

CONCLUSIONS OF REPORT N° 9 : MAIN OBSERVATIONS AND PERSPECTIVES

The research pursued along the three lines of the 1991 law, separation and transmutation, deep geological disposal, conditioning and long term storage, aim at offering a variety of solutions that can be used in part or as a whole to deal with long-lived high or medium activity radioactive waste.

Line 1

Research on advanced separation of minor actinides and caesium have resolutely entered the phase of technical feasibility demonstration. This stage started on solid scientific and organisational bases. However keeping to the programme schedule before 2005 for the Atalante facility (Marcoule) will require a close watch on the CEA's part.

On the other hand, studies on transmutation are in a preliminary stage. They concern the simulation of transmutation systems and the assessment of the evolution under irradiation of the inventories listing the transmutable elements within the context of scenario studies. At the same time, three experimental activities are being carried out. The first one concerns the manufacturing and behaviour of targets made with samples of minor actinides compounds and long-lived fission products placed in an irradiation reactor such as *Phenix*. The second one deals with the subsystems of an accelerator-assisted sub-critical system (linear accelerator, spallation target, sub-critical core) which is considered as a tool enabling the massive transmutation of minor actinides, even certain long-lived fission products. Finally the third one deals with basic studies (materials, nuclear data).

To date, the demonstration of transmutation technical feasibility is not completed, particularly when tackling the difficult issue of the manufacturing and reprocessing of irradiation targets loaded in americium and curium. Some ceramic compounds of americium that are under study, seem promising. Only preliminary results concerning irradiations in *Phenix* will be available before 2006 – and the Commission appreciates the fact that it is re-starting in 2003 for a first campaign at maximum power equivalent to 120 equivalent full power days. It is a first essential step, but the crucial step of the study on the behaviour of a pin and a complete assembly in a fast neutron reactor can only be truly envisaged with the development of a dedicated reactor (as *Super-Phenix* could have been). As for the sub-critical systems, the effort led at a European level continues with the 6th Framework programme, and the new element of this year is the perspective of a European demonstrator from the Belgium Myrrha project. There is a broad consensus for it on the part of the

European scientific community, and the CEN-SCK, an organism in charge of nuclear research in Belgium, has agreed in principle.

Finally, studies on transmutation aim at first treating already produced waste that extend today to some future reactors – so called 4th generation – One of their objectives is to be able to self-recycle their own long-lived radionuclides, even to produce less, as it is the case in the thorium cycle. The national scientific community, within the shared research group Gédépeon, is presently re-orienting itself in that direction.

Line 2

The Andra has defined the basic options of the main B and C waste deep disposal in the Callovo-Oxfordian argillite, a rock that will be studied in the Bure laboratory. These options that are deliberately simple and robust integrate reversibility since it allows a step by step management of packages and facilities.

An underground laboratory is a vital element in the study of long-lived high and medium activity waste disposal. The Andra has started building such a laboratory on the Bure site, in a relatively homogenous clay formation situated 480 meters under the ground surface. The sinking work of the main shaft and the auxiliary shaft started in the course of the summer 2000. They were suspended at 228 meter deep in the main shaft on 15th May 2002, following a fatal accident. Sinking started again in the auxiliary shaft on 30th April and in the main shaft on 26th May 2003. Taking this delay into account, the Andra scheduled a completely reviewed research programme at the beginning of 2003. It stated that a first experimental alcove situated above the level planned for disposal, would be finished in the main shaft in the second quarter of 2004, and that the drilling of the first reconnaissance gallery situated in the target level would start in the auxiliary shaft at the end of 2004. In order to produce a report at the end of 2005 on these bases assessing the feasibility of a possible repository in this formation, the schedule is maintained extremely tight, because many experiments to be made on site are long and delicate. The Andra is well aware of this.

Two aspects must be taken into account: the characteristics of the undisturbed rock and the near-field containment, an environment that will be very much disturbed by the drilling of the facilities and by the packages.

On site reconnaissance of the host layer will have begun end of 2005, but it will not present a large enough area to enable us to reach the conclusion that there are no discontinuities on

the scale of a possible repository. It aims at having a first assessment of the homogeneity of the rock and the possible presence of fractures and of their role in the gallery that will have been drilled. The Commission worried about this situation and in its report n° 8 it recommended additional directional drillings, which would enable to explore horizontally the formation chosen for the laboratory. The Andra will realize at least one drilling of this type. Besides, the current hydro-geological drillings and modelling efforts which will be carried out on the aquifers should provide a plausible image of the hydrology, but that image will need to be confirmed and new experiments to be done, this after 2006.

The disturbing effects of the repository building on its containment capacities mainly concern the excavated damaged zone (EDZ) which forms a potential transfer path towards the biosphere, the importance of which it is essential to assess. The Andra is planning to have an experimental EDZ interruption and sealing programme. This most important programme includes an experiment that should be the first of a series designed to determine the migration and diffusion speeds of radionucleides through an anchoring key. It seems difficult to envisage more from these tests than preliminary tests for the 2006 file. The study of reciprocal chemical modifications between concrete and argillite in the presence of water has gained ground. The alkaline perturbation is understood and modelled. The action of metallic materials on these environments in the presence of water is being studied in parallel. Concerning the observation of the damaging effects of excavation works on the rock, it can only be done in time, once the galleries have been drilled.

The Commission considers that the revised research programme presented by the Andra in January 2003 forms a relevant programme considering the given dead-lines and the minimum acceptable for acquiring data on site that makes it possible to elaborate the 2005 scientific file. The realization of two or three directional drillings carried out from the surface and duly instrumented with the best existing loggings, would allow to usefully widen the field of investigation. Although such drillings could never replace the underground laboratory if the Andra's experimental programme could not be implemented before 2005, they would then be the only element of horizontal exploration of the formation to be added to the file.

The CNE recommends that the quality and coherence of the scientific programme should not be questioned because of the 2006 dead-line. It is better to have a few geological observations and quality, even incomplete, scientific works, rather than interrupt them in order to reach the target-level more rapidly.

The Andra and the CEA are making great efforts to develop simulation tools and catch up with the delay observed by the CNE in its previous reports. Multi-dimensional calculations will be carried out but in terms of tri-dimensional calculations we may not be able to take into account all the details of the disposal site. The thermal calculation will be separated from the hydrological one and from the calculation of the radionuclides convection-diffusion. These calculations will be used to figure out the site evolution on the first millenaries and to propose conditions to the limits for calculating a far field simulating the future of radionuclides.

However, we can imagine that to begin with, the simulations will be exploitable in face of the great uncertainties on certain geological parameters (possible presence of fractures, damaging effect, etc.) and on certain phenomena to be modelled (evolution of packages and particularly their matrices, transfer mode of radionuclides into the undisturbed rock and the damaged zone, evolution of the geo-chemical properties of the near-field, etc.). After 2006, these calculations will have to be resumed.

Line 3

Research on waste conditioning are being pursued with studies on conditioning matrices, containers manufacturing materials, corrosion and operational models of aging, particularly those for vitrified waste and spent fuels.

Two matrices for the immobilization of separated minor actinides, selected in 2002 for their containment properties, are being tested for technical feasibility in the Atalante facility at Marcoule. Two others are being examined in Karlsruhe in collaboration with the Institute for Transuranium Elements. The point is to show that significant quantities of minor actinides can be contained in these matrices by studying their resistance to radiations, using in particular the plutonium 238 doping method. These programmes should make it possible, before the end of 2005, to start the modelling of matrices deterioration and of the possible release of elements. Matrices envisaged for iodine and caesium containment are in the process of final characterization.

Storage packages are mainly designed to be identical to disposal packages in order to contribute to the continuity between storage and disposal. The CNE is pleased to learn that demonstrators of storage containers have been made at the end of 2002.

On surface and sub-surface storage facilities designed for the long term are being studied. Studies only concern virtual sites which gives them, in the case of subsurface storage, a very preliminary quality because they do not enable the handling of all the practical problems which will be met in the geological, hydrological and heat transfer contexts. Following the present debate, criteria on the choice of sites should be decided. Provisions to ensure the robustness of these storage facilities, passive ones as far as possible, are being researched, but the durability and safety studies show that facilities surveillance and maintenance will always be required. Having no maintenance, even for a limited amount of time, could have significant consequences for the radiological surveillance, the containers corrosion and the atmosphere composition of the site.

To conclude on line 3, the Commission feels that, while waiting for a geological repository, containers and their closing devices for all waste categories, form a protection adapted to natural (ordinary or extraordinary) or human (errors or malevolence) phenomena, for all the workers and populations concerned, particularly during transport and future storage facilities. This protection would also be useful during disposal. All this has not been reached to date. Works done on containers should contribute to demonstrate that it is possible to prevent risks such as those connected to radioactivity, the majority of waste. The current programme goes in that direction.

Prospects for 2006

For all these lines, the research in chemistry that has been carried out for the past ten years on actinides and fission products will have given many results, whether it concerns the separation of spent fuels, their containment in solids or their behaviour in various aqueous environments and liquid – liquid and solution – solid interfaces. The knowledge acquired in that way will enable to defend scientific issues supporting concrete choices. All the same, experiments in chemistry should not stop in 2006, whatever strategic decisions are made.

In this respect, the transition to the stage of industrial feasibility in separation processes, like the advanced separation of minor actinides which will have probably successfully passed the stage of technical feasibility, presupposes that an industrial strategy has previously been adopted.

The transmutation of long-lived radionucleides contained in spent fuels would make it possible to reduce long-term potential radiological risks associated to nuclear waste disposal in deep geological layers. However the transmutation path has not the same status as deep

disposal, and this for two essential reasons. First of all, it cannot replace deep disposal, if only because some long-lived radionuclides (particularly fission products) are not in fact transmutable, and the separation-transmutation operations will produce ultimate waste, especially medium activity waste, that cannot be stored on the surface for safety reasons.

The implementation of large scale transmutation would suppose the manufacturing of a large number of dedicated reactors (between 10 and 50% out of the total power produced by a series of electricity-generating reactors, depending on the scenarios). Such a series would make it possible to reach an inventory stabilisation of the elements to be transmuted only after several decades in operation. In other words, transmutation can only be envisaged in the context of sustainable nuclear energy. In any case, a long effort in R&D continuing well beyond the 2006 deadline seems necessary before an industrial implementation of transmutation. The scope of it is so vast that it will have to be done along with an international collaboration. In this respect, the 2006 limit could be the opportunity to decide or not of the French participation to the project around a hybrid system demonstrator, possibly around the Myrrha project.

For the geological disposal study, if Andra's revised programme follows the new schedule which is extremely tight, one first appraisal of the containment capacities of the Callovo-Oxfordian argillite in the Bure area will have been achieved. The realization of directional drillings into the clay from the surface would be a precious guarantee of results, in front of mining works uncertainties.

The 2005 file must contain a minimum of data on rock homogeneity and the absence or not of conductive fractures in the layer, data also on physical and geo-chemical measures taken on large-size samples coming directly from the layer, as well as data on the excavated damaged zone following mining works. The 2005 file could then enable public authorities to make or not the decision to select this rock and launch the validation project of the disposal site, which entails in particular to survey the host rock on a wide extent, well beyond the area explored by drillings, shafts and galleries before 2005.

Diffusion experiments that use tracers will have lasted only between six and eighteen months and will only give data marred by great uncertainties because these tracers will have just about come out of the area damaged by the experiments implementation. The validation works in view of a possible repository, will therefore have to be carried out after 2006 to extend in-depth exploration through galleries, study their long-term mechanical behaviour

and continue on-site migration experiments for several years, in order to ensure the proper containment of the radionuclides that might have been placed inside.

As far as another type of rock or another potential site are concerned, little information will be available before 2006, except studies achieved from the surface on the Gard and Vienne sites, but without underground laboratories. The Andra will present a summary of foreign works on granite as well as a classification of French granites, but at best results will only be an indication, because each geological site has its own characteristics which cannot easily be transposed. Besides, the particularly favourable situation of the Canadian and Scandinavian shields, which have been stable for a billion years, is not known in France, therefore it does not offer the same advantages for a repository.

Intermediate storage is an industrial reality for vitrified waste. Studies carried out in the context of Line 3 by the CEA and the experience acquired by COGEMA confirm that the technical knowledge exists to ensure a centralised storage of long-lived high and medium activity waste and spent fuel for one century. Some containers on which security depends at that stage, will normally be ready and have reached the prototype step in 2004. Subsurface storage raises specific problems, particularly because of the high thermal stress the natural environment will have to stand. Some in-depth thinking on the choice criteria for the site, and in particular the maximum acceptable temperature, will have to be seriously done in order to have results available before the 2005 deadline. As far as the long-lived medium activity waste packages are concerned, their storage conditions remain to be studied so that they can be protected from corrosion attacks.

It has been envisaged that intermediate storage facilities of C waste or spent fuels should be periodically renewed and therefore extended for centuries, even millenniums. Such a solution counts on the stability of human societies and the durability of their institutions and technologies. The Commission recommends that this approach that seems to raise many problems, should be analysed in details for 2005 so that the Parliament can be informed both of the advantages, the risks and the importance of the economic and technical constraints this solution would impose on the societies of the future. The Parliament will then be able to assess this option in comparison with deep geological disposal which releases from these uncertainties.

Therefore it appears that for the three lines of the law, provided the schedules of studies are kept and the last recommendations mentioned above are put into practice, the corpus of

studies realized between 1991 and 2006 should give the Parliament the possibility to choose on a scientific point of view, between several possible solutions to ensure the future of nuclear waste and nuclear materials.