of population distribution around a site by using data from the last national census.

During the post-accident phase, the CTC, by virtue of the extensive powers vested in the IPSN, do not only have a purely logistical role (coordination of CEA intervention resources on the ground, made available to the public authorities), but must also participate significantly in the orientation of operations: in a similar fashion to their role in the accident phase, they must supply technical data enabling decisions to be taken concerning actions to be performed. Hence, the RESSAC program is not only designed to supply a technical basis for elaboration of the Post-Accident Action Plan, but also to result in the creation of interpretation and assessment tools (data bases, software) for soil rehabilitation actions.

Also crisis exercises performed over a period of several years with the operator, the safety authorities and, more generally, the public authorities, show that assessments issued by the CTC are better understood and more fully benefitted from by decision makers when they are supplied in the form of specific data maps. This led to the initiation of a project to equip the CTC with a mapping system (CART project) for display and overlay of data on map backgrounds, performing 'simple' calculations on displayed data (plotting isodose curves, calculation of the number of persons concerned by a counter-measure within a given perimeter, calculation of the volume of waste created by rehabilitation over a given surface area etc.) and preparation of data for utilization of specific codes (eg. for assessment of radioactive migration in the soil). A model for this project was constructed in 1989 and was successfully used during two crisis exercises. In the near future, the resulting maps will be submitted to partners located at some distance from the CTC by means of portable micro-computers. Obviously, the tools resulting from the RESSAC program must integrate easily with the computer environment thus defined.

3. PREPARATION FOR NEAR FIELD INTERVENTION

Data bases are compiled for the near fields around PWR sites (10 km radius). They are based on three factors:

a) pedological surveys aimed at classifying the different types of soil and determining those on which laboratory test described in section 3.3. below must be carried out.

b) Land use maps

These maps are drawn up on the basis of land surveys. They define homogeneous land use zones. Files accompanying these maps indicate:

- land use: areas given over to farming, areas not given over to farming (urban areas, surface water areas, waste land), wooded areas (deciduous or coniferous),

- where applicable, the type of farming activity, using the European Community classification,

- surface areas concerned.

c) Water table vulnerability maps

These maps are drafted in cooperation with the Geological and Mining Research Bureau (BRGM). They comprise an indication of vulnerability per zone, assessed on the basis of various parameters, such as the depth of the water table and aquifer permeability. The different water catchment points and their usage are also indicated (fresh water supply, crop irrigation, industrial usage).

As specified above, these data bases characterize the near field around PWR sites. They are also the reflection, at any given moment, of a situation liable to vary over time. Two different types of problem therefore arise which haven not yet been resolved by the RESSAC program: characterization of the far field and updating of the data base over time.

These two problems were examined in the context of the CART project described in chapter 2. The first conclusion is that, for the far field, less refined data is adequate: existing files, for example, concerning land use which were drawn up and updated on the national or European level can be used effectively. The second conclusion is that, again taking the main example of land use, there is no organized structure for updating the near field data (there is obviously no question of repeating surveys carried out in the context of the RESSAC project on a yearly basis). However, a research path has been identified. This consists in exploiting the SPOT remote detection satellite images and image processing software perfected by the company marketing SPOT products. This research path will be explored in the future, probably in the context of the CART project.

3.2. IN-SITU TESTS FOR SOIL REHABILITATION TECHNIQUES AND RESOURCES

Soil rehabilitation actions range from vegetation clearance (crops, meadows, forests) to topsoil removal. These actions depend little on the natural soil type.

Clearly, tests must be performed on a fairly extensive test site comprising varied plant life: a test site of several hectares, belonging to the nuclear test center at Cadarache, has been assigned to the RESSAC program and enables several types of vegetation to be cultivated (grassland, farm crops). For wooded zones, an agreement was reached with the national Water and Forestry Department. Radioactive deposition is simulated by emission, above the surface area under investigation, of a non-radioactive fluorescent product in the form of dry aerosols with an average diameter of about 1 μm.

These two types of test are performed in parallel.

3.2.1. Measurement of the plant interception factor

Various types of vegetation, characteristic of PWR sites in France, are cultivated: grassland, cereals, vegetables etc. At different stages of the plant growth cycle, contamination is simulated by the method described in section 3.2. and the plan interception factor (ratio of the quantity deposited on plants to the total quantity deposited, per soil surface unit and with reference to the vegetation mass per unit of soil surface area.

The results will enable a data base to be compiled enabling estimation of the advantage obtained by simple clearance of the vegetation, with respect to vegetation type, maturity and yield per unit of surface area.

3.3.2. Qualification of equipment and techniques for fixing and removing deposits

For obvious practical and economic reasons, the equipment (machines products) to be used for applying and removing deposits must be, insofar as possible, existing and widely-used standard equipment, commonly used for other applications. Also, equipment adaptations and special conditions for its use in soil rehabilitation actions should be as limited as possible in the interest of rapid implementation.

Various contamination application and removal techniques have been experimented with , depending on the type of plant cover.

a) Close plant cover

Initial action could consist in applying surface contamination by means of heat-expansible, peelable paint or foam. The Soviets have already utilized peelable paint following the Chernobyl accident and announce a decontamination efficiency factor varying between one and three decades. These products have two main advantages: firstly, they immobilize the radioactive products (no migration in the soil or entrainment in the soil due to precipitation); secondly, they enable, by penetrating into the soil up to a certain thickness (this is particularly true for foam), removal of radioactive products which have already penetrated the soil. Foam is spread by means of standard farm machinery normally used for spraying liquid fertilizer, after several simple adaptations.

A second action consists in removing the soil, whether or not it has been covered with paint or foam, to a certain thickness by means of conventional earthworking machinery (bulldozers).

b) Thicker plant cover (crops)

One harmful affect to be feared during removal of vegetation is a certain degree of re-suspension of radioactive products in the atmosphere. The method selected must, therefore, initially endeavor to minimize this effect. Also, operators must be protected (breathing mask, modification of driver's cabin on heavy machinery).

It would seem, a priori, that standard agricultural machinery of the silo filler or rotary cultivator type with suction in a covered trailer would enable crops to be removed in a sufficiently efficient manner with minimum re-suspension.

c) Wooded cover

For shrubbery, bushes and copses, standard Water and Forestry Department equipment can be used for clearing operations designed to prevent fire propagation can be used. The machinery chops the woody growths and sucks cuttings and leaves into the trailer. For trees, non-lethal defoliation can be performed, followed by leaf gathering using conventional forestry methods.

The same precautions as those outlined in section b should be taken (operators equipped with breathing masks, modified driver's cabins).

All the test described in section 3.2.2. should result in a definitive data base for each application:

- the best-adapted type of equipment,

- utilization procedures, including operator protection,

- efficiency, duration and cost of the operation.

3.3. TECHNICAL TESTS IN THE LABORATORY CONCERNING MIGRATION OF DEPOSITED RADIOACTIVE PRODUCTS

Soil rehabilitation actions must be undertaken in a certain order of priority, which depends on economic, social and technical parameters. A significant technical parameter to be considered is the possibility of migration of deposited radioactive products with respect to time and weather conditions within the soil and plant cover. The third and last phase of the RESSAC program currently underway is consequently aimed at modeling (data and software) migration of radioactive products in sols and plants, together with validation under realistic conditions. Two types of test are performed: analytical tests to determine the model and overall tests to validate the data and software obtained under realistic conditions. The radionuclides investigated are the main long-life radionuclides (Cs, Sr, Ru and Te isotopes).

3.3.1. Analytical Tests

a) Soil migration studies

We are not here interested in migration in the first soil horizons (the first 20 centimeters). Tests are performed on columns of reconstituted soil, homogeneous and bare, whether saturated or non-saturated with water. On the basis of pedological characteristics, we determine firstly, the water flow characteristics and secondly, the pollutant concentration profiles with respect to time and in the various soil phases (solid phase, flowing and stagnant water).

b) Soil-plant root transfer study

These tests, referred to as 'flower pot tests', are performed in a confined environment. A large number can be performed due to the low cost. The rational approach to this study is as follows:

- a method is perfected to determine the bioavailable fraction of a radionuclide contaminating any given soil, with respect to the agronomic soil characteristics. For example, the ratio of analog cations present (calcium for strontium, potassium for cesium),

- bioavailability factors are determined for a given radionuclide and plant, by growing the plant in a nutritive soil where the entire quantity of radionuclides present in the solution is considered to be bioavailable.

Breaking down the soil-plant transfer study into these two phases considerably reduces the number of parametric combinations to be investigated.

3.3.2. Overall Tests

As was indicated at the beginning of section 3.3., one of the objectives of these tests is validation of modeling based on the results of analytic tests described in section 3.3.1. A second objective is to confirm, for radioactive contamination, the effectiveness of soil rehabilitation methods tested with a non-radioactive simulant in the second phase of the program defined in section 3.2.

This requires the highest degree of realism possible at all three levels.

a) soils

Sample blocks of non-handled soil, of large dimensions (2m cubes), are taken from the environment of PWR sites. The synthesis of pedological surveys described in section 3.1.a enables the number of such sampling operations to be restricted to an acceptable number, from the points of view of both economy and representativeness.

b) environment

These blocks of soil are placed in lysimetric* tanks enabling simulation of the site climatic environment (sun, temperature, carbon dioxide gas concentration, precipitation, hygrometry) and groundwater vertical motion (regulation of hydrous potential). Various types of plants are cultivated under these conditions on blocks of soil.

* A lysimeter is an experimental device which enables study, by simulating conditions as close to natural conditions as possible, exchanges of all kinds between a soil sample with plant cover in its original physical environment.

c) contamination

Lysimeter contamination is achieved by means of a POLYR generator (pollution of RESSAC lysimeters). This device enables production and deposition of radioactive aerosols on the soil under conditions representative of those which would prevail during a severe accident on a PWR (physico-chemical forms, concentration).

Hence, plans have been made for construction of a purpose-built structure, at the Nuclear Test Center at Cadarache, to house these lysimetric tanks which will be subject to French regulations concerning facilities in compliance with environmental protection requirement. This building will comprise four hothouses each divided into three lysimeters, the POLYR generator and service facilities.

4. CONCLUSION

The results of the first phase of the RESSAC program described in this paper, will provide answers in the near future to many questions which might arise regarding soil rehabilitation following a severe accident on a PWR. In point of fact, the program began in 1986 and many results have already been obtained and utilized for drafting of the Post-Accident Action Plan (PPA) and selection of technical equipment to be installed in the IPSN's Crisis Center. Another paper to be delivered in the context of this conference /4/, will summarize the results which have been obtained up to this point in time and will present the sequencing schedule for the remaining tests.

However this initial phase does not enable us to reply to all those questions which might arise.

The main problem not currently covered by the RESSAC program concerns the future of the waste generated. Rehabilitation interventions would generate large quantities of waste material varying both in degree and type of contamination (topsoil removal, adherence foam, vegetation etc). This would inevitably require the creation of a provisional storage area. To reduce costs and harmful effects, eg. the risk of contaminating surface water or groundwater, it will be necessary to find methods enabling the volume of this waste to be reduced by decontamination, compaction etc. *Certain phenomena, related to the organic nature of the material, such as fermentation,* would disallow application of the standard methods for nuclear waste packaging and also make it impossible to postpone processing for very long. On the other hand, certain procedures enabling acceleration of natural decomposition processes to obtain a concentrate rapidly, could be beneficial. Discussion of studies to be undertaken in this context is, of course, already underway and it can be considered that the problem of the future of waste material will be a logical extension of the RESSAC program.

Other extensions to the program might also be considered (serious accident on an installation apart from a PWR, contamination of an urban environment). However, it would seem to us that firstly, the current RESSAC program (including the 'future of nuclear waste' extension), along with the knowledge obtained by the international community (particularly concerning rehabilitation of an urban community) already provide answers to a significant portion of these latter questions.

To conclude, we point out that the problems relating to waste contamination by the hydrogeological or hydrological paths have not been forgotten and are currently being investigated in another important IPSN research program.

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