**Geschäftsstelle**

Kommission
Lagerung hoch radioaktiver Abfallstoffe
gemäß § 3 Standortauswahlgesetz

Arbeitsgruppe 3
Entscheidungskriterien sowie Kriterien
für Fehlerkorrekturen

# Anhörung „Tiefe Bohrlöcher“ in der 9. Sitzung der Arbeitsgruppe 3 am 8. Juni 2015

Statement des Sachverständigen Andrew Orrell, International Atomic Energy Agency

**Kommission**
**Lagerung hoch radioaktiver Abfallstoffe**
**K-Drs. /AG3-26**

**Introduction**

Good morning. My name is Andrew Orrell, and I am the Section Head for Waste and Environmental Safety in the Division of Nuclear Safety and Security at the International Atomic Energy Agency. Any comments or opinions expressed are my own and do not necessarily represent those of the IAEA unless explicitly stated.

It is my pleasure to address the German Commission on the Storage of Highly Radioactive Materials and the working group on disposal, and I thank you for the invitation. Equally I very much appreciate the opportunity to have participated this past weekend in the workshop on "Final Disposal in Deep Borehole Using Multiple Geologic Barriers", and the visit to the Geo-Center at KTB site, near Windischeschenbach. The workshop and the KTB visit were informative and compelling to the issue of a deep borehole disposal feasibility.

Prior to joining the IAEA last year, I spent 24 years with Sandia National Laboratories in the United States, where my career was devoted to technical and managerial positions in nuclear waste management and specifically with repository sciences and deep geologic repository development. In those capacities I developed, contributed to and managed the development of the safety cases and performance assessments to stringent regulatory requirements for two deep geologic repositories, including the Waste Isolation Pilot Plant (WIPP) and the proposed repository at Yucca Mountain. Thus my experience included the executive responsibility to deliver the world's first safety case and license application for a DGR for HLW and SNF in what is arguably a very complex repository environment, as well as contributing to another safety case and application in a relatively simple geologic setting. In short, my expertise is in how to assess the long term performance and safety of a deep geologic disposal system, and in assessing the ability to license that system within a given regulatory framework.

**The Commission Working Group**

Now allow me to turn to the issue of deep borehole disposal options and the charge of this commission working group.

As I alluded to earlier, after many years and considerable expense, I and my organization delivered in June 2008 the world's first safety case and license application for a deep geologic repository for SNF and HLW. In about 2009, the new U.S. President effectively canceled further development of the Yucca Mountain repository. One could say this was in recognition that the existing policies for waste management had been troubled for decades, and as the Energy Secretary put it; "Yucca Mountain was no longer a viable option".

In response, the President directed the formation of a federal advisory commission, which by law are limited to two years, its membership should be fairly balanced in its points of view and represent a cross-section of interests, and the public should be afforded ample opportunity to provide input.

Thus, the Blue Ribbon Commission on America’s Nuclear Future (BRC) was formed in January 2010 to conduct a comprehensive review of strategies and programs for managing radioactive waste, including disposal options, and to recommend new strategies. I assume the parallels are obvious between the developments in the U.S. and German programs and their subsequent advisory commissions. It was an honor to be consulted by several members of the BRC on many radioactive waste management policy issues including possible strategies and options for disposal. In January 2012, the BRC delivered its final report and was disbanded. I offer a few

key points from their report that are relevant to this working group and specifically deep boreholes.

The BRC noted

> "...we [this commission representing this generation] owe it to future generations to avoid foreclosing options wherever possible so that they can make choices... about the management of the nuclear fuel cycle [including waste and disposal]...based on emerging technologies and developments and their own best interests."

To this end, the BRC was sensitive to its responsibilities, and to not rush to judgement, for or against, an emerging technology that could be of interest to the next generation, as the one which will undoubtedly inherit the problem of nuclear waste disposal that this generation has struggled to implement. Thus while it may be arguable whether deep borehole disposal technology is emerging or presently available, the caution remains the same to not unreasonably preclude certain technologies and foreclose options to the next generation.

As evident in the next excerpt from their report, the BRC thoroughly evaluated the deep borehole disposal concept and technology, and was unequivocal by explicitly including it in their recommendations, stating:

> "The *advantages have been cited that support further efforts to investigate the deep borehole option* [emphasis added]. These include the potential to achieve (compared to mined geologic repositories) reduced mobility of radionuclides and greater isolation of waste, greater tolerance for waste heat generation, modularity and flexibility in terms of expanding disposal capacity, and compatibility with a larger number and variety of possible sites."
>
> "Overall, the Commission recommends further RD&D to help resolve some of the current uncertainties about deep borehole disposal and to allow for a more comprehensive (and conclusive) evaluation of the potential practicality of licensing and deploying this approach, particularly as a disposal alternative for certain forms of waste that have essentially no potential for re-use. Likewise, EPA and NRC should begin work on a regulatory framework for borehole disposal, in parallel with their development of a site-independent safety standard for mined geologic repositories, to support the RD&D effort leading to licensed demonstration of the borehole concept."
>
> "DOE should develop an RD&D plan and roadmap for taking the borehole disposal concept to the point of a licensed demonstration."

Here the BRC fully recognizes the deep borehole disposal concept is less well understood from a licensing perspective, while recognizing the potential benefits warrant further development by demonstration.

After the BRC final report report of January 2012, the Administration issued a response in January 2013, stating:

> "In FY 2013, the Department is undertaking disposal-related research and development work in the following areas: an evaluation of whether direct disposal of existing storage containers used at utility sites can be accomplished in various geologic media; an evaluation of various types and design features of back-filled engineered barriers systems and materials; evaluating geologic media for their

impacts on waste isolation; evaluating thermal management options for various geologic media; establishing cooperative agreements with international programs; and developing a research and development plan for deep borehole disposal, consistent with BRC recommendations."

I draw attention on the last two points of the Administration's response; first the federal-level intent to support development of a deep borehole disposal option which will be further discussed in a moment, and second, the intent to establish cooperative agreements with international programs. If Germany opts to similarly develop deep borehole disposal, it is possible that a cooperative agreement could be reached for mutual benefit and accelerating the availability of the deep borehole disposal concept. This would be very similar to the very fruitful U.S. - German collaborations in salt repository science that have now been fostered for more than two decades.

Lastly, with regard to Commission views and conclusions, I note the U.S. government has in March of this year, issued a draft Request For Proposals for a field-test of the deep borehole disposal concept, with the intent in the next four years to;

1) site and drill two separate 5 km deep boreholes; a 21.6 cm characterization borehole, and a field test borehole at 43.2 cm at total depth,
2) characterize and test bedrock in-situ conditions,
3) collect relevant geochemical profiles, and
4) demonstrate the emplacement and retrieval of surrogate canisters.

This demonstration, while not specifically for spent nuclear fuel (perhaps due to unresolved legal issues surrounding Yucca Mountain), does share many of the same design elements and objectives for such a system. Such a demonstration will fulfill a key recommendation of the BRC and a key element of the Administration's efforts to address the disposal of radioactive waste. Regardless, the commitment of the federal government does not come without considerable review and deliberation on the merits of such an investment.

**My Personal Views**

In full disclosure, some of the developments mentioned in the discussion above can be connected to the technical work that was developed by my colleagues before and after I retired from Sandia. I was primarily responsible for setting the ball in motion in 2009 when I requested my staff to develop a preliminary safety case and performance assessment of a deep borehole disposal concept. After that safety analysis report was released, the subsequent developments unfolded largely on their own accord. I attribute this to a growing desire by governments and industry, to achieving safe disposal and wanting options to do so. As we have painfully experienced, the reliance on a single repository model comes with the real risk of having a single point of failure.

As I mentioned in my introduction, my experience in safety case development and licensing compels me to approach the evaluation of all geologic repositories, whether conceptual or real, from the perspective of understanding what constitutes safety, how to achieve it, and how to demonstrate compliance with safety criteria to a regulator. To do so, I must take into consideration all the various factual data (and its uncertainties), from all the various sub-disciplines (i.e. hydrology, geomechanics, radiochemistry, corrosion, engineering, etc.) and evaluate the overall system performance, i.e. safety.

The basic objective or standard of performance for any geologic disposal of radioactive wastes as articulated by the IAEA is: "*to provide sufficient isolation, both from human activity and from dynamic natural processes, that eventual releases of radionuclides will be in such low concentrations that they do not pose a hazard to human health and the natural environment*." The key here is the level of confidence or defensibility in our assessments of the waste isolation.

Every rock type (salt, clay, crystalline) and disposal concept (mined or borehole) have their particular advantages and disadvantages from a strictly technical perspective. It is readily argued that different geologic settings and emplacement methods may be better for particular types of waste. However, as every repository concept has a combination of natural and engineered barriers and some measure of defense in depth (i.e. multiple barriers) many or all of the concepts may ultimately be found to demonstrate acceptable performance for a wide range of wastes. There are no simple measures of "better" or "best" when dealing with complex systems that will evolve over millennia. Thus 'repository scientists and engineers' seek "sufficient isolation", i.e. below regulatory criteria, and with a high confidence in the defensibility of the assessment and the result.

When my colleagues at Sandia completed and published in 2009 a very conservative conceptual evaluation of a deep borehole disposal concept for spent nuclear fuel, the results were notable for the extremely low, diffusion-limited dose rates. In addition, we noted the system was robust, that is having few factors that would perturb that performance. And with regard to a hypothetical licensing, there was readily documented high confidence and conservatism in known or assumed parameters, and that makes for defensible safety cases and license applications. Beyond performance, cost and schedule were also estimated based on available analogs from the geothermal industry and even when scaled by experience, the numbers were again compelling.

Thus began my own thinking about two important aspects (true for any disposal concept including deep borehole disposal of HLW); the technical feasibility and the strength of a presumed licensing and safety case. Simply, can one build the concept, and can you defend that it will then perform as calculated.

**Feasibility**

On the issue of feasibility, I submit the answer is yes...it is possible, with today's technology to develop large diameter boreholes in crystalline rock of depths to 5 km.

The KTB, and several other similar boreholes around the world, provide compelling 'engineering analogues' for the feasibility of developing and implementing the deep boreholes disposal option. I note the KTB hole did reach at total depth of 9.1 km in challenging crystalline rock. Perhaps more importantly, in the first 2 years, from 1990 to 1992, the KTB hole was drilled AND cased with 13 3/8 inch (.34 m) casing to a depth of 6 km. This leaves me no doubt that continued German engineering and innovation could readily achieve a slightly wider diameter to only 5 km. The presentations this past week by experienced representatives from several drilling companies, and similar presentations at other workshops held in the U.S. echo this conclusion. To the observation that such diameters and depths have not been demonstrated in crystalline rock is explained simply by the lack of a prior commercial need or benefit. The application of all existing technology to new uses is not demonstrated until it is.

**Licensing**

To evaluate the strength of a licensing (the defensibility) there are a numerous considerations such as data quality assurance, repeatability, representativeness, epistemic and aleatoric uncertainty, alternative models, parameter distributions, coupled effects, etc. The assembly of a defensible licensing safety case is not a trivial exercise, but every geologic repository concept has this challenge.

To judge whether a particular safety case is defensible and would be compliant with (known or assumed) licensing criteria without a rigorous analytical, documented and reviewed effort should be based more on experience and less on conjecture. Based on the experience of numerous professionals that have direct involvement in licensing and safety case development, the answer to licensing and the defensibility of a deep borehole safety case is a qualified yes.

Simplistically, such judgements need at a minimum to know or assume:

1. a specific site and its characteristics,
2. the waste type and its characteristics,
3. the regulatory framework, criteria, standards, etc. and,
4. A description of the disposal concept, including the engineered barriers, in sufficient detail.

For most any repository concept not formally proposed, one can only make assumptions for much of the content that would be needed. By employing known or reliable analogues, and applying appropriate conservatisms, one can develop a sense the strengths and weaknesses of a particular hypothetical licensing effort. In the case of evaluating deep borehole disposal of HLW in crystalline rock, these principles were applied in the 2009 report, and continue to be applied in all subsequent work, with the same resulted a qualified sense of confidence as to the ability to license. Most uncertain perhaps are the licensing criteria and specifically the issue of retrievability.

The BRC recognized that the same level of retrievability common to mined repositories may not be practical or even necessary in the context of other disposal approaches, such as deep boreholes. The BRC recommended related regulatory requirements and time periods can and should be reassessed as part of a larger evaluation of disposal system performance objectives. Retrievability (in mined repositories or boreholes) can be addressed when the criteria and purpose are understood. The issues of retrievability, whether for mined or borehole systems, can only be adequately addressed when the purpose, intent, criteria and applicable timeframe for retrievability are understood.

Finally, many of the questions for the experts submitted prior to the Working Group 3 hearing can be answered simplistically but with qualification. All of the questions and many more are either the basis for regulatory criteria, and/or would be addressed and documented in detail in a draft or final safety case and supporting analyses. No safety case or license could ever proceed on assertions alone, however expert. Many of the questions have been answered in detail and with context, through the numerous careful analyses made available in peer-reviewed publications over the last 5-10 years.

My intent here today was to facilitate your own deliberations on the matter of deep borehole disposal concepts and whether they are feasible, and whether they should be pursued. As I hope I have made clear, I believe the hard evidence now available supports the conclusion that

such a disposal concept is feasible, and could be licensed under appropriate frameworks. Thus the addition of deep borehole disposal capability could provide a much-needed disposal capacity and option, neither of which exists today. I want to be clear that I am firmly of the position that it is NOT a question of whether to pursue only mined or borehole based disposal, but rather I urge the pursuit of both concepts in order to provide a waste management system with needed capability, capacity and the flexibility to perhaps begin to achieve this generation's obligation to safely dispose of the radioactive waste it produced and to avoid leaving it to future generations.

Thank you for your time and attention.