Geological Repository Systems For Safe Disposal Of Spent Nuclear Fuels And Radioactive Waste Woodhead Publishing Series In Energy

Fossil fuels will remain the backbone of the global energy economy for the foreseeable future. The contribution of nuclear energy to the global energy supply is also expected to increase. With the pressing need to mitigate climate change and reduce greenhouse gas emissions, the fossil energy industry is exploring the possibility of carbon dioxide disposal in geological media. Geological disposal has been studied for decades by the nuclear industry with a view to ensuring the safe containment of its wastes. Geological disposal of carbon dioxide and that of radioactive waste gives rise to many common concerns in domains ranging from geology to public acceptance. In this respect, comparative assessments reveal many similarities, ranging from the transformation of the geological environment and safety and monitoring concerns to regulatory, liability and public acceptance issues. However, there are profound differences on a broad range of issues as well, such as the quantities and hazardous features of the materials to be disposed of, the characteristics of the targeted geological media, the site engineering technologies involved and the timescales required for safe containment at the disposal location. There are ample opportunities to learn from comparisons and to derive insights that will assist policymakers responsible for national energy strategies and international climate policies.

This book will address concepts and techniques for preparation and disposal of low- (LLW) and intermediate-level (ILW) radioactive waste from the nuclear industry, the weapons industry, university labs, research institutes, and from the commercial industry. It will aid decision-makers in finding optimal technical/economical solutions, including how site investigations, design, construction, identification and selection of construction materials (clay and concrete), and monitoring can be made. It will also examine techniques for isolating soil and rock contaminated by leaking nuclear plants and from damaged nuclear reactors such as those at the Fukushima and Chernobyl nuclear plants.

Nuclear Waste Management Strategies: An International Perspective presents worldwide insights into nuclear waste management strategies from a technical engineering perspective, with consideration for important legal aspects. It provides a one-stop, comprehensive analysis of both historical and up-to-date nuclear waste management strategies, while consulting important legal aspects of decision-making and implementation processes. With case studies from around the world, this book provides a unique understanding of nuclear waste management technologies and methods available, ensuring that researchers and engineering professionals are equipped with the right knowledge to design, build, implement and improve their own waste management strategies. This book will benefit those researching and learning in the nuclear energy sector, especially those specializing in nuclear waste management strategies, as well as technical and legal communities within nuclear and environmental areas. It is also a valuable resource for lawmakers and regulatory bodies concerned with nuclear policy and waste management. Provides a one-stop location for reference material on nuclear waste management strategies from around the world Focuses on the associated technical engineering elements of planning for, and implementing, waste management strategies Includes real-life examples from Europe, North America, South America, Asia, the Middle East and Africa

Compared to other large engineering projects, geologic repositories for high-level waste present distinctive challenges because: 1) they are first-of-a-kind, complex, and long-term projects that must actively manage hazardous materials for many decades: 2) they are expected to hold these hazardous materials passively safe for many millennia after repository closure; and 3) they are widely perceived to pose serious risks. As is the case for other complex projects, repository programs should proceed in stages. One Step at a Time focuses on a management approach called "adaptive staging" as a promising means to develop geologic repositories for high-level radioactive waste such as the proposed repository at Yucca Mountain, Nevada. Adaptive staging is a learn-as-you-go process that enables project managers to continuously reevaluate and adjust the program in response to new knowledge and stakeholder input. Advice is given on how to implement staging during the construction, operation, closure, and post-closure phases of a repository program.

Geological Repository Systems for Safe Disposal of Spent Nuclear Fuels and Radioactive Waste, Second Edition, critically reviews state-of-the-art technologies and scientific methods relating to the implementation of the most effective approaches to the long-term, safe disposition of nuclear waste, also discussing regulatory developments and social engagement approaches as major themes. Chapters in Part One introduce the topic of geological disposal, providing an overview of near-surface, intermediate depth, and deep borehole disposal, spanning low-, medium- and high-level wastes. Part Two addresses the different types of repository systems – crystalline, clay, and salt, also discussing methods of site surveying and construction. The critical safety issue of engineered barrier systems is the focus of Part Three, with coverage ranging from nuclear waste canisters, to buffer and backfill materials. Lastly, Parts Four and Five focus on safety, security, and acceptability, concentrating on repository performance assessment, then radiation protection, environmental monitoring, and social engagement. Comprehensively revised, updated, and expanded with 25% new material on topics of current importance, this is the standard reference for all nuclear waste management and geological repository professionals and researchers. Contains 25% more material on topics of current importance in this new, comprehensive edition Fully updated coverage of both near-surface/intermediate depth, and deep borehole disposal in one convenient volume Goes beyond the scientific and technical aspects of disposal to include the political, regulatory, and societal issues involved, all from an international perspective

This Special Publication contains 43 scientific studies presented at the 5th conference on 'Clays in natural and engineered barriers for radioactive waste confinement' held in Montpellier, France in 2012. The conference and this resulting volume cover all the aspects of clay characterization and behaviour considered at various temporal and spatial scales relevant to the confinement of radionuclides in clay, from basic phenomenological process descriptions to the global understanding of performance and safety at repository and geological scales. Special emphasis has been given to the modelling of processes occurring at the mineralogical level within the clay barriers. The papers in this Special Publication consider research into argillaceous media under the following topic areas: large-scale geological characterization; clay-based concept/large-scale experiments; hydrodynamical modelling; geochemistry; geomechanics; mass transfer/gas transfer; mass transfer mechanisms. The collection of different topics presented in this Special Publication demonstrates the diversity of geological repository research.

Teaches the application of Reactive Transport Modeling (RTM) for subsurface systems in order to expedite the understanding of the behavior of complex geological systems This book lays out the basic principles and approaches of Reactive Transport Modeling (RTM) for surface and subsurface environments, presenting specific workflows and applications. The techniques discussed are being increasingly commonly used in a wide range of research fields, and the information provided covers fundamental theory, practical issues in running reactive transport models, and how to apply techniques in specific areas. The need for RTM in engineered facilities, such as nuclear waste repositories or CO2 storage sites, is ever increasing, because the prediction of the future evolution of these systems has become a legal obligation. With increasing recognition of the power of these approaches, and their widening adoption, comes responsibility to ensure appropriate application of available tools. This book aims to provide the requisite understanding of key aspects of RTM, and in doing so help identify and thus avoid potential pitfalls. Reactive Transport Modeling covers: the application of RTM for CO2 sequestration and geothermal energy development; reservoir quality prediction; modeling diagenesis; modeling geochemical processes in oil & gas production; modeling gas hydrate production; reactive transport in fractured and porous media; reactive transport studies for nuclear waste disposal; reactive flow modeling in hydrothermal systems; and modeling biogeochemical processes. Key features include: A comprehensive reference for scientists and practitioners entering the area of reactive transport modeling (RTM) Presented by internationally known experts in the field Covers fundamental theory, practical issues in running reactive transport models, and hands-on examples for applying techniques in specific areas Teaches readers to appreciate the power of RTM and to stimulate usage and

application Reactive Transport Modeling is written for graduate students and researchers in academia, government laboratories, and industry who are interested in applying reactive transport modeling to the topic of their research. The book will also appeal to geochemists, hydrogeologists, geophysicists, earth scientists, environmental engineers, and environmental chemists.
Many countries are currently exploring the option to dispose of highly radioactive solid wastes deep underground in purpose built, engineered repositories. A number of surface and shallow repositories for less radioactive wastes are already in operation. One of the challenges facing the nuclear industry is to demonstrate confidently that a repository will contain wastes for so long that any releases that might take place in the future will pose no significant health or environmental risk. One method for building confidence in the long-term future safety of a repository is to look at the physical and chemical processes which operate in natural and archaeological systems, and to draw appropriate parallels with the repository. For example, to understand why some uranium orebodies have remained isolated underground for billions of years. Such studies are called 'natural analogues'. This book investigates the concept of geological disposal and examines the wide range of natural analogues which have been studied. Lessons learnt from studies of archaeological and natural systems can be used to improve our capabilities for assessing the future safety of a radioactive waste repository.

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Within the next decade, many thousands of U.S. and Russian nuclear weapons are slated to be retired as a result of nuclear arms reduction treaties and unilateral pledges. Hundreds of tons of plutonium and highly enriched uranium will no longer be needed for weapons purposes and will pose urgent challenges to international security. This is the supporting volume to a study by the Committee on International Security and Arms Control which dealt with all phases of the management and disposition of these materials. This technical study concentrates on the option for the disposition of plutonium, looking in detail at the different types of reactors in which weapons plutonium could be burned and at the vitrification of plutonium, and comparing them using economic, security and environmental criteria.

This handbook is concerned with developing principles and standards for the safe disposal of solid radioactive wastes by burial deep in the Earth's crust. Radioactive wastes have focussed thinking on long-term environmental protection issues in an unprecedented way. Consequently, the way in which principles and standards are set, and the thinking behind this, is of wider interest than to the nuclear field alone. The issues are not just technical and scientific. There is also a much wider philosophical context to the debate, centering on ethics, human values and the expectations of society. In this handbook it is intended that all theses issues are brought together, suggesting appropriate ways forward in each area, culminating in a proposed structure for safety regulations. It also aims to provide a detailed discussion of some of the most difficult logical an ethical issues facing those wishing to dispose of long-lived radioactive wastes.

The safe management of radioactive wastes is of paramount importance in gaining both governmental and societal support for nuclear energy. The scope of this new textbook is to provide a comprehensive perspective on all types of radioactive wastes as to how they are created, classified, characterized, and disposed.Written to emphasize how geology and radionuclide chemistry impact waste management, this book is primarily designed for engineers who have little background in geology with low-level wastes, decommissioning wastes, high-level wastes and spent nuclear fuel.This textbook provides the most up-to-date information available on waste management in several countries. The content of this work includes transporting radioactive materials to disposal facilities. The textbook cites numerous case studies to illustrate past practices, current methodologies and to provide insights on how radioactive wastes may be managed in the future. An international perspective on waste management is also provided to help the readers better understand the diversity in approaches while highlighting what many countries have in common. Review questions for classroom use are provided at the end of each chapter.

This report considers key safety issues regarding the geological disposal of radioactive waste and focuses on the different functions of a repository within its life cycle. It describes the processes relevant to the containment of long-lived radioactive waste and other processes that might affect the long term integrity of the repository. Chapters include discussion of: the geological disposal concept; near field components and processes; far field barriers and processes; safety and performance assessments.

Damaged fuels originated from the accident at the Fukushima-Daiichi Nuclear Power Station, and the spent nuclear fuels from commercial light water reactors (LWRs) in Japan are considered to be disposed of in deep geological repository. For a prospective repository, as part of generic performance assessment, a criticality safety assessment (CSA) should be performed to ensure that the repository system including the engineered barriers and host geological formations remains sub-critical for tens of thousands to millions of years. For various repository concepts, CSA is considered to include three major stages in chronological order: (1) the stage before package failure, (2) the stage after package failure, while fissile nuclides remain within the engineered barrier system (EBS) and in the near-field region, and (3) the stage in which fissile nuclides originated from multiple packages are deposited in far-field host rocks. Defining the model for neutronics calculations plays a central role in CSAs, where conservative assumptions are usually made to cope with various uncertainties and to simplify the model. The aim of this dissertation is to develop neutronics models for different stages in the criticality safety study, and provide basic understandings for the long-term criticality safety for the disposal of spent nuclear fuel in geologic repository. In the near-field analysis, a neutronics model has been developed for a system consisting of a canister containing fuel debris from Fukushima reactors and the surrounding buffer, in a water-saturated deep geological repository. The fuel debris has been modeled as a hexagonal lattice of spherical fuel particles. Following key observations have been concluded from the numerical results: (a) the calculated neutron multiplicity (keff) is sensitively dependent on assumptions related to moderation, (b) the carbon steel canister plays an important role in reducing the potential for criticality, (c) the maximum keff of the canister-buffer system could be achieved after a fraction of fissile nuclides been released from the canister, and (d) under several assumptions, the maximum keff of the canister-buffer system could be principally determined by the dimension and composition of the canister, not by the initial fuel loading. Based on the preliminary results and findings, a parametric study has been made to identify the optimized lattice parameters for criticality. And the critical mass of damaged fuels for a single canister has been calculated. If this critical mass is used as the maximum canister mass loadings, roughly a thousand canisters are needed to contain the damaged fuels from the three damaged cores. For the LWR spent fuels, a parametric study has been performed to examine spent fuels with different designs and burnup histories. The numerical results indicate that, under the conditions assumed, for all UO2 spent fuels and most of the MOX spent fuels, the single canister model will always be subcritical. The far-field study has been focusing on neutronic analysis to examine the criticality conditions for uranium depositions in geological formations which result from geological disposal of damaged fuels from Fukushima reactors. Neutronics models are used to evaluate the keff and critical mass for various combinations of host rock and geometries. The present study has revealed that the planar fracture geometry applied in the previous criticality safety assessment for geological disposal would not necessarily yield conservative results against the homogeneous uranium deposition. It has been found that various far-field critical configurations are conceivable for given conditions of materials and geological formations. Prior to knowing the site location, some important points for selecting a site for criticality safety can be suggested. These include: (a) iron existing in the host rock reduces the likelihood of criticality significantly; (b) low host rock porosity is preferred for criticality safety; (c) the conservatism could change when comparing heterogeneous geometries for different fracture apertures; and (d) the importance of the mass of the deposition increases when it is smaller. As part of the improvement for the models developed in the far-field analysis, preliminary works on uranium depositions in randomly fractured rocks have been presented. The randomly fractured geometry could fundamentally influence the far-field criticality, because the system's keff value sensitively depends on the fracture aperture and the depositions at fracture intersections. No previous work has been made to study the effect of random geometry in the context of the long-term criticality safety in a geologic repository. Different numerical schemes have been developed and compared for the direct sampling of uranium depositions in randomly fractured rocks using MCNP. A general literature review of existing methods for neutron transport problems with random processes has been made. And the analytical Feinberg-Galanin-Horning (FGH) method has been derived and tested for a numerical example.

The Department of Energy's Office of Environmental Management (DOE-EM) is responsible for cleaning up radioactive waste and environmental contamination resulting from five decades of nuclear weapons production and testing. A major focus of this program involves the retrieval, processing, and immobilization of waste into stable, solid waste forms for disposal. Waste Forms Technology and Performance, a report requested by DOE-EM, examines requirements for waste form technology and performance in the cleanup program. The report provides information to DOE-EM to support improvements in methods for processing waste and selecting and fabricating waste forms. Waste Forms Technology and Performance places particular emphasis on processing technologies for high-level radioactive waste, DOE's most expensive and arguably most difficult cleanup challenge. The report's key messages are presented in ten findings and one recommendation.

The Microbiology of Nuclear Waste Disposal is a state-of-the-art reference featuring contributions focusing on the impact of microbes on the safe long-term disposal of nuclear waste. This book is the first to cover this important emerging topic, and is written for a wide audience encompassing regulators, implementers, academics, and other stakeholders. The book is also of interest to those working on the wider exploitation of the subsurface, such as bioremediation, carbon capture and storage, geothermal energy, and water quality. Planning for suitable facilities in the U.S., Europe, and Asia has been based mainly on knowledge from the geological and physical sciences. However, recent studies have shown that microbial life can proliferate in the inhospitable environments associated with radioactive waste disposal, and can control the long-term fate of nuclear materials. This can have beneficial and damaging impacts, which need to be quantified. Encompasses expertise from both the bio and geo disciplines, aiming to foster important collaborations across this disciplinary divide Includes reviews and research papers from leading groups in the field Provides helpful guidance in light of plans progressing worldwide for geological disposal facilities Includes timely research for planning and safety case development

Open system behavior is predicated on a fundamental relationship between the timescale over which mass is transported and the timescale over which it is chemically transformed. This relationship describes the basis for the multidisciplinary field of reactive transport (RT). In the 20 years since publication of Review in Mineralogy and Geochemistry volume 34: Reactive Transport in Porous Media, RT principles have expanded beyond early applications largely based in contaminant hydrology to become broadly utilized throughout the Earth Sciences. RT is now employed to address a wide variety of natural and engineered systems across diverse spatial and temporal scales, in tandem with advances in computational capability, quantitative imaging and reactive interface characterization techniques. The present volume reviews the diversity of reactive transport applications developed over the past 20 years, ranging from the understanding of basic processes at the nano- to micrometer scale to the prediction of Earth global cycling processes at the watershed scale. Key areas of RT development are highlighted to continue advancing our capabilities to predict mass and energy transfer in natural and engineered systems.

In The Road to Yucca Mountain, J. Samuel Walker traces the U.S. government's tangled efforts to solve the technical and political problems associated with radioactive waste. From the Manhattan Project through the designation in 1987 of Yucca Mountain in Nevada as a high-level waste repository, Walker thoroughly investigates the approaches adopted by the U.S. Atomic Energy Commission (AEC). He explains the growing criticism of the AEC's waste programs, such as the AEC's embarrassing failure in its first serious effort to build a high-level waste repository in a Kansas salt mine. Clearly and accessibly, Walker explains the issues surrounding deep geological disposal and surface storage of high-level waste and spent reactor fuel. He analyzes the equally complex and divisive question of fuel "reprocessing." He weaves reliable research with fresh insights about nuclear science, geology, politics, and public administration, making this original and authoritative account an essential guide for understanding the continuing controversy over an illusive and emotional topic.

A key challenge in the development of safety cases for the deep geological disposal of radioactive waste is handling the long time frame over which the radioactive waste remains hazardous. The intrinsic hazard of the waste decreases with time, but some hazard remains for extremely long periods. Safety cases for geological disposal typically address performance and protection for thousands to millions of years into the future. Over such periods, a wide range of events and processes operating over many different timescales may affect a repository and its environment. Uncertainties in the predictability of such factors increase with time, making it increasingly difficult to provide definite assurances of a repository's performance and the protection it may provide over longer timescales. Timescales, the level of protection and the assurance of safety are all linked. Approaches to handling timescales for the geological disposal of radioactive waste are influenced by ethical principles, the evolution of the hazard over time, uncertainties in the evolution of the disposal system (and how these uncertainties themselves evolve), and the stability and predictability of the geological environment. Conversely, the approach to handling timescales can affect aspects of repository planning and implementation including regulatory requirements, siting decisions, repository design, the development and presentation of safety cases and the planning of pre- and post-closure institutional controls such as monitoring requirements. This is an area still under discussion among NEA member countries. This report reviews the current status and ongoing discussions of this issue.

The safe disposal of the nation's nuclear waste in a geologic repository is one of the most significant and difficult scientific endeavors of the twenty-first century. Unique scientific challenges are posed by the very long-lived radioactivity of nuclear waste. Many radionuclides of vastly different chemical character must be retained by the repository for several thousand years. Some with longer half-lives, such as Pu-239 and Tc-99, need to be isolated for periods approaching a million years. In order to ensure the safety of a geologic repository, a detailed understanding of the mobility of radionuclides in complex natural systems is essential. Most of the radioactivity in a geological repository will be associated with spent nuclear fuel. In the United States spent fuel is derived from several sources. The majority is UO2 (LWR) spent fuel from commercial reactors. About 30,000 metric tons of spent fuel was in storage at commercial reactors by 1995, with the expectation that this quantity will more than double by 2010 (Integrated Data Report 1995). All spent fuel derived from commercial reactors is intended for eventual disposal in a geological repository. In addition, the DOE is the custodian of about 8000 metric tons of spent fuel, most of which is also intended for disposal in a geological repository. Although there are more than 250 types of spent fuel in the DOE inventory, the fuels may be broadly classified into (1) uranium metal fuel, (2) aluminum-based fuel, (3) mixed oxide (MOX) fuel containing substantial plutonium, and (4) graphite fuel (Colleen Shelton-Davis, personal communications, January 2000). Disposal of spent fuel in a geological repository requires detailed knowledge of the longterm behavior of the waste forms under repository conditions, as well as the fate of radionuclides released from the waste packages as containers are breached. The proposed Yucca Mountain repository is intended to hold 70,000 metric tons of high-level nuclear waste. Nine radionuclides considered in the TSPA-VA (Total System Performance Analysis - Viability Assessment) Base Case Performance Analysis (CRWMS, 1998, cf. Table 3-14 in section 3.5.1) are of special concern because of their long half-lives, radiological toxicities, and potential mobilities under repository conditions. These are five actinide isotopes, Np-237, Pu-239, Pu-242, U-234, and Pa-231, and four fission products, Tc-99, I-129, Se-79, and C-14. In addition, Am-241 is important because it is a parent of Np-237. An understanding of the behaviors of these elements under repository-relevant conditions is essential to safe disposal. Natural analogue studies of the mineral uraninite, UO2+x (an analogue for UO2 in spent fuel), as well as several laboratory-scale simulations, confirm that spent fuel is unstable under the moist, oxidizing conditions expected in the proposed repository at Yucca Mountain. Once containers are breached, alteration of the spent fuel m ay be rapid, with the most abundant alteration products being uranyl (U6+) phases. Shortly after groundwater or condensed water vapor contacts spent fuel in the proposed repository, uranyl phases are likely to be abundant in the vicinity of the spent fuel. Most of the uranyl phases that will form in the repository are already known as minerals from natural systems. Many of these uranyl phases can persist for thousands of years, as demonstrated by studies of natural analogues (Finch et al. 1996). It is likely that uranyl phases forming due to the alteration of spent fuel will incorporate many of the radionuclides contained in the spent fuel (Burns et al. 1997), thus having a profound impact upon the mobility of the radionuclides. Our ongoing research is leading to an understanding of the impact of incorporation of radionuclides into uranyl phases. Such information is essential to an understanding of the long-term performance of the geological repository. Knowledge of the crystal structures, chemistries, stabilities and paragenesis of uranyl minerals lag far behind most other mineral groups, owing in large part to the occurrence of these minerals as complex intergrowths of multiple phases, making routine analysis very difficult. Despite approval by Congress and the Bush administration and over seven billion dollars already spent, the Yucca Mountain, Nevada, site for disposal of highly radioactive spent nuclear fuel is not yet in operation. The reasons for the delay lie not only in citizen and activist opposition to the project but also in the numerous scientific and technical issues that remain unresolved. Although many scientists favor geologic disposal of high-level nuclear waste, there are substantial unknowns in projecting the performance of a site over the tens to hundreds of thousands of years that may be required by Environmental Protection Agency standards. Uncertainty Underground is the first effort to review the uncertainties in the analysis of the long-term performance of the proposed repository at Yucca Mountain. The book does not pass judgment on the suitability of the site but provides reliable science-based information to support open debate and inquiry into its safety. Experts from the geosciences, industry, and government review different aspects of the repository system, focusing on the uncertainties inherent in each. After an overview of the historical and regulatory context, the contributors investigate external factors (including climate change and volcanic activity) that could affect repository performance and then turn to topics concerning the repository itself. These include hydrologic issues, the geological conditions with which the nuclear waste in the repository would interact, and the predicted behavior of the different kinds of waste and waste package materials. Uncertainty Underground succeeds in making these important technical issues understandable to a wide audience, including policymakers and the general public.

During the next several years, decisions are expected to be made in several countries on the further development and implementation of the geological disposition option. The Board on Radioactive Waste Management (BRWM) of the U.S. National Academies believes that informed and reasoned discussion of relevant scientific, engineering and social issues can-and should-play a constructive role in the decision process by providing information to decision makers on relevant technical and policy issues. A BRWM-initiated project including a workshop at Irvine, California on November 4-5, 1999, and subsequent National Academies' report to be published in spring, 2000, are intended to provide such information to national policy makers both in the U.S.

and abroad. To inform national policies, it is essential that experts from the physical, geological, and engineering sciences, and experts from the policy and social science communities work together. Some national programs have involved social science and policy experts from the beginning, while other programs have only recently recognized the importance of this collaboration. An important goal of the November workshop is to facilitate dialogue between these communities, as well as to encourage the sharing of experiences from many national programs. The workshop steering committee has prepared this discussion for participants at the workshop. It should elicit critical comments and help identify topics requiring in-depth discussion at the workshop. It is not intended as a statement of findings, conclusions, or recommendations. It is rather intended as a vehicle for stimulating dialogue among the workshop participants. Out of that dialogue will emerge the findings, conclusions, and recommendations of the National Academies' report.

Focused attention by world leaders is needed to address the substantial challenges posed by disposal of spent nuclear fuel from reactors and high-level radioactive waste from processing such fuel. The biggest challenges in achieving safe and secure storage and permanent waste disposal are societal, although technical challenges remain. Disposition of radioactive wastes in a deep geological repository is a sound approach as long as it progresses through a stepwise decision-making process that takes advantage of technical advances, public participation, and international cooperation. Written for concerned citizens as well as policymakers, this book was sponsored by the U.S. Department of Energy, U.S. Nuclear Regulatory Commission, and waste management organizations in eight other countries.

Advanced separations technology is key to closing the nuclear fuel cycle and relieving future generations from the burden of radioactive waste produced by the nuclear power industry. Nuclear fuel reprocessing techniques not only allow for recycling of useful fuel components for further power generation, but by also separating out the actinides, lanthanides and other fission products produced by the nuclear reaction, the residual radioactive waste can be minimised. Indeed, the future of the industry relies on the advancement of separation and transmutation technology to ensure environmental protection, criticality-safety and non-proliferation (i.e., security) of radioactive materials by reducing their long-term radiological hazard. Advanced separation techniques for nuclear fuel reprocessing and radioactive waste treatment provides a comprehensive and timely reference on nuclear fuel reprocessing and radioactive waste treatment. Part one covers the fundamental chemistry, engineering and safety of radioactive materials separations processes in the nuclear fuel cycle, including coverage of advanced aqueous separations engineering, as well as on-line monitoring for process control and safeguards technology. Part two critically reviews the development and application of separation and extraction processes for nuclear fuel reprocessing and radioactive waste treatment. The section includes discussions of advanced PUREX processes, the UREX+ concept, fission product separations, and combined systems for simultaneous radionuclide extraction. Part three details emerging and innovative treatment techniques, initially reviewing pyrochemical processes and engineering, highly selective compounds for solvent extraction, and developments in partitioning and transmutation processes that aim to close the nuclear fuel cycle. The book concludes with other advanced techniques such as solid phase extraction, supercritical fluid and ionic liquid extraction, and biological treatment processes. With its distinguished international team of contributors, Advanced separation techniques for nuclear fuel reprocessing and radioactive waste treatment is a standard reference for all nuclear waste management and nuclear safety professionals, radiochemists, academics and researchers in this field. A comprehensive and timely reference on nuclear fuel reprocessing and radioactive waste treatment Details emerging and innovative treatment techniques, reviewing pyrochemical processes and engineering, as well as highly selective compounds for solvent extraction Discusses the development and application of separation and extraction processes for nuclear fuel reprocessing and radioactive waste treatment

Disposal of radioactive waste from nuclear weapons production and power generation has caused public outcry and political consternation. Nuclear Wastes presents a critical review of some waste management and disposal alternatives to the current national policy of direct disposal of light water reactor spent fuel. The book offers clearcut conclusions for what the nation should do today and what solutions should be explored for tomorrow. The committee examines the currently used "once-through" fuel cycle versus different alternatives of separations and transmutation technology systems, by which hazardous radionuclides are converted to nuclides that are either stable or radioactive with short half-lives. The volume provides detailed findings and conclusions about the status and feasibility of plutonium extraction and more advanced separations technologies, as well as three principal transmutation concepts for commercial reactor spent fuel. The book discusses nuclear proliferation; the U.S. nuclear regulatory structure; issues of health, safety and transportation; the proposed sale of electrical energy as a means of paying for the transmutation system; and other key issues.

The Waste Isolation Pilot Plant (WIPP) is a deep underground mined facility for the disposal of transuranic waste resulting from the nation's defense program. Transuranic waste is defined as waste contaminated with transuranic radionuclides with half-life greater than 20 years and activity greater than 100 nanocuries per gram. The waste mainly consists of contaminated protective clothing, rags, old tools and equipment, pieces of dismantled buildings, chemical residues, and scrap materials. The total activity of the waste expected to be disposed at the WIPP is estimated to be approximately 7 million curies, including 12,900 kilograms of plutonium distributed throughout the waste in very dilute form. The WIPP is located near the community of Carlsbad, in southeastern New Mexico. The geological setting is a 600-meter thick, 250 million-year-old saltbed, the Salado Formation, lying 660 meters below the surface. The National Research Council (NRC) has been providing the U.S. Department of Energy (DOE) scientific and technical evaluations of the WIPP since 1978. The committee's task is twofold: (1) to identify technical issues that can be addressed to enhance confidence in the safe and long-term performance of the repository and (2) to identify opportunities for improving the National Transuranic (TRU) Program for waste management, especially with regard to the safety of workers and the public. This is the first full NRC report issued following the certification of the facility by the U.S. Environmental

Protection Agency (EPA) on May 18, 1998. An interim report was issued by the committee in April 2000 and is reproduced in this report. The main findings and recommendations from the interim report have been incorporated into the body of this report. The overarching finding and recommendation of this report is that the activity that would best enhance confidence in the safe and long-term performance of the repository is to monitor critical performance parameters during the long pre-closure phase of repository operations (35 to possibly 100 years). Indeed, in the first 50 to 100 years the rates of important processes such as salt creep, brine inflow (if any), and microbial activity are predicted to be the highest and will be less significant later. The committee recommends that the results of the on-site monitoring program be used to improve the performance assessment for recertification purposes. These results will determine whether the need for a new performance assessment is warranted. For the National TRU Program, the committee finds that the DOE is implementing many of the recommendations of its interim report. It is important that the DOE continue its efforts to improve the packaging, characterization, and transportation of the transuranic waste.

Key components of the nuclear fuel cycle are short-term storage and long-term disposal of nuclear waste. The latter encompasses the immobilization of used nuclear fuel (UNF) and radioactive waste streams generated by various phases of the nuclear fuel cycle, and the safe and permanent disposition of these waste forms in geological repository environments. The engineered barrier system (EBS) plays a very important role in the long-term isolation of nuclear waste in geological repository environments. EBS concepts and their interactions with the natural barrier are inherently important to the long-term performance assessment of the safety case where nuclear waste disposition needs to be evaluated for time periods of up to one million years. Making the safety case needed in the decision-making process for the recommendation and the eventual embracement of a disposal system concept requires a multi-faceted integration of knowledge and evidence-gathering to demonstrate the required confidence level in a deep geological disposal site and to evaluate long-term repository performance. The focus of this report is the following: (1) Evaluation of EBS in long-term disposal systems in deep geologic environments with emphasis on the multi-barrier concept; (2) Evaluation of key parameters in the characterization of EBS performance; (3) Identification of key knowledge gaps and uncertainties; and (4) Evaluation of tools and modeling approaches for EBS processes and performance. The above topics will be evaluated through the analysis of the following: (1) Overview of EBS concepts for various NW disposal systems; (2) Natural and man-made analogs, room chemistry, hydrochemistry of deep subsurface environments, and EBS material stability in near-field environments; (3) Reactive Transport and Coupled Thermal-Hydrological-Mechanical-Chemical (THMC) processes in EBS; and (4) Thermal analysis toolkit, metallic barrier degradation mode survey, and development of a Disposal Systems Evaluation

Framework (DSEF). This report will focus on the multi-barrier concept of EBS and variants of this type which in essence is the most adopted concept by various repository programs. Empasis is given mainly to the evaluation of EBS materials and processes through the analysis of published studies in the scientific literature of past and existing repository research programs. Tool evaluations are also emphasized, particularly on THCM processes and chemical equilibria. Although being an increasingly important aspect of NW disposition, short-term or interim storage of NW will be briefly discussed but not to the extent of the EBS issues relevant to disposal systems in deep geologic environments. Interim storage will be discussed in the report Evaluation of Storage Concepts FY10 Final Report (Weiner et al. 2010).

Radioactive waste management and contaminated site clean-up reviews radioactive waste management processes, technologies, and international experiences. Part one explores the fundamentals of radioactive waste including sources, characterisation, and processing strategies. International safety standards, risk assessment of radioactive wastes and remediation of contaminated sites and irradiated nuclear fuel management are also reviewed. Part two highlights the current international situation across Africa, Asia, Europe, and North America. The experience in Japan, with a specific chapter on Fukushima, is also covered. Finally, part three explores the clean-up of sites contaminated by weapons programmes including the USA and former USSR. Radioactive waste management and contaminated site clean-up is a comprehensive resource for professionals, researchers, scientists and academics in radioactive waste management, governmental and other regulatory bodies and the nuclear power industry. Explores the fundamentals of radioactive waste including sources, characterisation, and processing strategies Reviews international safety standards, risk assessment of radioactive wastes and remediation of contaminated sites and irradiated nuclear fuel management Highlights the current international situation across Africa, Asia, Europe, and North America specifically including a chapter on the experience in Fukushima, Japan

Drawing on the authors’ extensive experience in the processing and disposal of waste, An Introduction to Nuclear Waste Immobilisation, Second Edition examines the gamut of nuclear waste issues from the natural level of radionuclides in the environment to geological disposal of waste-forms and their long-term behavior. It covers all-important aspects of processing and immobilization, including nuclear decay, regulations, new technologies and methods. Significant focus is given to the analysis of the various matrices used, especially cement and glass, with further discussion of other matrices such as bitumen. The final chapter concentrates on the performance assessment of immobilizing materials and safety of disposal, providing a full range of the resources needed to understand and correctly immobilize nuclear waste. The fully revised second edition focuses on core technologies and has an integrated approach to immobilization and hazards Each

chapter focuses on a different matrix used in nuclear waste immobilization: cement, bitumen, glass and new materials Keeps the most important issues surrounding nuclear waste - such as treatment schemes and technologies and disposal - at the forefront
In the different disposal concepts for high-level nuclear waste, corrosion of the metallic barriers and in particular the overpack/container is a major issue. It is imperative for performance assessment to predict the lifetime of these containers. In the lifetime prediction of metallic barriers for the disposal of high level nuclear waste (HLW) or of spent fuel, the presence of (reduced) sulphur species is an issue of growing importance, as the sulphur species are involved in localised corrosion phenomena. The international workshop on Sulphur-Assisted Corrosion in Nuclear Waste Disposal Systems (SACNUC2008) aimed to provide an exchange of information on the influence of sulphur species on the corrosion of metallic barriers. This workshop was a co-organisation of the Belgian Nuclear Research Centre, SCK*CEN, and the Belgian Agency for the Management of Radioactive Waste and Enriched Fissile Materials, ONDRAF/NIRAS, under the auspices of the European Federation of Corrosion (EFC event N 311). The proceedings are divided into five chapters: Chapter 1 provides a general overview of the disposal concepts of nuclear waste and the role of corrosion. Chapter 2 explains the mechanism of sulphur-induced corrosion processes. This chapter also contains information from outside the nuclear disposal field in which sulphur is known to act as a detrimental factor (e.g. oil and gas

industry). Chapter 3 addresses the role of microbial processes in sulphur-assisted corrosion. Chapter 4 covers the modelling of sulphide-assisted corrosion. Chapter 5 is devoted to a panel discussion aiming to identify open issues in the investigation of sulphur-assisted corrosion phenomena and how to incorporate these in robust lifetime prediction of metallic barriers.
This is volume two of a comparative analysis of nuclear waste governance and public participation in decision-making regarding the storage and siting of high-level radioactive waste and spent fuel in different countries. The contributors examine both the historical and current approaches countries have taken to address the wicked challenge of nuclear waste governance. The analyses discuss the regulations, technology choices, safety criteria, costs and financing issues, compensation schemes, institutional structures, and approaches to public participation found in each country.
Geologic Disposal of High-Level Radioactive Waste examines the fundamental knowledge and conditions to be considered and applied by planners and other professionals when establishing national repository concepts, and constructing repositories for the long-term isolation of highly radioactive waste from surrounding crystalline rock. It emphasizes the important roles of structural geology, hydrogeology, hydrochemistry, and construction techniques. It specifically examines the disposal of steel canisters with spent reactor fuel in mined repositories (MR) at medium-depth, and in very deep boreholes (VDH). While disposal in mined repositories has been widely tested, the option of placing

high-level radioactive waste in deep boreholes has been considered in the US, UK, and elsewhere in Europe, but has not yet been tested on a broad scale. This book examines the possibility of safe disposal for very long periods, proposing that the high salt content and density of groundwater at large depths are such that potentially contaminated water would not rise high enough to affect the more shallow biosphere. Features: Presents the best practices for disposal of spent fuel from nuclear reactors. Assesses waste isolation capacities in short- and long-term perspectives, and the associated risks. Describes site selection principles and the economics of construction of different types of repositories. Includes an appendix which provides the latest international recommendations and guidelines concerning the disposal of highly radioactive waste.

Radioactive wastes are generated from a wide range of sources, including the power industry, and medical and scientific research institutions, presenting a range of challenges in dealing with a diverse set of radionuclides of varying concentrations. Conditioning technologies are essential for the encapsulation and immobilisation of these radioactive wastes, forming the initial engineered barrier required for their transportation, storage and disposal. The need to ensure the long term performance of radioactive waste forms is a key driver of the development of advanced conditioning technologies. The Handbook of advanced radioactive waste conditioning technologies provides a comprehensive and systematic reference on the various options available and under development for the treatment and immobilisation of radioactive wastes. The book opens with an introductory chapter on radioactive waste characterisation and selection of conditioning technologies. Part one reviews the main radioactive waste treatment processes and conditioning technologies, including volume reduction techniques such as compaction, incineration and plasma treatment, as well as encapsulation methods such as cementation, calcination and vitrification. This coverage is extended in part two, with in-depth reviews of the development of advanced materials for radioactive waste conditioning, including geopolymers, glass and ceramic matrices for nuclear waste immobilisation, and waste packages and containers for disposal. Finally, part three reviews the long-term performance assessment and knowledge management techniques applicable to both spent nuclear fuels and solid radioactive waste forms. With its distinguished international team of contributors, the Handbook of advanced radioactive waste conditioning technologies is a standard reference for all radioactive waste management professionals, radiochemists, academics and researchers involved in the development of the nuclear fuel cycle. Provides a comprehensive and systematic reference on the various options available and under development for the treatment and immobilisation of radioactive wastes Explores radioactive waste characterisation and selection of conditioning technologies including the development of advanced materials for radioactive waste conditioning Assesses the main radioactive waste treatment processes and conditioning technologies, including volume reduction techniques such as compaction

Deep Geological Disposal of Radioactive Waste presents a critical review of designing, siting, constructing and demonstrating the safety and environmental impact of deep repositories for radioactive wastes. It is structured to provide a broad perspective of this multi-faceted, multi-disciplinary topic: providing enough detail for a non-specialist to understand the fundamental principles involved and with extensive references to sources of more detailed information. Emphasis is very much on “deep geological disposal – at least some tens of metres below land surface and, in many cases, many hundred of metres deep. Additionally, only radioactive wastes are considered directly – even though such wastes often contain also significant chemotoxic or otherwise hazardous components. Many of the principles involved are generally applicable to other repository options (e.g. near-surface or on-surface disposal) and, indeed, to other types of hazardous waste. Presents a current critical review in designing, siting, constructing and demonsrating the safety and environmental impact of deep repositories for radwaste Addresses the fundamental principles of radioactive waste with up-to-date examples and real-world case studies Written for a multi-disciplinary audience, with an appropriate level of detail to allow a non-specialist to understand

Geological Repository Systems for Safe Disposal of Spent Nuclear Fuels and Radioactive Waste, Second Edition, critically reviews state-of-the-art technologies and scientific methods relating to the implementation of the most effective approaches to the long-term, safe disposition of nuclear waste, also discussing regulatory developments and social engagement approaches as major themes. Chapters in Part One introduce the topic of geological disposal, providing an overview of near-surface, intermediate depth, and deep borehole disposal, spanning low-, medium- and high-level wastes. Part Two addresses the different types of repository systems - crystalline, clay, and salt, also discussing methods of site surveying and construction. The critical safety issue of engineered barrier systems is the focus of Part Three, with coverage ranging from nuclear waste canisters, to buffer and backfill materials. Lastly, Parts Four and Five focus on safety, security, and acceptability, concentrating on repository performance assessment, then radiation protection, environmental monitoring, and social engagement. Comprehensively revised, updated, and expanded with 25% new material on topics of current importance, this is the standard reference for all nuclear waste management and geological repository professionals and researchers. Contains 25% more material on topics of current importance in this new, comprehensive edition Fully updated coverage of both near-surface/intermediate depth, and deep borehole disposal in one convenient volume Goes beyond the scientific and technical aspects of disposal to include the political, regulatory, and societal issues involved, all from an international perspective

Published as part of the managing radioactive waste safely (MRWS) programme, this white paper sets out the UK Government's framework for managing higher

activity radioactive waste in the long-term through geological disposal, coupled with safe and secure interim storage and ongoing research and development to support its optimised implementation. It also invites communities to express an interest in opening up, without commitment, discussions with Government on the possibility of hosting a geological disposal facility at some point in the future. In June 2007 the Government published a MRWS consultation document in conjunction with the devolved administrations for Wales and Northern Ireland. Responses to this consultation have been taken into consideration in the development of this white paper. The paper sets out the framework for the future implementation of geological disposal that includes: the approach to compiling and updating the UK Radioactive Waste Inventory (UKRWI) and using it as a basis for discussion with potential host communities; the Nuclear Decommissioning Authority's technical approach for developing a geological disposal facility, including the use of a staged implementation approach and ongoing research and development to support delivery. The white paper covers the amount of waste for disposal; preparation and planning for geological disposal; protecting people and the environment: regulation, planning and independent scrutiny; site selection using a voluntarism and partnership approach; the site assessment process; timing and next steps.
This volume discusses the readiness of the U.S. Department of Energy's (DOE) Waste Isolation Pilot Plant (WIPP) facility near Carlsbad, New Mexico, to serve as a geological repository for transuranic

radioactive waste. WIPP is located in a Permian-age bedded salt deposit 658 meters below the surface. The committee has long reviewed DOE's readiness efforts, now aimed at demonstrating compliance with U.S. Environmental Protection Agency regulations. Site characterization studies and performance assessment modeling are among the topics considered in this volume.