

Challenging Issues for Nuclear Waste Disposal in Deep Geological Formations: Status Report on Fifth Worldwide Review

Fuel Cycle Research & Development

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ACRONYMS

BGR	Bundesanstalt für Geowissenschaften und Rohstoffe
CNEN	Commission National Nuclear Energy - Brazil
DGR	Director Geosciences Research
DOE	Department of Energy
DOT	Department of Transportation
ENRESA	Empresa Nacional de Residuos Radiactivos, S.A.
ENRRA	Egyptian Nuclear and Radiological Regulatory Authority
EPA	Environmental Protection Agency
FANC	Federal Agency for Sciences
HLW	High-Level Nuclear Waste
IAEA	International Atomic Energy Agency
ISSN	International Standard Serial Number
LBNL	Lawrence Berkeley National Laboratory
LILW	Low- and Intermediate-Level Nuclear Waste
NAGRA	National Technical Competence Centre in the Field of Deep Geological Disposal of Radioactive Waste
NDA	National Decommissioning Authority
NRC	Nuclear Regulatory Commission
NUMO	Nuclear Waste Management Organization of Japan
ORE	Oxford Research Encyclopedia
POC	Point of Contact
PURAM	Public Limited Company for Radioactive Waste
SKB	Swedish Nuclear Fuel and Waste Management Company
SNL	Sandia National Laboratories
SURAO	Správa úložišť Radioaktivních Odpadů
URF	Underground Research Facilities Network
WIPP	Waste Isolation Pilot Plant
WWR	Worldwide Review

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1. Objectives and Scope

An important issue for present and future generations is the final disposal of spent nuclear fuel. Over the past over forty years, the development of technologies to isolate both high-level nuclear waste (HLW) generated at nuclear power plants in deep geologic systems and low- and intermediate-level nuclear waste (LILW) in underground rock and sediments has faced a number of challenges. For example, significant quantities of LILW constitute a disposal challenge for the nuclear industry and environmental management. Finding an effective and safe solution (e.g., meets regulatory requirements for dose risk, etc.) for the geologic disposal of nuclear waste is a fundamental issue for the environment protection, and for the future continued reliance on nuclear power. The purpose of a deep geological repository for nuclear waste is to provide to future generations, especially to those in the far future, protection against any harmful release of radioactive material, even after the memory of the repository may have been lost, and whatever the technical knowledge of future generations.

The results of investigations on the technology for radioactive waste isolation from 19 countries were published in the *First Worldwide Review* in 1991 (Witherspoon, 1991). The results of investigations from 26 countries were published in the *Second Worldwide Review* in 1996 (Witherspoon, 1996). The results of investigations from 32 countries were summarized in the *Third Worldwide Review* in 2001 (Witherspoon and Bodvarsson, 2001). Finally, the latest results from 24 countries were compiled in the *Fourth Worldwide Review* on radioactive waste isolation (Witherspoon and Bodvarsson, 2006).

Since publication of the last WWR report (Witherspoon and Bodvarsson, 2006) on radioactive waste disposal approaches, there have been major developments in a number of national geological disposal programs. Significant experience has been obtained both in preparing and reviewing safety cases for the operational and long-term safety of proposed and operating (LILW) repositories. Disposal of radioactive waste is a complex issue, not only because of the nature of the waste, but also because of the regulatory structure for dealing with radioactive waste. There are a variety of stakeholders involved, and there are a number of regulatory entities involved. In the US, Federal government agencies involved in radioactive waste management include: the Environmental Protection Agency (EPA), the Nuclear Regulatory Commission (NRC), the Department of Energy (DOE), and the Department of Transportation (DOT). In addition, the states and affected Native American Tribes play a prominent role in expressing public concerns over the hazards of radioactive waste. In the US, the Waste Isolation Pilot Plant (WIPP), Carlsbad, New Mexico, was certified by the EPA to permanently dispose of transuranic radioactive waste, left from the research and production of nuclear weapons, for 10,000 years. In Europe, Sweden and Finland have already submitted applications to the public authorities to establish final repositories for spent nuclear fuel. France is planning to apply to build a final repository for high-level waste in 2015. Although these three countries are frontrunners in the area of nuclear waste disposal, many more countries are going to address this issue.

Lawrence Berkeley National Laboratory (LBNL) and Sandia National Laboratories (SNL) initiated preparation of the 5th Worldwide Review on the challenging issues of nuclear waste disposal in geological formations. The overall objective of the WWR-5 report is to give an overview of the development of technologies in different countries to isolate, in geologic disposal sites, both: (a) high-level nuclear waste (HLW) generated at nuclear power plants; and

(b) low- and intermediate-level nuclear waste (LILW), generated in different industries.

The Chapters presented in the report focus on the progress made in many countries in efforts advancing the isolation of radioactive wastes using deep geologic disposal as the final disposition. Substantial experience has been obtained both in preparing and reviewing safety cases for the operational and long-term safety of proposed and operating repositories. The Chapters will also cover a number of active discussions and debates related to the issues of nuclear waste disposal.

2. Project Description

The project has been planned in three phases:

Phase 1– The announcement and request to participate in an on-line survey for the WWR-5 for the representatives of countries working on the issues of nuclear waste disposal in geological systems. This first phase was established to facilitate the identification of key personnel in various countries willing to coordinate and contribute a chapter to the 5th WWR detailing their country's program. The questionnaire that was developed and sent to 28 countries is at: https://docs.google.com/a/lbl.gov/forms/d/1-koeo1gpo8hAEWYvizO2dOFSZ2bTM4AX_qCVo6NhSCA/viewform

The following countries have already participated in the online survey: Bulgaria, Brazil, Czech Republic, France, Finland, Germany, Hungary, Korea, Slovenia, South Africa, Ukraine, Spain, Sweden, and Switzerland. In addition, a point of contact (POC) for Romania was recommended by IAEA in late July, and it is expected that the POC for Romania will submit the online survey and submit an answer regarding contributing a Full Chapter.

Phase 2 – Collection of the papers from different countries, editing, and publication of the 5th World Wide Review volume. Phase 2 is planned for completion by the end of 2015. We developed the formatting guidelines for preparation of chapters of the WWR-5, following the general style of the previous WWR-4, and also taking into account the formatting style of the Oxford Research Encyclopedia (ORE). Following several conversations with the editor of the ORE, we achieved the following agreement, including the following three parts:

1. The report is published in a similar format to how it has been previously published, but now as an e-book (i.e., a digital version of the report in the universal PDF format), and with an International Standard Serial Number (ISSN) number to identify a publication. The information about the ISSN is given at <http://www.issn.org/understanding-the-issn/what-is-an-issn/> and <http://nsl.nisclair.res.in/issn.jsp>. (We may consider also publication of a limited number of hard copies of the report, depending on the price of publication.)
2. The ORE will feature a link to the digital version of the report (e-book in the PDF format) as open access. The link will be complimented by, and cross-referenced to, the overview article on nuclear waste geological repositories, which the ORE will publish. This will be a peer-reviewed publication.
3. The ORE will have a link to a blog that will provide a link to the WWR-5 chapters and a video.

Draft of the Table of Content of the WWR-5 is given in Table 1. The following countries have

submitted their full Chapters: Brazil, Canada, China, Czech Republic, Finland, France, Latvia, Lithuania, South Africa, Spain, Slovakia, Ukraine, and USA. The following countries are still in the process of preparation of their full Chapters, and promised to complete them in August-September: Belgium, Bulgaria, Germany, Hungary, India, Japan, Korea, Mexico, Romania, Switzerland, and UK. Slovenia submitted only an online survey, and will not be able to submit a full Chapter due to shortage of personnel to work on preparation of the Chapter.

Phase 3 – We plan on having a Workshop on the 5th Worldwide Review to be held in Berkeley, California. This workshop will summarize the experience and lessons learned documented in the WWR-5 Volume and seek to establish future cooperation/collaboration among the participating countries. Phase 3 Workshop is tentatively planned for early in 2016.

3. Conclusions and Scientific and Practical Benefits

The overall objective of the Fifth Worldwide Review is to document evolution in the state-of-the-art since the Fourth Worldwide Review that was released in 2006. Almost ten years after the previous WWR, it is timely to document major developments in a number of geological disposal programs of various nations throughout the World, and to summarize challenging issues from experience obtained both in preparing and reviewing safety cases for the operational and long-term safety of proposed and operating (LILW) repositories. The countries that are approaching industrial implementation of geological disposal of HLW will increasingly focus on the feasibility of safely constructing and operating their repositories. The Review will also address a number of specific technical issues and challenges in safety case development along with the interplay of technical feasibility, engineering design issues, and operational and post-closure safety, and stakeholder concerns.

Phase 1 of the project has practically been completed. Phase 2 of the project is ongoing, and planned to be completed by the end of 2015. The Fifth Worldwide Review on nuclear waste disposal will assess the lessons learned and facilitate future cooperation between the countries. The Report will be used to share practical experiences on preparing for, developing, and documenting projects on nuclear waste disposal in the subsurface in rock and sediments in terms of requirements, expectations, and experience gained in developing safety cases for long-term repository safety. The Report will help identify potential issues that may arise as a repository program matures, and to understand the importance of safety cases in promoting and gaining societal confidence.

Table 1. Table of Contents of the WWR-5 (Draft)

(Submitted Chapters are shown in bold font; other Chapters are expected in August-September 2015)

Chapter #	Country	Lead authors and Titles	Organizations
1	Introduction	Boris Faybishenko, Jens Birkholzer, David Sassani, and Peter Swift	Lawrence Berkeley National Laboratory, Sandia National Laboratories
2	Belgium	Frederic Bernier , Bernard Neerdael	Federal Agency for Nuclear Control (FANC)
3	Bulgaria	Doncho Karastanev “Site Selection Approach for Geological Disposal of High-Level Waste in Bulgaria”	Bulgarian Academy of Sciences
4	Brazil	Paulo Fernando Lavalle Heilbron Filho, Jesus Salvador Pérez Guerrero, Monica da Costa Pereira Lavalle Heilbron, Claudio de Morisson Valeriano, and Corbiniano Silva “Radioactive Waste Management in Brazil Including Spent Fuel”	Brazilian Nuclear Energy Commission, Brazilian Nuclear Regulatory Commission (CNEN)
5	Canada	POC: Mark Jensen Mark Jensen, Jo-Ann Facella, Paul Gierszewski, Chris Hatton, and Sean Russell “Progress Towards Long-Term Management of Used Nuclear Fuel in Canada”	Director DGR Geoscience and Research Nuclear Waste Management Organization Toronto, Ontario, Canada
6	Czech Republic	Jiří Slovák and František Woller “Progress of the Czech Deep Geological Repository Program”	Správa úložišť Radioaktivních Odpadů (SURA)
7	China	Ju Wang “Geological Disposal Program for High Level Radioactive Waste in China: Update 2015”	Vice President, Beijing Research Institute of Uranium Geology Head, HLW Disposal Program
8	Egypt	Prof. Dr. Mohamed Reda Ezz El-din, Chairman of ENRRA	Egyptian Nuclear and Radiological Regulatory

			Authority (ENRRA) Head of the Nuclear and Radiological Safety Centre.
9	Finland	Lahti Vira; Juhani Vira “Towards implementation of the spent nuclear fuel repository in Finland”	Posiva Oy
10	France	Gerald Ouzounian, Sebastien Farin, Thibault Labalette, and Frederic Plas “Progress towards geological disposal of high-level and intermediate-level long-lived radioactive waste at an industrial scale: the CIGEO project”	Agence Nationale pour la Gestion des Déchets Radioactifs (ANDRA)
11	India	R.K. Bajpai "Recent advances in Indian Geological Repository Programme and Associated Research & Development Activities"	Repository Engineering Section, Technology Development Division, Nuclear Recycle Group Bhabha Atomic Research Center
12	Hungary	Peter Molnar, PURAM Balint Nos POC: Balázs Molnár "Current Status of Geological Disposal Projects in Hungary".	Public Limited Company for Radioactive Waste Management (PURAM) Director, Head of Strategy Department and Engineering Office
13	Germany	Volkmar Bräuer Ingo Böttcher “Current Status of Nuclear Waste Disposal in Germany”	BGR
14	Japan	Hiroyuki Umeki	Nuclear Waste Management Organization of Japan (NUMO)
15	Korea	Haeryong Jung ¹ , Kyungsoo Kim ²	¹ KORAD ² KAERI

16	Latvia	Dr. Andrejs Dreimanis “On Interdisciplinary Approach in Geological Disposal: International Co-operation Imperative”	Radiation Safety Centre Riga, Latvia
17	Lithuania	Dr. Povilas Poskas “Approach To Disposal Of Radioactive Waste And Spent Nuclear Fuel In Lithuania”	Lithuanian Energy Institute Kaunas, Lithuania
18	Mexico	Dr. Enrique García Ramírez Dr. Federico Puente Espel	Instituto Nacional de Investigaciones Nucleares Mexico
19	Romania	Felicia Dragolici	National Institute of Research and Development for Physics and Nuclear Engineering "Horia Hulubei"- Bucharest, Magurele
20	Slovakia	Mr. Ing. Miloslav Božik Peter Salzer, Igor Slaninka, Vaclava Havlova, Miroslav Pereszlenyi “Development Of The Slovak Deep Geological Disposal – Status In 2015”	Contact: Peter Salzer, Nuclear and Decommissioning Company (JAVYS), Plc., Bratislava; State Geological Institute of Dionýz Štúr, Bratislava ÚJV Řež, a.s., Husinec-Řež, Czech Republic PC&G, Ltd, Bratislava
21	Slovenia	Tomaž Žagar	Director, ARAO— Agency for Radioactive Waste Management
22	South Africa	M.A.G. Andreoli, E. Raubeheimer, A.C. Carolissen, J.F. Beyleveld “Radioactive Waste Disposal In South Africa In 2015: Status And R& D Strategies”	South African Nuclear Energy Corporation, Pretoria, South Africa School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa
23	Spain	Juan Carlos Mayor	Empresa Nacional de Residuos Radiactivos,

		“Geological Disposal Of Spent-Fuel And High-Level Waste In Spain”	S.A. (ENRESA), Madrid Contact: Juan Carlos Mayor, jmaz@enresa.es
24	Sweden	Olle Olsson, Monica Hammarström (Title to be confirmed)	SKB
25	Switzerland	Vomvoris Stratis	NAGRA
26	UK	Simon Norris	NDA
27	Ukraine	Vyacheslav Shestopalov sh@hydrosafe.kiev.ua Lyubov Zinkevitch V.M.Shestopalov ¹ , Iu.A.Shybetskyi ¹ , M.I.Proskura ² , L.I.Zinkevich ² , R.G. Temny ³ “Geological Disposal Of Radioactive Waste In Ukraine: Background, Status, And Future Steps”	¹ National Academy of Sciences, ² State Agency of Ukraine on the Exclusion Zone Management, ³ National operator for radioactive waste disposal (SSE CEMRW).
28	USA	Bill Boyle, Prasad Nair “Research & Development Program for the Used Nuclear Fuel and High- Level Radioactive Waste Disposition in the United States”	DOE
29	IAEA	Stefan Mayer Underground Research Facilities (URF) Network (PPT file submitted)	IAEA – Underground Research Facilities (URF) Network

4. Acknowledgments

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- Witherspoon, P.A., & Bodvarsson, G. S., eds., (2001) Geological Problems in Radioactive Waste Isolation: Third Worldwide Review, Report LBNL-49767
- Witherspoon, P. A., & Bodvarsson, G. S., eds., (2006). Geological Challenges in Radioactive Waste Isolation: Fourth Worldwide Review. Geological Challenges in Radioactive Waste Isolation: Fourth Worldwide Review, Report LBNL-59808