



EUROPÄISCHE AKADEMIE

zur Erforschung von Folgen wissenschaftlich-technischer Entwicklungen
Bad Neuenahr-Ahrweiler GmbH

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FOCUS

Safe and secure management of radioactive waste

Klaus-Jürgen Röhlig, Clausthal

The question of how a safe and secure management of the radioactive waste arising from nuclear power production as well as from other activities can best be achieved has been a subject of numerous controversial, often aggressive, but not always well-informed debates. Often, such debates were linked to the question of nuclear power production. Sometimes, it was even claimed that the question of radioactive waste management can or should only be solved if and when nuclear power production will have been terminated – a line of thinking the author considers both irresponsible and illogical. However, given that the German debate on nuclear issues might lose much of its fierceness as a consequence of the changes of the German energy policy ensuing the Tōhoku earthquake and the resulting nuclear accidents at Fukushima, a new perspective on the waste management issue might arise. So far, however, this possible new perspective is hardly visible – despite of some rather general statements made by officials and stakeholders. In contrast, the issue of managing especially the heat-generating waste with a high radioactivity content seems hamstrung, not the least due to the history of the Gorleben project which seems to have resulted in a politically irresolvable situation. A recent project of the Europäische Akademie on radioactive waste, in which the author participated, addressed the issue using a multidisciplinary approach and attempted at proposing ways towards a solution.

The debate on radioactive waste very much focuses on disposal issues; it should, however, not be forgotten that safe and secure disposal is only the endpoint of a much larger strategy which also comprises processing, transportation and storage of materials (storage means emplacement with the intent of later retrieving the emplaced material while disposal means emplacement without such intent).

The choice of such strategies has a crucial impact on waste disposal and depends on numerous issues related to safety, security, environment protection, technical feasibility, economics, security of fuel supply, law, politics, public acceptance etc. Central decisions to be made when defining such strategies include the one whether or not to reprocess, i.e. whether the spent (used) nuclear fuel will be considered

as a resource and the reusable material (uranium and plutonium) will be separated and recycled. Further, it needs to be decided where to store the radioactive materials.

In Germany, several changes concerning these issues were made in the past. As a result, the heat-producing wastes with high radioactivity content to be managed include

- heat-producing vitrified waste from reprocessing stored at the Gorleben central storage facility or still awaiting transportation from France or the UK to Gorleben,
- spent nuclear fuel considered as waste and stored centrally at the storage facilities at Gorleben, Ahaus and Lubmin, and
- spent nuclear fuel considered as waste and stored de-centrally in the proximity of reactor sites.

These and some other materials are the ones for which a disposal solution is still lacking. In addition, there is a variety of wastes with intermediate or low radioactivity content and negligible heat production complying with the acceptance criteria for the Konrad facility near Salzgitter, a disused iron ore mine which is presently being transformed into a disposal facility which is planned to become operational in this decade. These latter materials represent about 90 % of the volume to be managed (less than 300,000 m³) but contain less than 1 % of the total radioactivity. If radioactive waste formerly disposed of at the Asse salt mine will be retrieved, it has to be clarified which part of it will be acceptable for Konrad and which part requires another solution.

According to present policy, this solution, as well as the solution for high-level heat-producing waste, has to be disposal in deep geologic formations. Possible solutions or “endpoints” of waste management strategies discussed in the past in Germany and abroad include

- a) disposal at the surface or in shallow geologic formations,
- b) disposal in deep geologic formations,
- c) long-term or indefinite storage on or below surface,
- d) partitioning of wastes and transmutation of radionuclides (P&T),
- e) direct injection of liquid wastes into rock strata,
- f) disposal at sea or in sub-seabed formations or in subduction zones,
- g) disposal in ice sheets, and
- h) disposal in outer space.

Amongst these options, e)–h) as well as several others and variants thereof have turned out to be not safe, insecure, hazardous or damaging to the environment, or not in compliance with international treaties. Option a) is, if at all, only applicable for certain waste types with limited radioactivity content and/or halflife.

In other words, for waste with high radioactivity content only disposal in deep formations and long-term or indefinite storage appear to be viable options. Partitioning and transmutation can be considered as a potential contribution to a solution but not as the solution itself: Transmutation means changing of one nuclide to another as a result of a nuclear reaction by bombarding the target with neutrons from a nuclear reactor or from a particle accelerator with the aim of ending up with shorter-lived or even stable nuclides. This has the potential of significantly lessening the timeframes needed for the reduction of the material's radiotoxicity and energy content to levels comparable to those of Uranium found in nature. It requires partitioning, i.e. chemically separating the radionuclides of interest. P&T schemes will obviously require a number of nuclear facilities and

are mostly considered in connection with advanced nuclear fuel cycles and advanced reactor types for nuclear power production. They aim in particular at actinides. The spent fuel, however, also contains other radionuclides (fission and activation products) which are hazardous for humans and the environment. As a consequence, P&T schemes have the potential to ease but not to eliminate the problems associated with radioactive waste. They are intensively investigated in several countries; some of them might become implemented at an industrial scale in the next decades, most likely in connection with advanced cycles for nuclear fuel management and nuclear power production. Recent discussions on the potential of P&T often neglect two issues: Such technologies can ease but not solve the problem, and they are only feasible as part of a developing nuclear industry.

Disposal in deep formations on the one hand and long-term or indefinite storage on the other can be distinguished with respect to several aspects:

- a) *(Potential) retrieval.* Storage is performed with the *aim* to later retrieve the material. Thus, storage cannot be seen as a real endpoint of waste management but rather as a way to keep options for such endpoints open and thus providing maximum flexibility to future generations. It has, however, the potential to become a permanent measure over the years, especially if no storage timeframe has been specified.
- b) *Dependency of safety and security on active measures.* By nature, storage requires regular record keeping, monitoring, inspections, control, maintenance, refurbishment, and periodic renewal of facilities or components thereof. To ensure all this, secure financial resources and political and societal commitment are required which can be considered a significant burden put on future generations. It also means that safety and security depend on political and economic stability over the timeframes considered which, given historical experiences, can hardly be guaranteed. In contrast, disposal in deep formations is performed with the aim to ensure safety and security by means of natural and engineered barriers acting independently from any human action.
- c) *Technical concept and facility depth.* Normally, disposal is associated with a facility depth of several hundred metres while storage takes place at or close to the surface. In principle, one could of course also conceive disposal at or close to the surface. Essentially, this would result in technical solutions similar to those used for storage and thus to a status of retrievability and permanent need for the active measures mentioned above. One could also conceive storage at several

hundred metres depth (the often quoted “underground parking lot”). In this case, the need for the above-mentioned human activities would remain, they would even become more complicated compared to surface facilities, and the question can be asked what would be gained from using deep formations in such a case.

Obviously, there is a target conflict between the aims of maximum flexibility for future generations on the one hand and of avoiding burdens onto these generations as well as of achieving a safe system on the other. Many countries dealing with highly radioactive waste, including Germany, have decided to prefer the latter, i.e. to investigate, plan and implement deep disposal. Often, measures for easing potential retrieval (without the *intention* of doing so) are considered, investigated, or planned as a kind of compromise between these targets. The research and development work done in these countries (which include Belgium, Canada, the Czech Republic, Finland, France, Germany, Japan, Sweden, Switzerland, the United Kingdom and the United States) leads to several conclusions:

- Safe and secure disposal in several deep formations appears to be feasible, despite of some open issues and remaining research and development. Host formations considered include indurated and plastic clays, rock salt and crystalline rocks such as granite. At least three countries (Finland, France and Sweden) are approaching industrial implementation.
- Different geologic host formations have of course different physical and chemical properties. Consequently, technical measures and repository layouts have to take advantage from favourable host rock properties and to compensate less favourable ones. This results in different safety concepts for different host rocks: In clays, an important safety function is to delay migration of toxic materials physically and chemically, while in crystalline rocks and in rock salt the major aim is to prevent such migration at all (in the former case by means of durable canisters, in the latter by means of the salt itself). Therefore, a choice of host rocks (if there is more than one option available) also implies a choice of philosophy and concept.
- Retrievability can be eased by technical measures. There are no such states as “not retrievable” versus “retrievable” but rather scales of retrievability. Generally, the ease of potential retrieval decreases with time and its costs will increase. Retrievability is usually considered for timeframes in the order of decades up to one century, focussing on the decades during which the repository is still in operation or at least only partially sealed. Dependent on the concept, the wish to ease retrieval (e.g. by keeping vaults open) might compete with

the wish to confine the toxic materials and thus with the aim to reach a safe state as soon as possible. There is also an antagonism between retrievable disposal and protection against access (security).

German policy is, at least so far, characterised

- by the aim to dispose of all radioactive wastes in deep geological formations,
- by the concept of a “confining rock zone” (“einschlusswirksamer Gebirgsbereich”) which is implemented into BMU’s safety requirements and which requires to assign major safety functions to the host rock rather than to technical barriers and which practically excludes crystalline rocks as host rocks, and
- by prescribing certain retrievability or recoverability measures in BMU’s safety requirements.

In particular the first two points can be seen as a consensus reached by the majority of scientists and technicians actively involved in the subject, irrespective of their attitude towards controversial issues such as nuclear power production or the suitability of Gorleben as a repository site.

The problems of the German situation are twofold:

Firstly, there is a lack of transparency about why and how decisions about the points mentioned above were achieved and a lack of clarity about how further necessary decisions (in particular about a repository site) will be reached. As a consequence, many ideas about long-term storage, absolute retrievability paired with absolute safety or the choice of granite as a host rock etc. are still being brought up on a regular basis without being aware of implications or of the reasons for which decisions were taken. This is not meant as a criticism against these ideas or their promoters but rather as a criticism against an information and discussion culture which often lacks consistency, information and context. Secondly, the existence and history of the Gorleben project results in ongoing controversial debates. While final conclusions about the feasibility of a safe and secure repository at Gorleben are still pending, some already claim that this site has to be the one and only for which disposal should be considered, while others would disagree with any plan in which Gorleben plays a role.

In order to maximize the chances of having a disposal facility available in the next few decades, the academy’s project group recommends that a plan for decision-making concerning high-level waste disposal, including a time schedule for decision points, should be developed as soon as possible. The plan should have the potential to survive changes of political power. Furthermore, a hybrid approach is advisable that allows for the continued exploration of the Gorleben site while at the same time carrying out surface investigations of al-

ternative sites: A “well-defined point in time for taking a decision in principle about whether and how to pursue the exploration of the Gorleben site and/or the alternative sites should be defined. The decision should be prepared and taken in a manner that makes it as robust as possible in the face of political changes.”

Amongst the numerous reasons for making these suggestions are the following:

Even in the unlikely case that from now on the Gorleben project would proceed without further delays, the emplacement of waste containers would start in the mid-30ies at the earliest. In every other case this would happen later. In other words, there is no reason for further delaying the process: At this time, it should be sufficiently clear what options (e.g. P&T) will be available. Not considering alternatives to Gorleben would result in a significant delay if Gorleben fails for technical, legal or political reasons. On the other hand, a process without Gorleben does not guarantee that another appropriate site will be found. Giving up Gorleben thus would mean giving up a potentially feasible solution in which time and resources were invested without knowing whether other options offer better perspectives (or any perspectives at all). In terms of public acceptance, the parallel search and investigation would increase the credibility of the selection process. It is likely that a process not involving Gorleben would be better accepted in the short run. This gain may be lost, though, at the point in time at which other sites will be named and local opposition will form. The project recommends details of a structured and transparent process with information and involvement of interested parties as the only way to ensure the maximal acceptance achievable.

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Professor Dr. rer. nat. Klaus-Jürgen Röblig is Professor for Repository Systems at the Institute of Disposal Research, Clausthal University of Technology, and member of the academy’s project group “Radioactive Waste. Technical and normative aspects of its disposal”. Its results will be presented on 10 October 2011 at the Berlin-Brandenburg Academy of Sciences and Humanities (see the following article).

PROJECT GROUPS

Book presentation on radioactive waste

■ On 10 October 2011 the Europäische Akademie will present the research results of its project on radioactive waste in their publication “Radioactive Waste. Technical and Normative Aspects of its Disposal” in Berlin (Berlin-Brandenburgische Akademie der Wissenschaften). As this topic is currently subject of widespread debate in Germany, the German summary of the book was published in advance by the working group (download: www.ea-aw.de).

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The publication can be ordered at Springer Verlag (Vol. 38 of the series “Ethics of Science and Technology Assessment”).

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Deep brain stimulation in psychiatry

■ From 26–27 May 2011, the international neuroethics conference “Brain Matters 2: Ethics in the Translation of Neuroscience Research to Psychiatric and Neurological Care” took place in Montréal. With more than 120 attendees from all over the world, the conference set a great stage for the academy’s project group on “Deep Brain Stimulation in Psychiatry” to present some of their main results. The 100 minutes panel session on “Deep Brain Stimulation for Neuropsychiatric Disorders – Towards Ethically and Legally Responsible Use in a Vulnerable Patient Population” was introduced by the project’s chair Professor Thomas Schläpfer, University Hospital Bonn. In the first of three subsequent lectures, Professor Joseph Fins, Weill Cornell Medical College, summarized the contents of the project group’s first publication

CURRENT PROJECTS OF THE EUROPÄISCHE AKADEMIE

- **Synthetic Biology** (duration 1/11–6/13)
- **Long-term planning. The relevance of social and cognitive resources for sustainable economic activities** (duration 9/10–2/13)
- **Nanoparticles for medical purposes. Technical, medical, and ethical aspects** (duration 5/10–9/12)
- **Development of novel nanotechnology based diagnostic systems for Rheumatoid Arthritis and Osteoarthritis (NanoDiaRA)** (duration 2/10–1/14)
- **Energy storages and virtual power plants for the integration of renewable energies into the power supply. Potentials, innovation barriers and implementation strategies** (duration 1/09–12/11)
- **Clinical research on vulnerable populations** (duration 12/08–6/11)
- **Deep brain stimulation in psychiatry. Guidance for responsible research and application** (duration 10/08–9/11)

“Misuse of the FDA’s Humanitarian Device Exemption in Deep Brain Stimulation for Obsessive Compulsive Disorder” (Health Affairs, Vol. 30, No. 2, 2011: 302–311). He was followed by Professor Reinhard Merkel, University of Hamburg, whose talk was entitled “With Autonomy Comes Responsibility: Reflections on Patients, Professionals and DBS”. Finally, project co-ordinator Dr. Thorsten Galert, Europäische Akademie, addressed the difficulties of “Assessing Personality Changes after Psychiatric DBS”.

CONFERENCES

Human nature and the life sciences

■ This year’s autumn conference of the Europäische Akademie on 22 September will discuss whether and how anthropology – as a method or a set of substantial assumptions – can and should be part of applied ethics: Does ethics of the life sciences need an anthropological foundation? Besides reflections on the methodological problems of the relation of ethics and anthropology, specific challenges to human nature posed by, for example, the neurosciences and modern medicine will be analysed.

Organisation: Priv.-Doz. Dr. med. Felix Thiele, M.Sc.

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Date and Conference Venue: 22 September 2011, Gustav-Stresemann-Institut Bonn

Animal research ethics

■ The organisers of the summer school “Does size matter? Ethical, societal, legal and biological aspects of large animals as biomedical models”, funded by the German Federal Ministry of Education and Research, invite to a German-speaking public podium discussion at the Carl von Linde-Akademie/Technische Universität München on 14 October 2011, 17.30 hrs. Together with the audience, Professor Dr.

med. vet. Brigitte von Rechenberg (Universität Zürich), Professor Dr. phil. Stephan Sellmaier (Ludwig-Maximilians-Universität München) and the participants of the summer school will discuss about ethical implications of species choice in animal research and the balance of interests necessary for the framing of rational regulations and guidelines.

Further information:

www.large-animal-research-ethics.de

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PUBLICATIONS

Thorsten Galert

■ J. J. Fins, T. E. Schlaepfer, B. Nuttin, C. S. Kubu, T. Galert, V. Sturm, R. Merkel, H. S. Mayberg: “Ethical guidance for the management of conflicts of interest for researchers, engineers and clinicians engaged in the development of therapeutic deep brain stimulation”, in: *Journal of Neural Engineering* 2011 May 10; 8(3): 033001

Carl Friedrich Gethmann

■ “Die Sprache der Wissenschaft”, in: Berlin-Brandenburgische Akademie der Wissenschaften (ed), *Welche Sprache(n) spricht die Wissenschaft? Streitgespräch in den Wissenschaftlichen Sitzungen der Versammlung der BBAW am 2. Juli und am 26. November 2010 (Debatte 10)*, Berlin 2011, 57–63

LECTURES

Carl Friedrich Gethmann • 17/6/2011

■ “Es gibt eine ethische Expertise, und die ist Teil des Rationalitätsparadigmas ‘Wissenschaft’”: *Versammlung der Berlin-Brandenburgischen Akademie der Wissenschaften (Berlin)*

PERSONALITIES



■ Cynthia S. Kubu completed her Ph.D. in Clinical Psychology at the University of Iowa, USA, and her residency training in Neuropsychology at Rush-Presbyterian-St Luke’s Medical Center in Chicago. Kubu is a board certified Clinical Neuropsychologist through the American Board of Professional Psychology. She was a staff neuropsychologist at University Hospital in London, Ontario/Canada, from 1992–2001 and joined the Cleveland Clinic as a staff neuropsychologist in 2001. She has worked throughout most of her career with functional neurosurgery teams and been very active in teaching and clinical research. Kubu has served in various leadership roles for Division 40 of the American Psychological Association and as the Director of Neuropsychology Training for various internship and post-doctoral residency programmes. Currently, she is Vice-President of the Cleveland Clinic’s Women’s Professional Staff Association. Kubu has authored numerous publications in neuropsychology, epilepsy, ethics and deep brain stimulation. She is the Principal Investigator (PI) on a grant funded by the National Institutes of Health (NIH) examining ethics, control and deep brain stimulation in Parkinson disease and PI on a Greenwall Foundation grant examining similar questions in epilepsy surgery. Kubu has also served as a Co-Investigator on various NIH and foundation funded grants involving neurosurgery.

Cynthia Kubu Ph.D., ABPP-CN, is a neuropsychologist and Vice-President of the Cleveland Clinic’s Women’s Professional Staff Association. She is member of the academy’s project group “Deep brain stimulation in psychiatry. Guidance for responsible research and application” (duration 10/08–9/11).

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