Nuclear Power, Nuclear Waste and Geological Disposal

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Introduction

For many years, nuclear supporters have been talking of a possible nuclear power renaissance. Today there are definite signs that this is finally beginning to happen. New nuclear power plants are being discussed or planned in countries that already use nuclear power, such as China, Russia, India, Japan, Korea, Finland, France, the UK, Bulgaria, Slovenia, Switzerland, Romania, Brazil, Mexico, and South Africa. In the USA alone, over 20 new units are being proposed. Countries like Vietnam, Indonesia, Poland, the Baltic States, Egypt, the Arab States, and even Australia (with its long anti-nuclear tradition) are choosing or debating initiating a nuclear programme. Finally, nuclear phase-out policies are being rethought in countries like Sweden, Belgium and Germany.

The degree of support for - or opposition to - these nuclear power developments will be strongly influenced by the progress of waste management programmes. Conversely, the growing realisation of the potential global benefits of nuclear power may well lead to increased support, effort and funding for initiatives to ensure that all nations have access to safe and secure waste management facilities. The greatest challenge in this respect is ensuring that all counties with hazardous long-lived radioactive wastes have access to the deep geological repositories that are recognised to be the only safe solution in the long term – but which are costly and politically difficult to implement.

A particular concern in recent times is to ensure that civilian use of nuclear power can be expanded without unacceptable increase in the risk of misuse of nuclear technologies or materials. Multinational efforts are required throughout the nuclear fuel cycle in order to achieve this crucial objective. However, the current cooperation proposals being made by the major nuclear nations neglect the problems of waste disposal and therefore provide too few incentives to small countries that are being urged to forego some of their rights under existing treaties.

A brief look back at geological disposal

The concept of geological disposal is a logical consequence of the easily observable decay of radioactivity with time, which leads to a continuous reduction in toxicity of these wastes. Finite hazardous lifetimes (and low volumes of wastes) led to development of concepts where environmental protection could be aimed at by isolating wastes from man's surroundings for long enough to allow such decay to occur. However, the feasibility of this approach depends upon our identifying disposal environments for which we have evidence of their sufficient stability over tens or hundreds of thousands of years. The risks involved in sending materials out of the terrestrial sphere into deep space have been tragically demonstrated by the space programmes as being too high. Deep geological formations are the most obvious candidate stable environments that can be accessed with today's technology. Consequently, concepts for geological disposal under the continental earth's crust have been developed over many years since the concept of disposal in deep geological formations was recognised by the US National Academy of Sciences back in 1957 to be the most promising form of confinement for long-lived wastes from the nuclear fuel cycle.[1]

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[1] National Research Council, *The Disposal of Radioactive Waste on Land,* Washington, D.C., National Academies Press (1957).

Despite the resulting, well documented history of disposal project developments, accusations have often been made by anti-nuclear groups that nuclear power was started without any consideration having been given to the management of its wastes. The experts in the nuclear community see this differently. They point out that for many years, or even decades, there was no technical need for disposal. The quantities of high level waste or spent fuel were too small to justify implementing repositories and, in any case, a cooling time of around 40 years was the sensible technical choice adopted by most countries (although not by the USA). In retrospect, however, there was indeed too little effort invested into organising long-term management and disposal; most attention was devoted to implementing practical measures for handling and storing radioactive wastes safely.

With time, however, things changed; dynamic waste disposal initiatives were started - and, paradoxically, the nuclear opponents were in large measure to thank for this. Because nuclear sceptics asserted that lack of demonstrated safe technologies for disposal should preclude the use of nuclear power, some governments (e.g. in Sweden, the USA and Switzerland) were pressured to demand specific projects that could provide this demonstration and nuclear power producers in some further countries took up the same challenge (e.g. in Finland and Belgium). There are also striking counter-examples, i.e. cases where nuclear opponents have slowed or stopped any progress in disposal. The reasons for opposition to progressing repository programmes are diverse. Some people genuinely believe that the safety of deep geological disposals has not been demonstrated sufficiently and that allowing years or decades for further work will produce some as yet undefined better solution – a "magic bullet". Others object for tactical reasons – an accepted waste disposal solution would remove one of their last anti-nuclear arguments, now that operational safety has been demonstrated by many years of operating reactors and the economics of nuclear power is clearly favourable.[2,3]

A real danger resulting from tactical manoeuvres of disposal opponents is that an "unholy alliance" could result. Indefinite storage could become the common solution that satisfies both the nuclear opponents (who wish to block a real final solution) and extremists in the nuclear industry (who know very well that the storage option is much less costly than implementing geological repositories). The losers, in this case, are our children and grandchildren, the future generations who then inherit an unsolved problem passed on to them by us because we did too little to clear up our own mess.

What are, today, the key issues influencing efforts towards implementing deep geological disposal? Work is still in progress on many of the technical issues that have been studied for decades, most importantly in the demonstration of long-term radiological safety of repositories. Of late, a new and frightening aspect has moved to the forefront. This is the growing concern about the misuse of nuclear materials by nations that are intent on gaining nuclear weapons capabilities, or even more worrying, by sub-national groups planning nuclear terrorist acts. In the recent past – in particular since the terrorist attacks on the USA in 2001 – the security issues associated with management of nuclear materials, including wastes, have assumed high profile. This is unfortunate for the world in general, but may be productive for waste management, if it leads to an increased willingness for countries to push ahead with implementing national and multi-national disposal facilities that can improve global security.

Status of Geological Disposal Programmes

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[2] World Nuclear Association, *The New Economics of Nuclear Power*, (2006) http://www.world-nuclear.org/economics.pdf

[3] IEA and OECD, *Projected Costs of Generating Electricity: 2005 Update*, 232 pages, ISBN: 92-64-00826-8 (2005)

For at least 25 years after the original 1950's publications on the concept of geological disposal, the validity of this approach was not questioned. It was formally adopted as a final goal, through policy or legal decisions, in many countries, including the USA, Canada, Sweden, Finland, Belgium, Switzerland, France, Spain, South Korea, the UK and Japan. However, virtually every geological waste disposal programme in the world ran into difficulties in keeping to originally proposed schedules. Slippages in deadlines, however, are common in large projects; disposal programmes are not unusual in this respect. Less common are decisions of the type taken in some countries – namely to indefinitely postpone implementation of geological repositories. Backing off from the choice of geological disposal as the preferred national strategy took place in France, the UK and Canada. In all three, extensive public and political consultation exercises, took place. In all cases, however, the resulting recommendations were that geological programmes should move ahead, although in an extended staged process.[4,5,6]

This rather sobering look at the slow progress of geological repositories in some countries contrasts with the advances made in some other parts of the world. In the USA, the WIPP deep repository for transuranic wastes has been operating successfully for some years and has recently been recertified to continue doing so. In the Northern European countries, Finland and Sweden, the deep repository programmes are very advanced; these have shown that sites can be selected with the consent of local populations, that all necessary technologies are mature enough for implementation and that definitive dates for repository operation can be set.[7,8] In most other countries of the world, the combined technical and societal approaches employed in the Scandinavian countries are looked upon as role models for how things might be arranged also in other programmes.

A broad look at the present status of geological disposal around the world today reveals the following. Technologies for implementing deep geological disposal have been developed and extensively tested in a number of countries - but they have been fully implemented in only a very few cases. These technologies are based on different conceptual designs for deep repositories; there are multiple feasible options for the choice of the engineered barriers that enclose the used nuclear fuel and also for the geological medium in which the repository will be sited. In all of the different programmes, the safety of the deep geological system - as assessed by the range of scientific methodologies developed for this purpose[9] - is invariably shown to be

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[4] *Planning Act No. 2006-739 of 28 June 2006 Concerning the Sustainable Management of Radioactive Materials and Waste*
http://www.legifrance.gouv.fr/WAspad/UnTexteDeJorf?numjo=ECOX0600036L
Translation at http://www.industrie.gouv.fr/energie/anglais/pdf/loi-28-06-06-ang.pdf

[5] DEFRA, *Response to the Report and Recommendations from the Committee on Radioactive Waste Management (CoRWM) By the UK Government and the devolved administrations (2006)*
http://www.defra.gov.uk/environment/radioactivity/waste/pdf/corwm-govresponse.pdf

[6] NWMO, *Choosing a Way Forward The Future Management of Canada's Used Nuclear Fuel (Final Study Report)* 2006
http://www.nwmo.ca/default.aspx?DN=1487,20,1,Documents

[7] SKB, *Site Investigation Oskarshamn - Annual Report 2005*, Svensk Kärnbränslehantering AB (2006) and SKB, *Site Investigation Forsmark - Annual Report 2005*, Svensk Kärnbränslehantering AB (2006)

[8] Posiva, *Annual Report 2005*, http://www.posiva.fi/esitteet/Posiva_annual_report_2005_lores.pdf

[9] A good example of a recent work is NEA/OECD, *Post-Closure Safety Case For Geological Repositories: Nature And Purpose*, © OECD 2004, NEA No. 3679, Nuclear Energy Agency Organisation For Economic Co-Operation And Development (2004)

very high. Assessing the safety is based upon analysing how the entire repository system will behave far into the future. This estimation in turn is based upon a sound scientific understanding of how the materials will evolve in the deep geological environment, and of how any radionuclides released might be transported through the deep underground, back towards the environment of humans. The safety assessment is not a purely theoretical desk exercise. The models are based upon experimentation in the laboratory and in the field. The understanding that is built up is checked by observing how natural systems with similar properties behave over the very long time-scales considered. Although there are still dissenters to be found, these are often critics of specific repository projects rather than of the general concept of geological disposal.[10] In the scientific community there is general acceptance of the feasibility of safe disposal, if the site and engineered system are well chosen. Unfortunately, this general consensus does not yet extend to the majority of members of the public.

The current status of national geological disposal programmes illustrates that progress is being made in many countries – but that this is a slow process. To achieve the necessary levels of global safety and security, however, nuclear materials, including spent fuel and high level radioactive wastes, must be properly managed whenever and wherever they are being produced. Interim surface storage facilities can be constructed and operated in such a way that they are safe and secure – provided that the necessary resources for continued control are available. Ultimately, however, long-lived wastes must be emplaced in deep repositories. Advanced fuel cycles, transmutation etc. can alter the quantities of such wastes, but they can not remove the need for deep disposal. For some countries, national repositories may be difficult or infeasible because of the lack of favourable geological formations, shortage of technical resources, or unacceptably high costs. For these multinational repositories are a potential solution and, in recent years, there has been a rapid increase in interest in this possibility as described in the following section.

Multinational initiatives

The past five years have seen a continual growth in the interest of many national waste management programmes – especially those of small countries – in the concept of multinational or regional disposal facilities. The prime drivers were originally the economic and political problems that might be lessened by being shared between countries facing the same challenges. The potential safety and safeguards benefits were also recognised at this early stage. Increasingly – in particular after the terrorist attacks in the USA in 2001 and in connection with nuclear proliferation concerns – attention has focused on the security advantages that could result. . The most recent manifestation of this is the Global Nuclear Energy Partnership (GNEP) promoted currently by the US Government[11]. The IAEA has been careful to point out that risks must be minimised also at the "back-end of the back-end" of the nuclear fuel cycle, i.e. not only in enrichment and reprocessing but also in storage and disposal, in particular of spent fuel. In its publications in this area, the IAEA has described two potential routes to achieving international disposal: the “add on approach” and the “partnering scenario”.[12]

In both these potential disposal approaches to multinational disposal, significant progress is being made. In the add on option**,** a single country, or a network of countries with appropriate

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[10] Rodney C. Ewing and Allison Macfarlane **“**NUCLEAR WASTE: Yucca Mountain**”,***Science* 26 April 2002: 659-660.

[11] USDOE, *The Global Nuclear Energy Partnership*, (2006) http://www.gnep.energy.gov/

[12] IAEA, *Developing and implementing multinational repositories: Infrastructural framework and scenarios of co-operation,* TECDOC 1413, (2004)

facilities working together, would provide extended fuel-cycle services to countries adhering to the NPT and wishing to use nuclear power. This could limit the spread of those sensitive technologies that are allowed under the Treaty, namely enrichment, reprocessing and storage/disposal of fuel. Crucial pre-requisites would be security of supply of services to all co-operating users, as emphasised by the Multilateral Approaches Group established by the IAEA[13] and the World Nuclear Association[14], and close international monitoring by the IAEA.

Within this international fuel cycle scheme, the fuel leasing component is certainly the closest to being an accepted practice. Recent proposals[15] from the US Government have indicated its support for such a scheme in Russia or in the USA, through the GNEP initiative. The proposals are primarily aimed at making the nuclear fuel cycle more secure, but they ultimately require the fuel suppliers to take back the spent fuel or for a third party, trustworthy country to offer storage and disposal services. From a waste management perspective, GNEP does not add much to the existing Russian proposals[16]. In fact, the additional elements in GNEP – in particular the very ambitious or even unrealistic intentions to develop wholly new fuel cycles - may lead to the more pragmatic proposals, such as fuel leasing, being postponed for the long times needed for such fuel cycle developments.

In both Russian and USA proposals, the service providers concentrate on offering to client countries enrichment, fuel supply, and reprocessing. Although both mention the take back of spent fuel, this is a sensitive political issue in both countries. Although the return to US or Russian manufacturers of fuel provided to client nations in the future may be acceptable, this will solve only part of the problem. There are other fuel suppliers in the market; there are existing inventories of hazardous radioactive wastes that must also go to a deep disposal facility. A more comprehensive offer of disposal services is necessary. In fact, an offer of this type may be the only sufficiently attractive inducement that would lead small countries to accept the restrictions on their nuclear activities that are currently being proposed by the large powers and the IAEA. The emphasis on ensuring security of supply of other services such as reactor construction, fresh fuel, enrichment and reprocessing is rather misplaced. All of these services are supplied commercially at present and a customer country has currently a choice of suppliers that may well be wider than would result from implementation of initiatives like GNEP that create a two tier system of nuclear countries. The key inducement that might persuade small countries to give up some of the rights given to them as an "inalienable right" in Article IV of the NPT[17] may well be the offer of a safe, secure and affordable disposal route based on disposal in a multi-national repository in another country.

The second option for implementing multinational repositories - partnering by smaller countries - has been particularly supported by the European Union through its promotion of the potential benefits of regional solution, i.e. facilities shared by contiguous or close Member States. For the

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13 IAEA, *Multilateral Approaches to the Nuclear Fuel Cycle*, Expert Group Report submitted to the Director General of the IAEA, 22nd February 2005

14 WNA, *Ensuring Security of Supply in the International Nuclear Fuel Cycle,* www.world-nuclear.org

15 USDOE, *U.S and Russia Develop Action Plan to Enhance Global and Bilateral Nuclear Energy Cooperation.* Press Release 2006, http://www.doe.gov/media/USRussiaPressRelease121906.pdf

16 S. V. Ruchkin and V. Y. Loginov, "Securing the Nuclear Fuel Cycle: What Next?", *IAEA Bulletin*, 48/1, Sep 2006.

17 *Treaty On The Non-Proliferation Of Nuclear Weapons* http://www.fas.org/nuke/control/npt/text/npt2.htm

partnering scenario, in which a group of usually smaller countries cooperate to move towards shared disposal facilities, exploratory studies have been performed most recently by the Arius Association, which also co-manages the European Commission SAPIERR project on regional repositories[18].This project aims to establish a dedicated multinational organisation that would develop the shared repository option in a staged process similar to that favoured by national programmes.

We definitely need geological repositories – but when?

As argued above, geological disposal is a necessary final step in the fuel cycle if nuclear power is to be sustainable in the sense that unnecessary burdens are not passed on to future generations. Continuing with nuclear power is therefore justified only if there is a sufficient consensus that safe geological repositories can be implemented. It is often argued that the public confidence needed to achieve this consensus can be achieved only by having operating repositories. This is a dangerous argument for several reasons, the most urgent of which is that decisions on expanding nuclear power are needed much sooner than the 10-15 years which will pass before even the most advanced programmes have operating HLW/SNF repositories.

What then is the long-term solution that can justify continuing with and expanding nuclear power production? Disposal solutions must be **demonstrated to be feasible**. This is not accomplished by simply building a facility. The following requirements are both necessary and sufficient:

- A technical concept involving engineered and natural safety barriers must be developed and its expected performance analysed using appropriate scientific modelling, backed up by comprehensive data collection. The safety level that the facility offers must be recognised by scientists – and by the public.
- The engineering skills needed to implement such facilities must also be recognised as being available today. This can be best done by ensuring that construction of the facilities requires only geotechnical and engineering skills that have been applied already in comparable projects.
- The funding needed to implement repositories must be conservatively estimated and the required funds should be accumulated in dedicated funds that can not be diverted to other uses.
- Finally, given the considerable societal and technical challenges involved in selecting a suitable site, this step should ideally also be accomplished. This means, in the best case, that a specific site has been identified and, in all cases, that the feasibility of doing so is accepted.

When all of these conditions have been satisfied, then the repository implementer can, with a good conscience, sit back and leave the decisions on when to move to implementation to be taken in a broad societal context. Today, the conditions are not satisfied for most countries.

Conclusions

The conclusions that can be drawn from a review of the past history and present status of geological disposal can be summarised as follows:

- Despite the widening acceptance of, or support for, nuclear power production as a safe, economical and environmentally friendly electricity production technology, serious reservations continue to be expressed on two issues – nuclear security and long-term waste management. These issues are linked and are both being addressed today by

[18] Neil Chapman, Charles McCombie and Vladan Stefula, *Possible Options and Scenarios of Regional Disposal and Future RTD Recommendations*, SAPIERR project report – Deliverable D-3, European Commission (2005)

intensifying efforts to ensure that all hazardous radioactive materials (and in particular fissile materials) are being moved into well safeguarded storage facilities.

- Deep geological repositories are an essential component of the long-term management of radioactive wastes. There is no technical need for these to be implemented on a short timescale; they can not be implemented on timescales affecting urgent decisions on expansion of nuclear power; enough must, however, be done to establish technical and political confidence in the feasibility of safe disposal. Many nations are trying to progress plans and projects for implementing the deep geological repositories that will be needed to provide long-term safety and security in any credible waste management system.
- For some countries, it will be infeasible or impossible to implement the costly deep repositories that will be needed to safely store their relatively small quantities of hazardous long lived wastes and/or spent fuel. Therefore national efforts must be complemented by multinational cooperative initiatives that will make appropriate storage and disposal facilities available to all countries that make use of nuclear technologies. Implementation projects that arise from such cooperation could bring huge and mutual benefits to both host countries and user countries of shared multinational repositories.
- The most effective ways forward to ensure security and long-term safety are that immediate efforts are made to ensure secure storage of all hazardous radioactive materials, that advanced disposal programmes continue towards realisation of repositories, and that active steps are taken towards the realisation of shared multinational facilities for both storage and disposal of HLW and SNF. Current initiatives to increase global security by restricting nuclear capabilities of NPT signatory countries will have a greater probability of success if the services provided to small, “Tier Two” countries by the “Tier One” nuclear nations include disposal of spent fuel, high-level radioactive wastes and other wastes requiring deep geological disposal.