The Uranium Institute 24th Annual Symposium
8-10 September 1999: London

The Deep Geological Repository: an Unavoidable and Ethically Correct Solution

Maurice Allègre

Finding a solution for nuclear waste is a key issue, not only for the protection of the environment but also for the future of the nuclear industry. Fifteen years from now, when the first decisions for the replacement of existing nuclear power plants will have to be made, the general public will require to know the solution for nuclear waste before accepting new nuclear plants. In other words, an acceptable solution for the management of nuclear waste is a prerequisite for a renewal of nuclear power.

On the other hand, there is apparently no need to hurry:

- The volumes of waste are not that great; in 2020, the order of magnitude for the whole world will be 300 000 cubic metres for high level and long lived waste, and less than one million cubic metres for intermediate level long lived waste.
- Most existing wastes are being stored in safe conditions waiting for a permanent solution, with some exceptions in the former Eastern Bloc. Temporary surface or shallow storage is a well known technique widely used all over the world.

With deep ocean disposal in stable clay in the seabed being excluded for legal and political reasons, there is a strong consensus among all major countries that the deep geological repository is the only possible permanent solution, and this is being studied extensively. Recently, a very significant step was taken by the United States: the operation of the Waste Isolation Pilot Plant (WIPP) was authorised in 1998, and in early 1999 the first cubic metres of intermediate level long lived military waste were put for ever into the repository, in a deep stable layer of salt in New Mexico. This was the first operation of its kind in the world.

The issues to consider now are:

- Is the geological repository a good and workable solution?
- Is it a fair, ethical and acceptable solution?
- Is it the only one?
- When should it be proved and implemented ?

The aim of this paper is to contribute to answering these questions.

The Deep Geological Repository Solution

The purpose of a deep geological repository is to provide to future generations, especially to those in the far future, passive protection against any harmful release of radioactive material, even after the memory of the repository has been lost, and whatever the technical knowledge of those future generations.

The "ideal repository" would be located in a stable area and would be deep enough to be protected against surface erosion, large climatic changes (such as a new ice age), earthquakes (which are much less severe at depth), and human intrusion. It would be located in an impermeable formation, with sedimentary salt or clay layers being the most suitable formations. A well designed and sufficiently thick waste packaging, and an engineered barrier complementary to the geological barrier, would guarantee that there would be no release of highly active and dangerous short lived radionuclides during the first thousand years, the time needed for them to decay completely. After that first period, the two man made barriers (the packaging and the engineered barrier) and, in the longer timescale (over 10 000 years), the geological barrier, will prevent long lived radionuclides leaking significantly into the biosphere, where future generations will live.

The remaining radioactive elements after 1000 years will be mostly heavy transuranic elements[1] which have a low level activity (the longer the half-life, the lower the activity). But, being alpha emitters, these could induce cancers if inhaled or ingested in significant quantity. The underground enemy of a repository is not water itself; it is circulating water which can leach waste packages and, in a lengthy process, carry away radioactive elements to the biosphere. The solution to this is very obvious: to set the repository in an impermeable host formation.

Impermeable means that no water or only a very slight amount of water can circulate in the geological formation. Given that these heavy elements have a very low solubility and mobility in water and are strongly absorbed by the geological formation, one can understand how and why a repository can work in sedimentary salt (e.g. WIPP) or clay formations.

The main question is: is the geology reliable? Two reasons may be given to support a positive answer to this question:

- Natural analogues prove that in many cases nature has been able to sustain impermeable conditions for a very long period of time. Transuranics have been trapped for two billion years by a few metres of clay at the Oklo "natural reactors" found in Gabon. Moreover, there are plenty of examples of mobile elements trapped for millions and sometimes hundreds of millions of years

[1] And also some beta emitting fission products

by sedimentary salt or clay formations: these include oil and gas fields all over the world.

- The stability of a geological formation for some hundreds of thousands of years is very difficult to comprehend for a human being because the geological timescale is quite different from the human one. Geological changes are generated by plate tectonic movements induced by very slow convection currents in the viscous mantle of the earth. Near surface active faults are driven by plates moving at a very low speed which cannot significantly change in less than several hundreds of thousands or even millions of years. In other words, it is possible to forecast that over the next hundreds of thousands of years there will be no significant change in the active faults network of a stable and simple area. If a geological repository is sited in a formation which has been stable for millions of years and is distant enough from active faults, it is quite justified to think that there will be no change in the formation conditions for the next hundreds of thousands of years.

Moreover, if the geology of the host formation is stable and simple, modelling it will be simple and reliable and it will be easier to convince all the stakeholders that the passive containment of long lived radionuclides has been achieved.

There are those who are strongly of the opinion that in the future some high level or long lived waste could be used for scientific or energy-producing purposes which we cannot imagine now, or that a way to reduce the danger posed by the waste could be developed one day. In such cases, it could be useful to retrieve and retreat the waste. Several remarks must be made:

- Intermediate level wastes (and technological wastes), which represent the largest volume of waste, are too dilute to think of any reuse or re-treatment in the future. The only possibility for such waste is a deep repository without any need for retrievability.
- For high level and long lived waste with a high content of radionuclides (i.e. spent fuel or vitrified waste), it would be possible to keep galleries in a repository partially or totally open for a certain time after the end of the filling period, before the final closure. Even after the closure, mining techniques could allow the possibility of retrieving containers so long as their integrity was maintained. An essential requirement would of course be that no measures taken to favour retrievability should jeopardise the passive self sufficient safety of the deep repository in the very long term.

Nowadays, the retrievability concept is becoming so fashionable that it has tended to replace and overshadow the original repository concept, leading to erroneous and unethical conclusions (see below).

A significant research effort has been made by the main nuclear electricity producing countries over the past thirty years, both on the

surface and in underground laboratories, although it has been sometimes been dispersed over too many host media. It is likely that some deep repository projects will be demonstrated to be feasible, as the WIPP has been, during the next twenty years. But will such repositories be acceptable to the general public?

Acceptability of a Deep Geological Repository

Although the two events have nothing to do with nuclear waste, Hiroshima and Chernobyl are weighing heavily on the public's perception of risks attached to radioactive waste.

The radioactive waste risk perception is very much exaggerated when compared to the large variety of risks encountered every day by any human being. People are very easily frightened by those who draw their attention to radioactivity, whatever the dose, even when it is much lower than ambient radioactivity. Yet, the precautionary principle cannot mean zero release, zero risk anywhere or in any human activity, nuclear included.

Decision making for a repository is a long and difficult process because the waste can always wait, more studies can always be thought necessary, and politicians do not like to take risky decisions when they can find good reasons for an additional delay. Siting a repository is an issue of national interest but there are always local people living near the site who have to be convinced that this repository is necessary and will not be harmful to them or to their descendants.

For these reasons, any government involved in the problem of siting a repository knows now that such a decision will be possible only after a lengthy, fully open, democratic and stepwise process including all the stakeholders, including politicians, scientists, local communities and associations.

The major concern is that the public debate must be centred on relevant and important questions, using honest arguments in good faith, and must not degenerate into a kind of religious war. Unfortunately, in most cases, the debate is on the wrong issues. For instance, there are many difficult scientific and technical matters to discuss, but, maybe because of the very difficulty of these matters, repository opponents do not really want to argue about them. It is easier for the opponents to say without any demonstration that "nuclear garbage" will be harmful to future generations and that a repository is a solution which is contrary to ethics. This last claim is so important that it needs to be discussed in detail.

Questions About Ethics

The ethical aspect of nuclear waste is a fundamental one. What is ethically correct and what is not? What kind of guidelines can ethics give us?

The golden rule is “never do to anybody something you would not like him to do to you”. This rule usually applies to people living at the same time as us, and one can imagine applying it to our grandchildren and their children. But it is much more difficult to conceive how to apply this principle to generations which are so far in the future that it is impossible even to imagine what they will look like. The only solution is to protect them whatever they will be. For the long term, passive self-sufficient protection is necessary.

Our generation enjoys the benefits of the nuclear produced electricity. Our duty is not to leave the negative effects of producing nuclear energy to future generations, including those in the near future. We cannot leave to the next generations the burden of finding a long term solution. Since we have no magic wand to make waste disappear, our duty is not to leave the problem unsolved to the next generations. Passing on to them the hot potato would not be ethically correct!

The duty of our generation is to find a good solution to assure long term passive protection to far future generations (not leaving this burden to the near future generations), or at least to demonstrate that a good solution has been found and to create a consensus about this. It is also our duty to provide the financial resources for the implementation of this solution. This rationale shows that the only behaviour compatible with ethics is to “hurry up slowly” to site deep repositories and to progressively put aside the necessary funds.

Thus, the underground repository appears to be a good solution, for the following reasons:

- If correctly sited in a stable and simple impermeable formation, it is very likely that safety can be demonstrated.
- The public acceptability challenge can probably be dealt with if the decision making process is long, open, stepwise and democratic enough.
- The passive long term protection offered to far future generations is ethically correct.
- Our generation is committed to finding a solution, for it would not be ethically correct to leave this burden on the shoulders of the next generations.

Nevertheless, strong criticisms are made of this solution, especially on the ground of ethics. The proposed alternate solutions for long lived waste are separation and transmutation, and surface or shallow storage.

Separation and Transmutation

Trying to transform dangerous long lived radionuclides into less harmful short lived or stable elements is a logical idea. It is indeed possible to incinerate or transmute heavy atoms of long lived elements in fast breeder reactors or even in pressurised or boiling water

reactors. There are also new types of reactors which could be used, namely accelerator driven systems. But many problems still remain:

- It is necessary to separate an element before trying to transmute it in a dedicated reactor. So, the use of reprocessing techniques and even of enhanced reprocessing technology would be necessary. It is illogical to hear people who are both strongly opposed to reprocessing and in favour of transmutation!
- Huge investments would be necessary. For instance, one fast breeder would be needed for four nuclear power plants. Less and less effort is being made to develop the technology of fast breeders (e.g. the closure of Superphenix).
- Like any industrial process, the yield of transmutation/incineration cannot be 100% for technical (all processes are half life type) and economic reasons. The process takes time in a reactor and is never fully completed: 10 years in the reactor will give no more than 90% destruction. All elements are not transformed.
- Transmutation/incineration will produce its own waste and its own risks for workers.
- Accelerator driven systems are still only at the pre-feasibility fundamental research stage. A very long and costly effort would be necessary to prove that all the technical difficulties had been overcome. The preceding remark about incomplete transformation will also be valid for this type of reactor.

Thus, it appears that separation and transmutation:

- would require huge investments, both in fundamental research and in development of industrial facilities.
- would require decades of continuous and costly effort without any guarantee of success.
- would not be applicable for diluted (intermediate level) wastes, which represent the major volume of long lived wastes (see above).
- could not achieve a 100% yield, even if a successful technique was deployed.
- could not be used with some existing waste which has already been packaged.

This technique, then, could not pretend to make an underground repository unnecessary. At the end of a very long and expensive scientific and technical effort, separation and transmutation might give a partial solution for long lived waste. The type of waste to be disposed of in a deep repository and the degree of hazard it presented might be changed. The volume and activity of the waste could be reduced, but never to zero. A deep geological repository would still be needed. Separation and transmutation is thus not a solution able to replace the deep repository solution, it is only a complementary solution.

Notwithstanding the great scientific interest in such matters, the question of the cost effectiveness of such an effort in order to partially transform 0.3% of spent fuel material must be raised.

Surface or Shallow Storage

For intermediate level waste, there is no other solution than the deep repository (see above), and there is thus no need to wait once a repository is available. In the meantime, these types of waste are stored on the surface.

High level and long lived wastes (spent fuel and vitrified waste) contain a mixture of high activity (heat producing) short lived nuclides and low activity long lived alpha emitting nuclides. To avoid any alteration due to temperature of the engineered or geological barrier surrounding the waste underground, it is necessary to store the packages on the surface for several decades (50 years or more) to allow a sufficient temperature decrease before disposing of them underground. In all cases, surface (or shallow) storage is needed as a temporary solution.

Today, however, some people envisage surface storage as the long term solution for long lived waste. The odd expression “perpetual surface storage” has even been used in official conferences! What is wrong with such a misuse of the word storage?

The reasons put forward for “perpetual storage” are generally the following :

- To ensure retrievability, it is better to keep waste where it is available at once.
- It is easier to check continuously the safety of packages if you have them in view where you cannot forget them.
- In order for a solution to be publicly acceptable, the waste must remain accessible and where it can be monitored, to give future generations a chance to deal with the problem if and when a better solution is found.
- It is ethically correct not to impose a solution (the deep repository) now on future generations, but to leave them free to choose their solution in the future, when science will offer better guarantees.

These justifications are wrong. I will discuss them one at a time.

The retrievability concept was emphasised mostly by politicians initially, thinking that it would be better to show the public that everything would be done step by step and that advantage would be taken of possible scientific breakthroughs in the future. The answer has been already given above: retrievability can be maintained for some time, but final closure has to happen one day in order to assure the passive protection in the very long term. Choosing the length of the period before final closure will be the responsibility of the next

generations. In any case, after final closure it will still be possible to extract the waste.

It is a somewhat contradictory attitude to think that science will provide a wonderful solution sometime in the future but not to trust present day science to be able to demonstrate safety for a well sited repository!

It is possible and safe to keep waste in a surface storage for a long time, a hundred years or even more. But it is not reasonable to keep waste in a surface storage for an indefinite period of time, as the waste then has to be continuously monitored and maintained. What institutions will take care of the waste in 1000 years, in 10 000 years? How could we rely on civilisations that we cannot imagine? Safe monitoring of stored waste is conceivable only for a limited period of time, not for an indefinite period.

Moreover, leaving waste on nuclear plants sites is still more unreasonable, because leaving dangerous wastes in many locations (more than 70 for the USA alone) increases the risk of the misuse or mismanagement of them. In comparison, the risk of transporting wastes to gather them in a central location seems much smaller. One can add that the transportation risk is the same for a central interim storage as it is for a deep repository.

Leaving the waste on the surface would mean leaving to future generations the whole burden of the waste without caring to provide them with any workable solution. Surface (or shallow) storage must be considered only as a temporary solution and cannot replace the unavoidable solution: the deep repository. This is the only solution to offer passive protection to far future generations, whatever their civilisation will be like. The purpose of a deep repository is not to forget the waste underground. On the contrary, it is to put the waste in a safe place where it will continue to be harmless even after it has been forgotten.

Conclusion

It is sometimes difficult to understand how such divergent opinions can be sustained on these matters. Radioactivity is indeed a very touchy issue, but there are other reasons.
The nuclear industry finds it difficult to explain the technical questions involved, and is not completely trusted after several communication mistakes made in the past. Scientists are very happy to get funding to carry out research on very interesting and long term projects. The aim of anti-nuclear groups is to fight as strongly as possible by any means the deep repository concept, in order to be able to say in fifteen years time that nuclear energy has not been able to find a solution for the disposal of waste, that this is a major concern, and that it is thus not reasonable to renew the existing nuclear park!

In trying to clarify the debate, the conclusion can be summarised in the following statements:

- The deep geological repository is the only ethically correct solution in the long term which gives passive protection to far future generations. It allows retrievability, if needed, for a certain time before final closure. The deep repository is in all cases an unavoidable solution. Separation and transmutation could be a partial, and very expensive, solution. It could only be a complementary solution to a deep repository.
- Surface or shallow storage is a temporary solution. It could never be considered a permanent solution. The do nothing option, i.e. to leave the waste indefinitely in scattered surface storage locations, is not ethically acceptable. Our generation must prove that a solution does exist to provide passive protection to far future generations against nuclear waste.
- Our generation must provide the financing, make all the studies, and create a consensus to demonstrate the feasibility of deep repositories. Our children will have the responsibility to take the decision to implement or not to implement such repositories. Our grandchildren will have the responsibility to keep such repositories open for a certain period of time, and eventually to close them to assure long term passive protection.