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## Safety of direct disposal of spent fuel and of disposal of reprocessing waste

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### **Abstract:**

In 2005, the French Agency for Radioactive waste management (ANDRA) established a report on the feasibility of the geological disposal of high level and intermediate level long lived radioactive waste, in a clay formation. The hypothesis of spent fuel direct disposal was also considered. By the end of 2005, IRSN performed a complete technical review of ANDRAS' report, aiming at highlighting the salient safety issues that were to be addressed within a process that may possibly lead to the creation of a disposal facility for these wastes. The following publication presents the main conclusions of this technical review.

### **IRSN CONCLUSIONS ON ANDRA'S STUDIES ON THE FEASIBILITY OF A GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE IN CLAY**

In 2005, the French Agency for Radioactive waste management (ANDRA) established a report on the feasibility of the geological disposal of high level and intermediate level long lived radioactive waste, as well as of spent fuel, in a clay formation investigated by means of an underground research laboratory located at Bure, eastern France. This report ("Dossier 2005 Argile") comes as the conclusion of a 15 years research effort on this matter in application of the orientations set by the law on 1991 on radioactive waste management. It presents a safety case aiming at enabling decision making on the follow up of the law for possibly moving to next stages for the management of the above mentioned waste

The Institute for Radiation protection and Nuclear Safety (IRSN) has periodically assessed the safety issues related to deep geological disposal project development over the last 15 years, that lead to identify critical points for safety to be accounted for in order to assess the feasibility of such disposal in clay. By the end of 2005, IRSN performed a complete technical review of ANDRAS' safety case. In order to highlight the salient safety issues that are to be addressed so as to enable taking decision on the process to be implemented for possibly creating a disposal facility, IRSN has evaluated the following elements :

- the basic data required for designing a deep disposal facility, i.e. that related to the radioactive waste and spent fuel inventories and to the geological formation and its environment,
- the safety strategy adopted to design the facility, in consistency with the above mentioned data, and to account for uncertainties,
- the perturbations and transient conditions that the facility is likely to encounter, both in short and long term,

- the safety assessment for the construction and operation of the facility, as well as safety issues related to reversibility,
- the long term safety assessment from closure of the facility, comprising the assessment of barrier performances, the robustness of the facility with regard to likely and unlikely perturbations, and the estimation of long term radiological impacts.

The main conclusions of IRSN technical review are presented hereafter.

It was at first emphasised that ANDRAs' report presents a major compilation of data, studies and interpretations that allow assessing whether a high-level and intermediate level long-lived waste repository in the studied clay layer is likely to ensure sufficient protection of man and the environment against the harmful effects of this waste, in the short and long term. It was also considered that ANDRA had adopted a sound safety strategy for project development consisting in designing a facility in consistency with the defence in depth principle, in identifying the phenomena responsible for possible changes in the containment properties of the various repository components along with their related uncertainties, and in assessing the weight of these uncertainties on the ability of the repository installation to prevent the dissemination of radioactive matter contained in the waste. ANDRA also addressed all the critical points for repository safety highlighted during previous reviews of the development stages of the feasibility study. The overall quality of the work performed and reported in the "Dossier 2005 Argile" was underlined.

Regarding the critical points for repository safety, IRSN noted in particular from its assessment of the report that :

- the Callovo-Oxfordian clay layer (studied in the Bure laboratory) would probably comprise sound blocks of a size consistent with the large disposal modules envisaged by ANDRA,
- if additional studies were deemed necessary to improve the understanding of underground flows in the limestone formations surrounding the clay formation, the data acquired in the area where ANDRA considers that the geological formations have properties that in principle favour the installation of a repository did not, however, indicate circulation of fluids between these aquifers nor rapid flows within them, except for the mapped fault zones,
- the main disturbances (thermal, hydric, mechanical, chemical and gas-related) did not appear to produce effects ruling out the containment capability of the facility, based on current knowledge,
- particular attention had been paid by ANDRA to the sealing of engineered structures in the most recent project developments, the design of seals being adapted to account for the excavation damaged zone surrounding underground vaults and drifts. Possible orders of magnitude of their containment properties had been estimated, requiring confirmation in the future, however,
- a first safety analysis of repository operation had been performed, from which it could be concluded that, at this stage, the systems envisaged by ANDRA did not present adverse obstacle to the transfer of packages under safe conditions into the repository infrastructures, nor major difficulties in managing risks from fire, criticality or an earthquake occurring.

IRSN found that the identification and consideration of uncertainties were clearly listed in the report and noted that ANDRA had elected to encompass them widely through special design provisions or by adopting hypotheses of a partial or total loss of function of the various repository components, allowing a conservative appraisal of uncertainties incidence on safety. In particular, IRSN considered that the envisaged repository concepts were likely to prevent rises in temperature that could prejudice the containment capabilities of the repository components and that the adoption of an over-pack (surrounding vitrified waste packages and spent fuel) was relevant to prevent releases of activity in temperature conditions where transport phenomena are difficult to appraise. IRSN also noted that uncertainties on the evolution of containment performances of engineered repository components (packages, over-packs, seals) were taken into account by postulating failures of these components with varying degrees of severity. If additional hypothetical situations might have been accounted for, especially to cover uncertainties on possible local discontinuities of host rock which IRSN considered not totally ruled out from present investigations, IRSN estimated nevertheless that the assessment results presented by ANDRA were sufficiently convincing to, allow concluding on the robustness of the repository and its capability to maintain low radiological impacts despite possible component failures.

Thus, in the light of the elements examined, IRSN concluded that a radioactive waste repository in the clay formation studied in the Bure underground laboratory appeared “feasible” inasmuch as it was not at this stage identified any obstacle ruling out a “safety demonstration” of such an installation in the future.

It was nevertheless pointed out that several points would have to be examined in greater detail if a policy decision on geological disposal was taken by the Parliament in 2006, to establish this demonstration. Among these points, IRSN emphasized the need to select a site:

- by defining a surveying strategy enabling the identification of possible fracturing in the host formation and the geological layers surrounding it. In this respect, IRSN considers that it will probably be necessary to use a high-resolution geophysical technique like 3D seismics, combined with a survey of the clay formation through boreholes above the most pronounced seismic indices possibly detected in the underlying formations,
- by improving knowledge of underground flows and by detailing the hypotheses relating to existing biospheres or those likely to exist on the selected site. For the biospheres, IRSN underlined that the choice of hypotheses describing them is not based on strict technical expertise alone and that it could be useful to define them by relying as much as possible on a consensus of the various stakeholders concerned.

Confirmation would also be required that the dimensioning hypotheses for the various repository components are well founded, with the aim of constructing containment barriers that are as effective as is reasonably achievable. In this respect, IRSN felt that it was particularly important to :

- confirm the likely performances of a sealing engineered structure, taking into account the effects of potential chemical disturbances over time and of a pressure build-up of the gases in contact with the engineered structure. The engineered structure design should also be based on an understanding of the mechanical behaviour of the rock which should be improved further,
- check the relevance of present design of the metallic repository components (canisters in particular) with respect to corrosion phenomena. Significant uncertainties

exist over corrosion rates of these components, due particularly to a lack of knowledge on transient environment conditions and their duration,

- confirm the design of support equipment for large engineered vaults and generally improve the knowledge of the physical and chemical properties of the concretes in their initial and altered state, taking into account the influence on these properties of the conditions for industrial implementation of cement-based components,
- justify in greater detail the relevance of the concepts adopted in the Dossier 2005 Argile, particularly with respect to the risk of explosion related to radiolytic hydrogen produced in the B waste cells, the ability to remedy a situation caused by a package drop in these cells and the possibility of retrieving C waste and spent fuel packages. In this respect, IRSN does not question that the arrangements planned by ANDRA, aiming by their very nature to minimise degradation of packages and engineered structures in the long term, can offer the possibility of easy retrieval of waste packages over long periods, but cannot reach a conclusion in the current state of knowledge on this possibility already being acquired over two or three centuries.

IRSN underlined that these additions should be based especially on tests *in situ*, in conditions as close as possible to those planned in a repository installation. In IRSN's view, repository engineered structure demonstration tests will be necessary to demonstrate at industrial scale the safety of such an installation.