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This is particularly the case in relation to the disposal of long lived and/or high level waste and spent nuclear fuel (SNF) in geological repositories. It is generally accepted that such repositories should be designed to be passively safe with no intention of retrieving the waste.

No. NW-T-1 - IAEA
Geological Society of America ... safe; that's like a few grains of sand in an Olympic-size swimming pool. Compare that to arsenic, a toxic element whose safe limit is 10 parts per billion -- much ...

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

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.

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.

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.

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.

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

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.

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).

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.

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 CO_2 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 CO_2 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.