REGIONAL AND INTERNATIONAL REPOSITORIES: NOT IF, BUT HOW AND WHEN

Charles McCombie, Neil Chapman
Arius
Association for Regional and International Underground Storage
Mellingerstrasse 207, 5405 Baden/Switzerland

Abstract

Geological disposal is the only foreseeable way of ensuring adequate safety and security in the long-term management of spent fuel and high-level radioactive waste. Implementation of a suitable deep repository may, however, be difficult or impossible in some (especially small) countries because of challenging geological conditions or restricted siting options, or because of the high costs involved. Shared regional or international storage and disposal facilities are widely recognized as being a necessity, if a clean global environment is to be passed on in a sustainable fashion to future generations and if nuclear power world-wide is to have a credible future.

However, public opinion currently seems to reflect a preference for national repositories and some countries that are pursuing national programmes are at a sensitive stage in their siting and implementation process. It is important that discussions on shared facilities do not derail such national programmes. It is equally important that future development of regional and international projects is not unnecessarily blocked by short-term national considerations. Although there is no urgent technical need for implementing final disposal of power reactor wastes in any country, all nuclear programmes, whether large or small, should be able to point to possible solutions of their waste problem. This can involve national or multinational approaches, and, for small countries, the existence of specific initiatives in the latter area can help build the public and political confidence that is necessary to justify past and future use of nuclear power.

The Arius association was formed in February 2002 to facilitate progress towards multinational solutions. Whereas other recent projects (such as NPT and Pangea) have advocated rapid development of commercial stores or repositories in specific regions of the world, Arius is non-commercial, and considers all siting and design options. It has initiated a long-term, low-profile promotion strategy whose initial goal is to ensure that multinational storage and disposal options remain a topic for discussions on the world stage and are recognized as a feasible future choice for countries which opt for this strategy.

The challenges of managing radioactive wastes

Long-term Safety

Long-lived radioactive wastes are produced in nuclear power generation and in nuclear weapons programmes– but also in other applications such as medical isotope production, medicine, research and industry. These wastes present a potential hazard to living organisms if they are not isolated from the environment. The isolation times required to ensure safety are in some cases extremely long (over 100,000 years) - although never infinite, as for some chemo-toxic wastes. The largest inventory is in the form of spent reactor fuel, of which there are currently about 130'000 tonnes stored around the world, in over 400 nuclear facilities. This is growing at a rate of around 10'000 tonnes per year.

Ensuring the safety of all future generations by proper management of these wastes is the ethical responsibility of current generations that benefit from nuclear technologies. The benefits are enjoyed not only by consumers of nuclear electricity, but also by suppliers of services through the nuclear fuel cycle and furthermore by all societies making use of nuclear technologies.

Nuclear security

Security is the term used when discussing a different type of hazard potentially arising from nuclear materials. Highly enriched uranium and plutonium are fissile materials, which can be used to make nuclear explosives. It is imperative to ensure that such materials are not illegally diverted and misused. Moreover, the welcome move towards disarmament by the major weapons states is, in the short term, increasing the hazard potential. Hundreds of tonnes of plutonium and thousands of tonnes of highly enriched uranium will become available for other purposes as surplus weapons are dismantled (Bunn et al., 2002).

Society must face the challenge of ensuring that the weapons-grade materials are converted into forms unsuited for use in bombs and are safeguarded permanently from misuse by states or by terrorist groups. Terrorists could, it is feared, also spread radioactive materials using conventional explosives in a 'dirty bomb'.The aim must therefore be to safeguard all sensitive nuclear materials by making them inaccessible to such groups.

Geological disposal

The only foreseeable sustainable solution

The challenge is to ensure the safety and security of current and future generations by permanently isolating long-lived radioactive materials from the environment. Isolation can be achieved for long times by building, maintaining and guarding strong and secure surface storage facilities. However, the consequence of this approach is to pass on a legacy to future generations who must continue to commit resources and maintain institutions to care for the storage facilities.

The ideal solution would be to remove the material permanently from Earth (e.g. by ejection into space) or change it to a less harmful form. The former option has been considered periodically

since the 1970's and has always been found to be too risky and too costly. Transforming long-lived radionuclides to shorter-lived radionuclides is possible using nuclear transmutation processes in a reactor or a particle accelerator. This has also been studied for 30 years. The current consensus is that transmutation is a complex and immensely costly process, that can only reduce the quantities of some long-lived radionuclides, which can, in any case, be readily contained in a geological repository. Transmutation cannot get rid of many of the more problematic radionuclides, nor does it do away with the need for geological disposal.

Today, the single solution judged by scientists as being capable of removing the hazards of radioactive waste without placing undue burdens on future generations is deep geological disposal. This view has been supported by the US National Academy of Science (NRC, 2001) and by the UK Royal Society. It is also enshrined in the legislation of various countries (such as the USA, Sweden, Finland, Japan and Switzerland) and is the chosen approach in many others. Although some countries (e.g. France, Canada and the UK) have re-opened the question of whether real alternatives are available, no-one has developed a scientifically feasible, sustainable and ethically justifiable alternative.

The status of geological disposal programmes

Virtually every waste disposal programme in the world has experienced delays - often very significant - in its originally proposed schedules for disposal of spent nuclear fuel or high level wastes (SNF/HLW) (Witherspoon and Bodvarsson, 2001). The USA has always been the country with the earliest proposed operational dates for a geological repository. This is partly explained by the US intention to dispose of relatively young spent fuel, as opposed to many other countries, which plan for a cooling period of 30-50 years. The Nuclear Waste Policy Act of 1982 set out a strategy leading to geological disposal. Following years of field work and expenditure of several billion dollars, on 15th February 2002 the Secretary of Energy recommended to the President that he approve the Yucca Mountain site for development of the nation's first repository for these radioactive wastes. The president almost immediately approved. The State of Nevada vetoed this decision, and this veto was overturned by Congress on 10th July 2002. A license application should now be prepared by DOE for submission to USNRC. DOE aims at disposal by 2010, but the delays that may result from law suits are not calculable at present.

The next most ambitious timing has been in Sweden where an early decision to close down nuclear power meant that a definite final waste inventory could be planned for. Finland has caught up with, or overtaken, its neighbour and has successfully nominated a site for spent fuel disposal. Today it still appears that the USA may be the lead nation, if the Yucca Mountain project passes its current hurdles. Finland and Sweden may follow closely so that there could be three operating repositories by around 2020. In other countries, e.g. Japan, Switzerland, there is no need to, and no intention to, implement deep disposal of SNF/HLW before about 2050. In some countries e.g. the UK, Spain, Canada and the Netherlands decisions on geological disposal are wide open and implementation, if it happens, may be a hundred years off.

All of the countries mentioned thus far have run waste disposal research programmes of various intensities, for many years. Other countries, e.g. Taiwan and South Korea, that rely strongly on nuclear power have initiated disposal studies only quite recently, and numerous smaller

countries, with limited nuclear facilities, will have problems finding sufficient resources to develop appropriately scaled national R&D programmes.

Does every country need a national geological repository?

Achieving acceptable levels of long-term safety requires suitable geological environments to be available. However, repository designs are flexible, and requirements on the natural barriers can be matched to the degree of sophistication of the engineered barriers. This can be seen in the range of designs that is currently being developed by the advanced national programmes. Thus, most countries should be able to find suitable disposal sites. However, the availability of a worldwide choice of regions would make it easier to choose sites in stable, simple geological and hydrogeological settings so that the uncertainties in long-term safety assessments are reduced. Within the Pangea project (Miller et al., 1999), studies were performed on identifying such regions and investigating their safety performance (Black & Chapman, 2001).

Even where a national repository is technically feasible, it may be ruled out by economics. A deep geological facility for long-lived radioactive wastes can cost several billion US dollars, no matter how small the volume of wastes to be disposed, and it is inconceivable that each country with such wastes will be able to provide adequate resources. Some countries have only a single reactor; some have no power reactors but still produce long-lived wastes from medicine research and industry. For such countries, shared geological repositories are essential. For other countries, complex geology, intense land use, or economic optimisation will justify pursuing international options, even if national disposal could be realized. Various small countries (e.g., Switzerland, Belgium, Hungary and Taiwan) have also advocated a ‘dual track’ approach in which international options are kept open while a national option is also being considered.

There is a strong sustainability argument behind the drive to ensure that a geological disposal option is available to each country. Geological disposal is recognized as being the only sustainable solution to managing long-lived wastes, because it does not pass on problems to future generations who may have neither the resources nor the capability to handle them. This argument applies in any country and to any size of programme. However, it is perhaps an even more cogent argument for those countries, including several European countries with small nuclear power programmes, where pressure on resources is already evident.

It is important for the global nuclear industry as a whole, and for the wider interests of environmental safety and nuclear security, that the radioactive –waste management community demonstrates that the challenges of properly managing the wastes of ‘small users’ and countries with limited resources are being properly addressed (i.e., not being ignored while larger countries progress with strictly national programmes). Providing such solutions will also give the smaller programmes the confidence to make best use of their nuclear power facilities and to have greater flexibility in choosing future power generation options. In short, there should not be a two-tier system for disposal of hazardous wastes, and hence for the application of nuclear technologies. It is in everyone’s best interests that equivalent technologies are available on equivalent time scales to all those countries that need them.

International, multi-national or regional repositories have advantages

In recent years there has been an active debate on the pros and cons of repositories shared by several countries. These are labelled international or multinational, with the latter term preferred by those who do not wish to presuppose a necessity for overarching international controls. The term regional is used to describe repositories shared by geographically close countries (e.g. in Europe, Asia or South America). Shared repositories can definitely have advantages, as summarised in the following sections.

Safety

In the area of safety, in particular **long-term safety**, there is no difference in principle between a multinational repository and a national project. On the one hand, there is no need to tighten the already rigorous safety requirements set for national disposal facilities; on the other, it is definitely not ethical to seek regions or countries where less stringent safety measures could be acceptable. In both multinational and national cases, we need a disposal system providing the same internationally agreed, high level of safety over very long times. Thus the technical challenges in implementing a safe international repository are equivalent to those in leading national programmes. In both cases, the repository should provide demonstrable safety based on a robust barrier system using engineered containment and geological retention of radionuclides. There are, nevertheless, safety issues which affect the choice of disposal concepts and sites. The key issue is the **confidence** with which one can predict future safety. This depends upon the complexity of the disposal system and especially on the predictability in spatial and temporal terms of the geological environment hosting the repository. The problem of reliable prediction of future repository behaviour can be eased by adopting the approach that the long term containment of waste materials will be easier to achieve and to demonstrate in a simple, stable geological environment chosen without the restrictions imposed by political boundaries.

The above discussion concentrates upon the issue of long-term safety, but issues concerning operational safety are also of obvious relevance – in particular to the host state for an shared repository. Safe operation of nuclear facilities is a long-established practice in many countries in the world. At a broad level, therefore, the question most directly affecting the choice of national or international repository options concerns the availability of appropriate technical expertise in potential host countries. The optimum situation is when the host has nuclear technology capabilities and would itself be capable of implementing a safe repository. Otherwise, know-how must be transferred from others.

Security

International facilities offer additional, specific features relative to the inherent safeguard advantages of a national deep repository; for example:

- Many countries with spent fuel may not have repositories soon, or ever.
- Host countries can be identified that have especially good safeguard credentials.
- Control becomes even more international than through the current IAEA regime.
- Repository sites can be selected in regions that are extremely remote and more amenable to surveillance.

An international repository in a country acceptable to all nuclear weapon states could facilitate the process of obtaining the necessary political agreements to reduce the number of nuclear weapons further. It could also contribute to the release of the inherent economic value of these materials and provide a commercial source of financing to address non-proliferation goals that are currently difficult for governments to fund. This point is especially important to Russia. The supreme importance of ensuring full safeguards for fissile materials may be one of the more powerful arguments for a potential repository host state, as discussed in the following section.

Reducing negative environmental impacts

Environmental protection can become easier for all parties if there is a world-wide choice for a disposal site. On a global scale, the extensive use of nuclear power contributes to limiting carbon dioxide emissions; this can continue, however, only if feasible and cost-effective disposal solutions are found even for countries with complex geology. An international repository can contribute here. At a national scale, small, crowded countries or geologically complex countries with limited siting choices also have a difficult problem in implementing any new and large industrial project while minimising impacts on the human environment. In a host country with remote areas far from the public, siting can be less contentious. Indeed, there is a definite potential for using a well-funded repository implementation project as a vehicle for improving facilities and conditions in inhospitable areas. Nevertheless, a major international repository, with its necessary transport and site infrastructure, will obviously have a significant environmental impact – comparable perhaps to a mining project. To compensate for this asymmetric burdening of host and client, appropriate benefits may justifiably be expected by the host.

Economic issues

Shared repositories are attractive from an economic point of view. Deep geological repositories have life-cycle costs in the billions of US dollars. This is true even for small countries with low projected waste volumes; for example, the Swiss estimate of life-cycle costs for disposing of HLW or spent fuel from a 120 GW(e) nuclear programme is around 3 billion US dollars (McCombie et al., 1996). Moreover, a large part of the costs of any deep repository are fixed independently of the inventory since they are needed for exploration, for gaining access to the underground by shaft sinking, for installation of infrastructure, and for the complex permitting and licensing procedures. The marginal costs of excavating more disposal volume underground are relatively small. Accordingly, large savings are possible if small countries combine their efforts or if a large disposal programme were to accept wastes from foreign sources.

For a country accepting foreign wastes for disposal, there could clearly be enormous direct economic benefits. For countries paying for wastes to be disposed abroad there could also be financial advantages because economies of scale allow lower unit costs (and excellent geological conditions can obviate the need for very expensive engineered barriers). For society in general, it is certainly better to channel resources to other causes rather than expending them on duplication in numerous countries of expensive technical work.

Public acceptability

Only if the safety, security, environmental and ethical aspects are clearly seen to be taken extremely seriously by all parties, and if the economic and infrastructure benefits are very clear, is it conceivable that public acceptance in a host country can be achieved. A serious host country will not allow itself to be 'bought'; there must be also a clear perception that the host is undertaking a service which helps less advantaged countries fulfil their moral responsibilities for their waste in an ethical manner. A serious customer nation will insist on being assured that the highest standards of safety and environmental protection are applied to any facility accepting its waste. Switzerland, for example, has built such safeguards into its new Nuclear Law.

The ethical principles espoused by the waste management community concern, among other matters, intragenerational and intergenerational equity. This involves adequate protection of all persons and of the environment now and in the future, irrespective of national boundaries. Clearly an international repository must and could be implemented in accord with such principles. In particular, the level of safety required for populations around any repository cannot be a function of the facility location. The aspect of disposal of unwanted materials from disarmament raises a new and powerful ethical argument. A responsible, secure host nation which accepted the responsibility of the guardianship of materials which might otherwise cause mass destruction anywhere in the world would occupy high moral ground.

Not withstanding these indisputably positive arguments, public acceptance for accepting foreign wastes will be extremely difficult to achieve in any potential host country. NIMBY (not-in-my-backyard), which functions universally on a national scale, will certainly also be a problem internationally. The environmental impact of any large project which serves the good of a wider public will almost always create localised opposition. Public attitudes towards shared repositories may be changing, however, The Eurobarometer results of 2002 (INRA, 2002) show that supporters in Europe of regional repositories, although still in the minority, are increasing in numbers.

Political issues

There are few or no stumbling blocks hindering international repositories on technical, economic or institutional grounds. Politically, however, it has, as yet, proved difficult for many countries to support international disposal plans - especially if they are a potential host for the repository. Indeed, in some countries legislation has been enacted to ensure that foreign wastes cannot be imported for disposal (e.g. France, Sweden, Russia). In some cases where there is no legislation, import of wastes has been explicitly stated to be against government policy (e.g. Australia, U.K.). However, in international agencies such as the IAEA and the EU it is increasingly acknowledged that shared disposal facilities are inevitable. Some countries, most notably Russia, are openly considering plans for importing waste for storage and possibly disposal.

International repositories: a win-win proposition

There are thus potential benefits of international solutions for both repository host countries and for user countries. These can be summarized as follows:

A valuable service to countries with:

- small areas, complex geological environments
- limited nuclear power
- no nuclear power - but long-lived wastes
- limited financial means
- interest in economic optimisation
- commitment to non-proliferation

A valuable asset for countries with:

- suitable geological and environmental conditions
- remote, low population areas
- a stable political system
- the trust of the international community
- ability to provide high-tech infrastructure
- interest in economic development
- interest in expanding their global influence

International repositories are compatible with national programmes

Countries with active national programmes sometimes express understandable concern about discussions of international repositories because people may fear that their national repository will later choose to - or be compelled to - accept foreign wastes. In Sweden, for example, opponents of national programmes have deliberately attempted to use such arguments, despite the existing Swedish legislation ruling out waste import. For this leading programme, which is on the way to developing one of the first spent-fuel repositories, public fears are easily played upon. A further concern in some national programmes is that the prospect of a politically easier or economically better external solution might lead national politicians or waste producers to be less committed to preparing a national solution. This argument is irrelevant in those countries (e.g., the Netherlands), where national geological repository preparations are not being made, in any case. It is also not very important in those countries that have chosen a "dual track" strategy, investigating both national and international disposal options.

For those countries fully committed to national disposal, these concerns are very real. They can, however, be countered by their firmly emphasising the national strategy, without denying the needs of others for shared solutions. We believe that national and international programmes can be mutually supportive.

Options for implementing international solutions

A national programme that has decided not to develop a deep geological repository of its own has a limited range of waste management options available to it:

- It can store its wastes indefinitely within its own borders
- It can store its wastes at home or abroad until an international solution is available.

In the latter case, it must then either:

- Await the development of a national or international facility offering a disposal service, or
- Participate in pursuing and developing an international solution.

The biggest question……where??

The impasse in discussion of shared solutions concerns the feasibility of finding potential host countries. That there are real benefits for a host country was made clear above. But will the political leadership in any country be decisive enough to support any suggestion of hosting a shared a facility, knowing that this will inevitably raise strong opposition in some circles? History does not give much cause for optimism here. In countries such as the UK and France that did accept foreign wastes for disposal, policies were reversed in order to try to reduce opposition to national nuclear industries. In some countries where the proposal to host a repository began to be debated (e.g. Australia), many politicians rushed to express disapproval, despite significant support in scientific and business circles. In Russia, one of the few countries where Government agencies support waste import, public opposition has grown. In some circles there has even been strong opposition by national programmes to the issue of multinational repositories being a subject for discussion.

Is advocacy of international or regional repositories a lost cause? Certainly not – because the need for such facilities is almost universally accepted. Even those countries or organisations that have opposed opening the issue now acknowledge that shared disposal must come, for safety, environmental and economic reasons. The commonly heard reservation is that one or several national deep geological repositories must first 'show the way'. It is unproductive to debate the correctness of this view, since national facilities will, in any case, come first. But preparations for international disposal should nevertheless start now. Technical, public and political confidence in the use of nuclear technologies in small countries depends upon having safe multinational disposal routes available. Where might these be?

The prime candidate at present is Russia, since the Government would like to see such projects implemented. The advantage for Russia, apart from the obvious economic gains, are that resources would become available for urgently required clean-up programmes. There is, however, a negative attitude towards Russian proposals in many other countries. The main reason is insufficient trust that the authorities would implement environmentally suitable solutions to the highest international standards. In the USA, whose assent is needed for any international repository scheme involving spent fuel disposal, there are further political hurdles

preventing support of a Russian solution. With good will and a concerted action programme, however, an acceptable Russian solution could be possible. Extreme measures, such as effectively ceding a part of their territory to international control may be needed. The IAEA could play a key role in such an approach; its original charter shows that such concepts are not new.

A further solution that could become more attractive with time is a regional solution in some part of the world. East Asia or Europe are obvious candidates. In fact, although some individual members of the current EU are opposed to shared repositories, officials in Brussels openly recognise that this could be a sensible approach. The planned increase in EU membership involves a number of candidate countries that would be obvious partners in disposal projects. Existing members would do well to support such initiatives technically and politically. As mentioned below, the new Arius association, whose mission is the promotion of international and regional facilities, has submitted an expression of interest to the EC in co-ordinated studies aimed at investigating the potential for regional repositories in Europe.

Finally, if or when geological disposal becomes a normal and widespread technology, countries that have especially suitable conditions for hosting a repository may well be inclined to take advantage of the positive features that nature has endowed them with. In the Pangea Project (Black & Chapman, 2001) a number of especially suitable areas of the world were identified in Australia, Southern Africa, South America and China. Of these, only Australia was studied in any depth, and the technical findings made the case for safe and environmentally friendly disposal clear. These studies could be picked up again and extended to other areas, as soon as the political situation would allow this. Politicians in such countries will, however, hardly promote such proposals unless there is clear support and encouragement from the developed nuclear nations of the world.

The way ahead for regional and international facilities: the Arius association

There have been various initiatives in the past for encouraging international storage and disposal of radioactive wastes. These include:

- Early proposals from the IAEA and from INFCE
- Concepts in the 1990's involving China, Canada, Australia
- Proposal of M. Bunn, N. Numark and T. Suzuki (Bunn et al., 1998)
- The Global Peace Initiative proposed by Atsu Suzuki (Suzuki, 1998)
- Proposals of the Russian government
- The Non-Proliferation Trust (NPT) (Cochrane and Paine, 1998)
- The Pangea Project (Miller et al., 1999)

In February 2002, a small group of organisations from five countries inaugurated a new association to support the concept of sharing facilities for storage and disposal of all types of long-lived radioactive wastes. The new body - called Arius (Association for Regional and International Underground Storage) – is an organisation without commercial goals (Arius, 2002).

The mission of the association is to promote concepts for socially acceptable, international and regional solutions for environmentally safe, secure and economic storage and disposal of long-lived radioactive wastes.

A key objective will be to explore ways of making provision for shared storage and disposal facilities for smaller users, who may not wish to - or may not have the resources to - develop facilities of their own. Consequently, the initial membership of the Arius Association is predominantly from countries with smaller nuclear programmes, although it also includes industrial organisations that are interested in promoting the international disposal concept. The founding members are from Belgium, Bulgaria, Hungary, Japan and Switzerland. The Association is open to all organisations sharing its goals, and discussions with further potential members are underway. The inaugural meeting was also attended by an observer from the European Commission and continued interactions with this and other international bodies such as the IAEA and the NEA is foreseen by Arius.

As Arius develops, it plans to undertake a number of studies that are aimed at answering some of the principal questions surrounding international solutions. These include:

- Feasibility of regional storage of long-lived waste in Europe
- Issues affecting transport to international storage & disposal facilities
- Feasibility of regional repositories in Europe (an expression of interest for a European Pilot Study for Regional Repositories - EPSRR - has been submitted to the EC)
- Feasibility of international repositories outside Europe
- Treaties/agreements/liabilities affecting the import/export of wastes
- Regulatory and licensing processes for international facilities
- Economics of shared storage and disposal facilitiesPublic attitudes to import and export of wastes

The key research components of Stage 1 of the proposed EPSRR project are to identify problematic issues underlying the following topics and to develop ways of resolving them:

- radiological safety implications of disposing of waste in shared facilities; this involves the development of a basic safety concept for a multi-functional repository that could accept a wide range of long-lived wastes and also the study of transport issues.
- social factors that will affect the development of multi-national disposal facilities; this includes evaluation of available data nationally and Europe-wide and extension of Eurobarometer polling;
- economic aspects; this involves comparative cost considerations and study of models for economic management of shared repositories;
- legal and political boundary conditions that would control the feasibility of building multi-national repositories in Europe (researching all agreements, laws, national legislation, historic practices, etc).

The output of the Stage 1 feasibility study will be a range of options for development of one or more shared repositories, together with an implementation proposal to allow the enlarged EU to decide whether to move forward and solve the safety and security problems of these wastes in a timely fashion. Stage 2 of the project would begin with a period of consultation with all European countries that choose to participate and a parallel research exercise to identify actual regional siting possibilities, potentially leading to consideration of specific locations. This Stage of the project will involve mainly scientific research studies:

- consideration of specific European geological environments in interested Member States that may be suitable for a multi-purpose (i.e. for various waste types) repository.
- development of formation-specific and environment-specific safety concepts for such repositories;
- application of multi-attribute analysis techniques to compare siting environments, locations and repository design concepts from technical, safety and social viewpoints.

Conclusions

There is a constantly widening and growing acceptance that international and regional repositories can bring environmental benefits and help to improve global safety and security. They will not replace national repositories, some of which are now moving towards implementation. Both national and international facilities will be needed. The path towards identifying potential hosts for an international repository may be long and rocky. It will be necessary for the international nuclear community – which is well represented at this meeting of the WNA –actively to provide support for the general concept of shared repositories and, specifically, for any country willing to consider hosting one. One avenue of support for the concept can be through the new non-commercial association, Arius. Arius will work closely with international bodies, national governments and national waste management programmes with a view to exploring the scientific, legal and societal issues that affect the feasibility of sharing storage and disposal facilities. By approaching its mission in a co-operative and open manner, Arius hopes to make a positive contribution to a key global environmental challenge.

References

Arius, Association for Regional and International Underground Storage (2002). www.Arius-world.org.

Black, J.H. and Chapman, N. A. (2001). Siting a High Isolation Radioactive Waste Repository . Technical Approach to Identification of Potentially Suitable Regions Worldwide. Pangea Technical Report PTR-01-01, Pangea, Baden, Switzerland, 52pps.

Bunn, M., Numark, N. J. and Suzuki, T. (1998). A Japanese-Russian Agreement to Establish a Nuclear Facility for MOX Fabrication and Spent Fuel Storage in the Russian Far East. BCSIA Discussion Paper 98-25, Kennedy School of Government, Harvard University, November 1998.

Bunn, M., Holdren, J. P. and Wier, A. (2002). Securing Nuclear Weapons and Materials: Seven Steps for Immediate Action. Project on Managing the Atom. Belfer Center for Science and International Affairs, John F. Kennedy School of Government Harvard University.

Cochran, T. and Paine, C. (1998). Proposal for Augmenting Funding for the Disposition of Russian Excess Plutonium. Paper from NRDC, Washington.

INRA (2002). Europeans and Radioactive Waste. Eurobarometer 56.2. Prepared for European Commission DG Energy and Transport. EC, DG Press and Communication, Brussels. 48 pps and Annex.

McCombie C., Weyermann P., Lieb R. (1996). The costs of disposing of radioactive waste in Switzerland; Nagra Informiert / Informe / Bulletin no 28, pp 10-20.

Miller, I., Black, J., McCombie, C., Pentz, D. and Zuidema, P. (1999). High Isolation Sites for Radioactive Waste Disposal: A fresh look at the challenge of locating safe sites for radioactive repositories, WM99 "HLW, LLW, Mixed Wastes and Environmental Restoration -Working Towards a Cleaner Environment", 28 February - 4 March 1999, Tucson, USA.

National Research Council (2001). Report by a Committee, Disposition of High-Level Waste and Spent Nuclear Fuel. The Continuing Societal and Technical Challenges. National Academy Press. Washington, District of Columbia.

Suzuki, A.(1998). Reported in Nuclear Fuel 14th Dec 1998

Witherspoon, P.A. and Bodvarsson, G.S. (2001). Geological Challenges in Radioactive Waste Isolation, Third Worldwide Review. Berkeley National Laboratory, University of California.