N A T I O N A L S C I E N T I F I C

E V A L U A T I O N C O M M I T T E E

REPORT N° 6 - JUNE 2000

MAIN CONCLUSIONS AND RECOMMENDATIONS

The assessment of research half-way through, presented here under, is an intermediate report which also includes the main conclusions of the 1999-2000 auditions. The main recommendations stemming from these auditions can be found together on pages XII -XIII.

Assessment of research half-way through

The National Assessment Committee, stemming from the December 30th 1991 law, was set up in 1994, when survey works on the study of the possibilities of underground disposal started again, after the 1990 moratorium. The period set by law for the studies to be carried out, in the research centres as well as in the underground laboratories, expires on December 30th 2006. Considering the actual beginning in 1994 of the main work lines followed within this law, we can consider that the year 2000 is approximately half-way. Therefore it seems appropriate to examine the results already obtained and assess the importance of the research still to be carried out within the remaining period in order to provide answers to the legislator.

Already in its first annual report, the Commission had expressed the need to have a scientific and technical coordination of the organisms participating to the research; such an approach aimed in particular at identifying the main gaps in the programmes, clarifying the targeted objectives and defining a balanced research strategy between the three lines of the 1991 law and involving the national scientific community. The strategy to define and implement research programmes now induces a reflection coordinated by the Ministry in charge of Research and Technology. It is thus possible to express opinions on the coherence of the research as well as on how it fits in with the objectives of the law and, for some of it, how it answers industrial needs, even if there remain a few points on which the collaboration of the actors and the involvement of the academic scientific community should be improved. The Commission notes that already a few Research Groups combining the CNRS to other organisms participate to the research on the three lines defined by law and substantially contribute to works carried out by the CEA and the ANDRA, in charge of these lines.

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Line 1

The first orientation of the law, so called "Line 1", aims at reducing the radiotoxicity of nuclear waste through the transmutation of the most harmful long-lived radionuclides. It requires to carry out chemical separations in very radioactive materials, and which go well beyond those being done in the present reprocessing of irradiated fuels for separating uranium, plutonium and other elements (fission products and minor actinides). Minor actinides have been priority objectives because of their high level of toxicity, but the Commission insisted on the advantage of separating certain long-lived fission products, considering their major impact on a deep disposal option. In front of various scientific and technical difficulties inherent to transmutation, the Commission suggested to combine to the Separation – Transmutation concept (S-T) the concept of Separation – Conditioning (S-C), that is to incorporate these separated elements in matrices with increased confinement ability in a geological environment.

The present appraisal of new chemical separations adapted to those that are already possible with the present Purex reprocessing method, is encouraging : the scientific feasibility of several processes to separate minor actinides is already within reach (particularly the Sanex and Sesame processes) or even already achieved (the Diamex process). So is the case of certain important fission products such as iodine, caesium (the Calixarenes process) and part of technetium. There still remains to examine the case of other of fission or long-lived activation products for which research has been intensified. The technical feasibility of separations will have been assessed and it should be possible to estimate the industrial feasibility of some of them. We can therefore believe that the appraisal of research already carried out on **separation** allows to serenely consider the deadline of 2006.

In order to leave open the choices of radioactive material management that could be envisaged by the research included in line 1 and the research concerning the specific conditioning methods required by a (S-C) disposal, it is necessary to consider waiting reversible conditioning of radioactive materials that were separated from spent fuels. In this respect, studies are in process. They open possibilities that will have to be assessed in 2006. While preparing this waiting conditioning, we must also get prepared to answer the objective aiming at reducing liquid or gas discharges of radioactive products, namely in the sea, decided on at Sintra by the ministerial meeting of the OSPAR Commission for the application of the Agreement for the protection of sea environment in the North-East Atlantic, brought into force in 1998, and which will be imposed on to the nuclear industry.

The implementation of the transmutation also requires the preparation, the control and the analysis of particular fuels or irradiation targets as well as their future chemical treatment, to reach, via the recycling of the radionuclides to be transmuted, the desired output.

Research on transmutation are mainly led for actinides and some long-lived fission products (iodine 129, caesium 135, technetium 99) by the CEA and the CNRS. Two paths can be examined. **The first one** corresponds to processes using the **present method** of pressurized water reactors, and research focuses mainly on new fuels that would permit the multi-recycling of plutonium and of previously separated minor actinides, in other words a once through destruction. This first path is being explored by the CEA which successfully led the corresponding studies. The study of scenarios has confirmed the possible performances of these processes. The implementation of the processes (MOX, MIX, APA, Th-Pu methods…) now depends on operational decisions after the developments of industrialization.

The **second path** of research is the one with **fast neutron** reactors or **innovative solutions**. The research effort has mainly been concentrated on accelerator-aided sub-critical systems, for which a basic R&D was engaged in 1996. The results obtained in France and abroad allow us to envisage now a fast neutron hybrid system demonstrator, that is being elaborated by the CEA, the CNRS and their European partners. A motivation document is being assembled. Studies on complete systems of transmutation (including, for instance, melted salt reactors, pyrochemical systems of fuel processing…) are engaged. The development of new nuclear fuel matrices and the study of their behaviour are at the heart of all this research. Few tangible results have been reached so far. The behaviour studies under irradiation are of the utmost importance: it is to be feared that the ambitious programme planned on PHENIX will be jeopardized by the short operating period now planned for this reactor at the end of its life, unless this period is postponed until the experimental programmes are finished. The future Jules Horowitz reactor must contribute to these works, namely in terms of fast neutrons. We are then well after the year 2006.

Whatever the result of this research, there will remain a limited quantity of ultimate waste which will have to be disposed of in the conditions that will be planned by the legislator. The separation-transmutation (S-T) path of research, relying on complex and costly processes, will only be applied to the most harmful long-lived, high activity waste (C-waste) with a volume limited to a few thousands m^3. The long-lived medium activity waste (B-waste), which will represent some100.000 m^3 in 2020, will not be able to benefit from it and will have to be disposed of.

Line 2

The second orientation of the 1991 law, so called "Line 2", aims at studying in an underground laboratory the disposal possibility of waste in geological formations, and for which no future treatment has been planned. The Commission, which had already noted this in its first report, considers that the amount of time given to the ANDRA to carry out this task is very tight, especially if we compare it to the duration of experiments conducted under similar conditions in the other OCDE countries (often 15 years). It had also noted that not knowing the quantities and the characteristics of the waste to be taken into account would slow down the development of these studies. Incoherent assessments of the waste inventory had been presented to the Commission; the mission entrusted to the President of the ANDRA by the Government means that the inventory can now be done on a reliable basis.

Three potential sites have been identified by the ANDRA during the period between 1994-1997, which led the Government to select on December 8th 1998 the Eastern site, in order to build there a research underground laboratory, and to ask ANDRA to look for a new potential site for a second laboratory, where granite would be outcropping. These Government decisions on December 8th 1998 have opened namely two very important fields of study and thought : the choice of disposal reversibility which will have to be taken into account in the mining engineering as well as in the containers characteristics; the specificities of disposal types which will have to be adapted to the type of waste concerned.

In this perspective, we may think that if the digging of the underground laboratory in Bure takes place from the autumn of 2000 to the end of 2002, the period 2003-2005 will require a very intensive effort of research, particularly in rock mechanics, in hydrogeology and geochemistry. The knowledge that the ANDRA acquired by participating to or being in charge of experiments conducted in shales abroad (particularly in Mont-Terri in Switzerland and in Mol in Belgium), will make it save an appreciable amount of time for the implementation phase of these experiments. However, it should be noted that a tracers diffusion experiment in shale, like the one carried out at Mont-Terri, is essential in Bure and requires over two years of experimental work. This phase must be followed by a detailed interpretation using complex digital modelling techniques taking into account 3D geometry, the heterogeneity and the anisotropy of the rocks. Besides, the results obtained by the 3D geophysical campaign show a continuity and a regularity of the layers which still remain to be confirmed by the more in-depth interpretation that is still being done.

The **modelling**, also, is running late and will require added efforts. The ANDRA has already decided to strengthen this area. Following the expert report that has just been completed, it is engaging in a

development programme of the modelling of the long-term behaviour of a waste disposal site, and of the phenomena that could result from the deterioration of containers, from radionuclides being carried away by water and their return to the biosphere. It should then be possible to distinguish, through sensitivity studies, the main parameters, and to simulate various scenarios of the repository's evolution, in order to be sure of its robustness.

The coherent network of calculation codes, related to a site, is a tool that integrates knowledge and assesses the sensitivity of that knowledge for the laboratory's objectives. It involves the ANDRA's responsibility; therefore it is directed under the ANDRA work-task hierarchy, whether it concerns time, space from the sources of disturbances caused by the underground structure to the initial site, or the scale of hazards and risks. A non-negligible amount of clearing up and identification work has been carried out. The making of this "responsible" network remains to be done.

Under these conditions, and if we keep to the calendar, the ANDRA should be able to hand out in 2006 a substantial report concerning the disposal possibilities in a clay environment. As for a new granite site, the work is running late and leaves little hope to present in 2006 scientific conclusions sustained by research completed in an underground laboratory on our national soil. The ANDRA runs the risk, then, to have to present a report based mainly on the generic works to which it participated in foreign laboratories with a different geological environment. It will also be able to base itself on data obtained from the surface thanks to fully instrumented drillings and geophysical studies. The deep repository project in Finland is a good illustration of the potential supply of knowledge from these techniques.

In order to be in accordance with the government decisions taken on December 8th 1998, a major effort of research must be launched so that to each type of waste we could associate an optimized disposal concept taking into account both the waste characteristics and the geological characteristics of the site. For example, B-waste is ultimate waste that emits only a low amount of heat power. There is no technical reason to pursue the intermediate storage of the waste that has an appropriate conditioning. On the other hand, C-waste requires a cooling period of several decades, which will have to be determined according to the characteristics of the final disposal site and the properties of the engineered barriers. The low volume of vitrified C-waste, and the advantages of a long cooling period, mean that there is no urgency. The storage facilities in La Hague can already receive about thirty years more glass production in which C-waste is inserted. Such a period, which could be extended, would allow both to improve in the field of transmutation and elaborate a robust concept of reversible disposal for high activity waste. Besides, the options concerned by storage disposal depend on the previous intermediate storage period.

Line 3

The third orientation of the law, so called "line 3", concerns intermediate storage understood as necessarily limited in time and in the containerisation of the waste. The global assessment of this line requires a clarification of the interactions between the various partners of the 1991 law, as well as the finality and the duration (decades or hundreds of years?) targeted for a long term storage, which are not precisely mentioned in the law. The variety of opinions which could exist on these points deserves to be quickly clarified in order to reach a global strategy on line 3, in coherence with the strategy on line 2.

The specific problems connected to the intermediate storage are, for one part, connected to the fact that the retrieval of the waste packages is here an obligation, not simply a possibility. The problems of long term resistance of the containers, and those involving engineering (mining if we are dealing with subsurface disposal), that is to say problems of loads circulation and transportation, of dewatering, ventilation, evacuation of heat etc. are becoming predominant. **The research coordination** between long term storage, namely in subsurface, and reversible disposal, is still to be organized. This coordination should help proposing common solutions avoiding reconditioning which would have the disadvantage to present new risks for the workers.

A long term disposal policy can be considered for (high activity) C-waste or used UOX fuels. If it was necessary to make this choice, a very long term storage of irradiated fuels, especially MOX fuel, would require a specific study; serious difficulties can already be foreseen because of its very important heat load.

A long term storage policy for B-waste would not be justified. It would pose a much more delicate problem, considering the often mediocre quality of the conditioning, or even the absence of conditioning. These waste should be considered as ultimate waste that does not come under Line 1 and are candidates for final disposal as soon as it will be available.

Packages and **containers** present the Commission with a particular problem : there remains at present a fairly large part of uncertainty about the objects that would be placed in a waste storage facility and above all in a geological repository. This uncertainty weighs, of course, on the reversibility of these storages, and on a possible reconditioning of the stored waste. An effort to clarify the situation has become necessary, in order to approach these problems in good time.

The description of the packages is now felt as an urgent need to enable the ANDRA to give level 1 approvals. In this respect, information documents are expected to arrive from the CEA at the end of 2000. These elements are not sufficient : it is also necessary to describe the complete packages that will have to be disposed of, giving the basic parameters (size, mass, package materials, etc.) without which the engineering is not made concrete, as well as the specific parameters of these packages linked to their radioactivity, without which it is difficult to design a nuclear site and assess its safety. It goes without saying that the full collaboration of EDF, CEA and COGEMA with the ANDRA is necessary for the definition of the packages envelopes. The information necessary for the ANDRA to decide on level 2 specifications and approvals must be carefully considered.

In connection with the concept of a separation-conditioning (S-C) path, the research of new matrices for the conditioning of separate elements, and that has been followed for several years, is being developed in three areas : vitreous, ceramic and glass-ceramic materials. Already, the confinement of some ceramic matrices in which radionuclides are inserted in the crystalline structure appears to be promising.

The study on the long and middle term behaviour of the matrices of glass, concrete and bitumen, that was started a long time ago for glasses and more recently for the others, seems to be going well. This type of research is long and must be continued to ensure the credibility of the models used in the performance analysis of repository constituents. The studies concerning the new matrices started with the benefit of the experience acquired while carrying out the first ones. They will have to be conducted taking into account the near field including containers corrosion, namely in a deep geological repository. Spent fuel assemblies are also being studied. Well structured programmes are being developed (CLTC, PRECCI, PRESTANCE). These phenomenological studies will undergo numerical modelling to simulate several scenarios. In the conditioning field, one may believe that in 2006 the state of knowledge will enable us to describe the behaviour of waste packages in the near-fied for intermediate storage, and reversible disposal if the temperature does not exceed 100°. Besides, formulations of new matrices should have been acquired.

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When we have a global overview of the **results already obtained** and the perspectives offered by the various actors on all the research paths, five subjects pose problems, that affect two or even all the objectives of the 1991 law, and require a clear and rapid answer :

1 - Waste management according to the three lines of the law involves radiations that can affect the workers concerned, and present and future populations. The share of research devoted to these **radiobiology** phenomena, in terms of what has been presented to the CNE, seems to be totally insufficient and out of proportions compared to the global effort on the 3 lines. The CNE has noted several times the inadequacy of the state of knowledge on the effect of ionising radiations on man and on the biosphere. Has it been heard?

In a recent report of the Science Academy devoted to radiochemistry, Professor Maurice TUBIANA clearly expresses the inadequacy of our knowledge : "We know that the foundations on which is built the whole radioprotection philosophy are outdated but we do not see clearly what could replace them" (Académie des Sciences, Rapport RST n° 4, Ed. Tec&Doc, July 2000).

The Cordoue conference held in March 2000 has, itself, asked similar questions. The CNE is requesting, for its part, to significantly increase the research in these fields. Moreover, an assessment of the relevance of **radioprotection** evaluation over long periods, based on health criteria adapted to these long periods, will have to be developed.

2- The high activity waste will first spend its life in **containers** stored for durations that can be more or less long. This will also be the case, at the minimum, in the reversible phase of a possible final disposal facility. **During this long period of time, the protection of workers and populations will have to be guaranteed by the container**. The research, developments and realizations connected to these containers (there will be thousands of them) did not convince the Commission by their validity, and the maturity of these works, realizations and tests has not yet been reached. As for B-waste, while waiting for the opening of a possible repository, it will still be waste storage in containers that will prevail during a few decades, and this for tens of thousands of containers. The same comments on the part of the Commission apply here again.

The container is a central element of the global multi-barrier concept : The consequences of the uncertainties on the other barriers would be reduced if we had at our disposal a container that would guarantee the confinement for several thousands of years, as it is the case in Sweden, Canada, Finland and the United States. Moreover, we shall convince the population only when a real object with technically proven qualities is available to us.

3 - The separation of plutonium has led, in the absence of fast neutron reactor programme, to its recycling in MOX fuels loaded today in 20 reactors. This means that we can control its annual flow and therefore the stock, and can help to satisfy the criteria of safety and non-proliferation. The solutions presented to the CNE concerning the management of radioactive waste coming from irradiated MOX fuels lead to a very long term storage, different because of its very important heat load, and to an underground disposal that would occupy a substantial part of the area devoted to

a possible repository. The inventory of some highly radioactive and radiotoxic actinide isotopes in these used MOX elements gives it a very particular weight in the management of these elements according to the three lines of the law : a global radioprotection assessment, in space and time, should be elaborated and include the impact of these actinides so created, when this will be possible.

4 - The various types of waste external to the fuel cycle of the present EDF plants also pose serious problems (tritiated waste, graphite, propulsion, etc). If concepts of processing and of disposal have been studied, no realization has started yet.

5 - The international treaties (OSPAR agreement) let us imagine that, in the future, iodine 129 will have to be recuperated and its conditioning or effective processing will have to be done, all the more since the very low content of iodine (compared to all the iodine produced) contained in B-waste already represents the main radiological impact to the discharge area of a possible repository.

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At the end of this assessment, we can look upon the years 2000-2006 as a period when research should, if it continues without being delayed, produce results that would make it possible to set orientations in several fields : separation, conditioning and intermediate storage. As for disposal in a shaly environment, even if all the experiments are not finished, the amount of knowledge at our disposal should give the legislator the possibility to present a draft of a repository in shales, if the results obtained with the research are favourable.

The December 30th 1991 law has clearly planned, for the elimination of long-lived high activity nuclear waste, to compare three options at the end of the research that is presently being carried out, and the progress of which has been summed up above. These three options, as we saw, apply to C-waste. In any case, the line 1 (separation-transmutation) alone will not be able to solve all the problems, it may just reduce their acuteness. Which place will take line 2 (deep reversible disposal) and line 3 (intermediate storage) relatively to the first one? By examining the present results of research we are able to propose the following comment.

At a given time, it is always possible to decide to build a long term intermediate storage site for C-waste (vitrified residues). This storage facility site can be built for durations ranging from 50, 100 years to several hundreds of years. Our Society today is fully able to run such a storage facility safely, by giving it, besides the proper means of surveillance, the means necessary for an intervention like

placing new barriers in case its deterioration would demand it. Therefore it can indeed be envisaged that, every now and then, our Society could compare the respective advantages of the final disposal option against the storage option, and decide, repeatedly, and always within a limited period of time, to continue with storage and never to dispose of. There are no physical or technical reasons that would prevent that type of storage, periodically renewed, from going on for centuries, even millenniums, providing the technology remains available. It is the question of the durability of human societies, of their technical systems and their institutions, in particular to supervise such storage facilities, that can pose a problem. Each time a decision is made to create or prolong a waste storage for a reasonable amount of time, our Society bets on the fact that its institutions will remain stable and reliable, and that the adequate technologies will still be available over that same period of time.

On the contrary, the decision to choose deep disposal is based on the will not to generate a constraint of surveillance, maintenance and technical adaptation which would weigh on future generations, and therefore to free ourselves from the bet on the stability of the institutions. If our Society decides to choose deep waste disposal, it means that it is convinced that the unavoidable uncertainties concerning the functioning of the repository are minimum and acceptable, compared to those connected to the continuous functioning of the institutions. Therefore we have on one hand uncertainties of a geological nature, and on the other hand, those of a behavioural nature for future societies which could come and perturb the repository with unplanned works, the existence of the repository having been forgotten, or because of a malevolent and deliberate intrusion.

The use of intermediate storage and of final disposal concerns our Society : do national and local communities trust the durability of the institutions, and the choice to maintain a temporary solution? Have they acquired the conviction that the natural environment in depth offers less certainties than those on the stability of the institutions? These are in fact two a priori incommensurable uncertainties, that the works planned by the December 30th 1991 law will help to better evaluate.

It is of course up to the political order and not to the technical one, responsible for giving elements to assess uncertainties of a scientific nature, which has to orientate choices. In this respect, the December 30th 1991 law implies that the respective weights of these two uncertainties in the eyes of the public will have to be assessed, in order to enlighten political choices. Is research on human sciences necessary to enlighten this debate and allow such a comparison? An illustration of the interest of such studies is given by the difficulties recently met while looking for a granite site for a second underground laboratory.

Main questions and recommendations expressed in the Assessment report n° 6.

The Commission recaps hereunder the main recommendations, expressed in the present report covering the auditions from September 1999 to May 2000.

- The question of health hazards being considered outside the field of the 1991 law, which organisms are responsible for the corresponding research? What are the main fields concerned?
- The Commission recommends to pursue the effort on already used or future confinement matrices. On the other hand, it regrets that the problem of containers should still be at an embryonic state. It recommends that their function both on a storage site or in a final disposal facility, either reversible or not, should be translated into a physical realization comparable to what exists in other countries, combined to a test programme ensuring the quality of the confinement.
- The Commission expresses its general approbation on the proposals presented by the President of the ANDRA for a method of waste inventory. It wishes that appropriate means be implemented for the realization of this inventory which is totally essential to the operational plan, as well as for total transparency on the management of the radioactive waste that has to remain in France.
- With the inventory that will be done, the Commission recommends a clarification of the waste classification, that should be funded on their content of long-lived radionuclides and chemical toxic elements, and that should take into account their final destination.
- The Commission finds it necessary to pursue research in pyrochemistry for the processing of special fuels and targets of transmutation systems.
- The Commission encourages the pursue of the development of new fuel matrices for the transmutation system. It asks itself questions on the availability of the necessary irradiations means until the end of the period set by law.
- The Commission approves the present rigorous, concrete and essential approach, which consists in developing basic research on hybrid systems and in experimentally studying the technical aspects connected to the three subsystems - IPHI accelerator, spallation target (MEGAPIE) and sub-critical mass (MUSE). This is an approach that could not be replaced by simulation alone.

- The Commission very strongly recommends the ANDRA to maintain in all cases the priority on scientific objectives over operational constraints, since the ultimate justification for building an underground laboratory is precisely to acquire scientific information on the geological environment in view of a qualification for a possible repository.
- The ANDRA must have state-of-the-art competences in the field of simulation, but also its mathematical modelling experts must be capable to master the other aspects of the safety analysis, with a highly qualified scientific supervisor having at his disposal the necessary means to integrate all the elements of this analysis. It is essential to devote a vigorous programme and an increased importance to numerical simulation.
- This programme must focus on the hard points of the problem like the expression of source words (taking into account the containers when they will be defined) and the expression of couplings source terms – near field – distant field.
- The Commission recommends to stimulate research on biosphere in order to reach calculation patterns and codes adapted to the specific problem of geological disposal, and validated.
- The Commission recommends that all the research conducted on the R7-T7 glass packages (and on the approaching formulations that would aim at vitrifying solutions of waiting fission products) should be integrated in a structured programme, like other actions connected to used fuel were in the PRECCI programme.
- The Commission underlines the importance of acquiring the necessary elements to assess the uncertainties of a scientific nature linked to the surveillance of long term storage facilities and to the maintenance of packages.
- Concerning many problems linked to disposal and storage (containers, reversibility, underground structures), the Commission wishes that the ANDRA and the CEA should constantly remember that their modelling uses the same resources and should closely collaborate.