Evaluating New Waste Form Impacts on Repository Capacity from a Total System Perspective

D.K. Kim
U.S. Department of Energy
Office of Radioactive Waste Management
1000 Independence Avenue, S.W., Washington DC 20585

W.M. Nutt[1]
Golder Associates Inc.
1551 Hillshire Drive, Suite A
Las Vegas NV 89134

A.N. Dravo and M.G. Seitz
Booz Allen Hamilton
955 L'Enfant Plaza North, Suite 5300
Washington DC 20024

ABSTRACT

This paper summarizes the steps that need to be taken to develop a long-term performance assessment of a repository and discusses the potential impacts on the existing performance assessment model that could result from a national decision to dispose of wastes from an advanced fuel cycle, such as that envisioned under the Global Nuclear Energy Partnership (GNEP). The objective is to establish a common understanding of what activities would potentially need to be conducted, and why, to support the disposal of high level wastes from an advanced nuclear fuel cycle.

The long-term performance of the proposed repository at Yucca Mountain is currently evaluated using a methodology called Total System Performance Assessment (TSPA). The TSPA methodology can be applied to evaluate the safety of the disposal of nuclear wastes arising from GNEP technologies.

The entire TSPA would need to be updated in accordance with U.S. Nuclear Regulatory Commission (NRC) requirements for a license to accommodate GNEP wastes. The revised TSPA would have to reflect the entire repository system as configured to dispose of these wastes. Major changes in the TSPA expected from introduction of GNEP wastes would be in two areas. First, the features, events and processes (FEPs) that might affect performance of the geologic system would have to be re-evaluated considering the GNEP wastes and any corresponding changes to the repository design. The modeling hierarchy used in the TSPA would then be modified to reflect any revised FEPs and scenarios.

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[1] W. Mark Nutt is currently employed at Argonne National Laboratory, 8700 S. Cass Avenue, Argonne IL 60439

Secondly, the input and boundary conditions of some models used in the TSPA would have to be revised based on characteristics of the GNEP nuclear wastes and any associated change to the repository design. Some new models would likely have to be developed, for example due to new waste form types. These model revisions would likely require additional data such as characteristics of new waste forms.

Post-closure performance assessment should be an integral part of the GNEP program with models developing in an iterative and integrated manner. Testing, analyses, and modeling of nuclear wastes supported by GNEP should strive to meet the requirements for data and processes established by NRC regulations and the U.S. Department of Energy's Office of Civilian Radioactive Waste Management (OCRWM). This rigor will assure that a revision to the post-closure safety analysis is technically defensible in a regulatory environment. Qualifying data to describe changes introduced by GNEP wastes would have to undergo the same rigor and compliance with procedures as the data collection and modeling that supports the original license application.

INTRODUCTION

This paper focuses on the potential impacts to post-closure performance assessment modeling of a repository site in a licensing environment that could materialize from implementation of an advanced nuclear fuel cycle, such as the Global Nuclear Energy Patrnership (GNEP) initiative. This paper also shows, in general outline, what needs to be done for performance assessment modeling to be useful for comparing the impacts of different waste forms in a repository environment.

Recent studies by the Nuclear Energy Agency / Organisation for Economic Co-operation and Development (NEA/OECD) apply performance assessment (PA) to evaluate the impact of new fuel cycles on disposal concepts in different geologic media. Impacts can be estimated extrapolating results from existing repository performance assessments [1]. To allow for more accurate impact assessment, HLW types arising from advanced fuel cycles and modifications of existing repository concepts can be specifically evaluated [2]. The ability to accurately use PA to evaluate GNEP impacts will improve through an iterative process involving development of data on actual GNEP waste forms, and revising assessment models to reflect the total system environment created by new waste forms in a specific geologic site.

PA is an important evaluation tool because estimating the potential increase in repository capacity requires consideration of interdependent issues: radionuclide content, thermal output, volume, and packaging of waste. Understanding how performance assessment is developed and applied helps put into perspective the complexity of determining the extent to which improvements in repository capacity can be achieved.

Total System Performance Assessment (TSPA) is the methodology that is being used to complete the post-closure safety analysis for the current proposed repository site at Yucca Mountain. In accordance with 10 CFR 63, the TSPA for Yucca Mountain will ultimately be included in a license application for repository construction. The TSPA uses a systematic approach to effectively evaluate all factors affecting long-term radiological impacts of disposal of high level waste or spent nuclear fuel in a geologic repository.

DOE has been evaluating post-closure performance of the proposed Yucca Mountain repository using TSPA since the inception of the site characterization program, including conducting post-closure performance assessments in support of the site recommendation decision. The first section of this paper discusses the sequence of events leading to the current Yucca Mountain TSPA. This serves as a basis for understanding how the performance assessment is formulated and its dependence on underlying information.

There are several requirements governing post-closure repository performance assessments, including regulatory and quality assurance requirements. These are discussed in the next section of this paper. Any changes to studies, experiments, or modeling based on the impact of GNEP wastes would have to undergo the same rigor and compliance with procedures as the original modeling and assumptions, and data collected under the auspices of similar quality assurance processes and procedures. Testing, analyses, and modeling relating to GNEP should strive to meet these requirements from the initial stages to ensure that a post-closure safety analysis for GNEP-generated waste is technically defensible in a regulatory environment.

The GNEP program can support future repository licensing efforts by developing data and waste forms using methods consistent with the TSPA developed for licensing the proposed Yucca Mountain facility. The GNEP initiative, if implemented, has the potential to result in significant changes to the types of wastes that are disposed of, the radionuclide inventories in the waste, and the design of the repository facilities. These changes are likely to directly affect post-closure performance assessment modeling. The GNEP initiative is at a very early stage with definitive concepts to be defined over coming years. It is not presently necessary or even possible to anticipate specific impacts using licensing-quality TSPA methodology. However, the use of performance assessment for GNEP will help focus research and development activities, ultimately leading to a performance assessment that would comply with all requirements and that could be used to support a licensing process.

The third section of this paper describes the potential impacts of the GNEP initiative on the post-closure repository performance assessment. It is not presently possible to determine post-closure repository impacts in a quantitative fashion (e.g., in terms of dose that could potentially be received by the public) with a high level of accuracy. Such impacts have been assessed in a relative fashion using simplified models to demonstrate the potential benefits that could be realized [1] [2] [3] [5]. Thus, this discussion focuses on those areas of the current TSPA model that would likely be impacted and where significant modeling changes, supported by research and development, would be needed.

OVERVIEW OF THE TOTAL SYSTEM PERFORMANCE ASSESSMENT

Iterative and integrated TSPA analyses were used throughout the Yucca Mountain site characterization program to evaluate post-closure performance of the proposed Yucca

Mountain repository. TSPA analyses supported the 2002 Site Recommendation decision. The multi-year TSPA development process resulted in a TSPA that will be used to demonstrate post-closure repository performance in accordance with the requirements at 10 CFR 63. The TSPA will provide the information needed by the NRC to complete the review of the post-closure performance safety analysis portion of DOE's license application for a construction authorization for the proposed repository at Yucca Mountain. The TSPA evaluates performance of both the natural and engineered barriers, and models all aspects important to repository performance such as ground water seepage and the ability of the waste package and engineered barriers to withstand creep and corrosion.

The first step in the performance assessment methodology is the generation of a comprehensive list of features, events, and processes (FEPs) that could potentially affect repository performance. Once the list is determined to be complete, the FEPs are screened using risk-based probability and consequence criteria to identify those FEPs that need to be considered in the performance assessment. The remaining FEPs are then combined into performance scenarios that cover the post-closure period. These scenarios are then screened according to risk-based probability and consequence criteria. This process ultimately leads to a list of FEPs and scenarios that must be included in the performance assessment model.

With FEPs and scenario screening complete, a modeling hierarchy is used to develop the overall TSPA model. First, the entire suite of available information is used to develop detailed models of natural processes at the site and on a regional scale, including the processes that affect the engineered barriers. Subsequently, several sub-system process-level models are developed. These include modeling the amount of water that infiltrates into the mountain; the manner in which water can seep into the repository tunnels; the coupled evolution of the thermal, hydrologic and chemical environment; the manner that the waste package materials and contained waste forms degrade, and the transport of any released contaminant within the repository itself and its movement through the geologic barriers. All "included" FEPs are treated in this process-level modeling.

Integration of the complex process-level subsystem models into an overall total system framework using currently available technology would result in a very complicated, non-transparent, and computationally inefficient model. To make models more efficient, the results of detailed component modeling efforts are used to develop more simplified, or abstracted, models. These abstracted models are ultimately used in the overall repository system model. Development of abstracted models uses a risk-informed approach where the most critical aspects necessary to model the subsystem are explicitly included in the abstraction. The abstracted models are then combined into a single, overall representation of the repository system. This effectively integrates all FEPs and scenarios into the performance assessment model.

The performance assessment model is then used to evaluate repository performance. Sensitivity and uncertainty analyses can be used to identify those factors that have a significant influence on repository performance. This information provides important feedback to research and development (R&D) activities and can serve to focus future work. Subsequent R&D results can be included in the next iteration of the performance assessment resulting in better understanding of repository performance. This iterative and integrated performance assessment methodology was successfully used on the Yucca Mountain Project and a similar approach could be used for development of a TSPA to support disposal of GNEP wastes in a repository.

REQUIREMENTS GOVERNING PERFORMANCE ASSESSMENT

Regulatory and quality assurance requirements associated with post-closure repository performance assessment must be met so that the results assessment can be used to support a post-closure safety case in a licensing action. Developing a license to allow for disposal of GNEP waste in a repository would presumably need to satisfy the same requirements as the Yucca Mountain repository license (or license application). These requirements are summarized to provide the overall framework under which testing, modeling, and analysis activities must ultimately be conducted such that the waste forms generated by the GNEP initiative could be included in a performance assessment that would support a post-closure safety case in a repository licensing action. Early scoping-level analyses do not necessarily have to meet these requirements; however efforts should be taken as early as possible in the development of the GNEP concepts to meet these requirements. This would maximize the amount of information available for ultimate use in a performance assessment that would support such an amendment to the post-closure safety case.

First, the regulatory requirements are presented. The DOE considers post-closure performance assessment as scientific modeling and analysis rather than traditional engineering calculations and analyses. The quality assurance requirements relating to scientific activities are next presented. Lastly, the criteria under which the NRC will review and ultimately accept DOE's post-closure safety analysis are presented.

Regulatory Requirements

The primary requirements governing the post-closure performance assessment for licensing of a proposed repository at Yucca Mountain are from the U.S. Code of Federal Regulations, 10 CFR 63.

Section 10 CFR 63.2 of the regulation provides the definition of performance assessment, stating:

> "*Performance assessment* means an analysis that:
>
> > (1) Identifies the features, events, processes (except human intrusion), and sequences of events and processes (except human intrusion) that might affect the Yucca Mountain disposal system and their probabilities of occurring during 10,000 years after disposal;

(2) Examines the effects of those features, events, processes, and sequences of events and processes upon the performance of the Yucca Mountain disposal system; and

(3) Estimates the dose incurred by the reasonably maximally exposed individual, including the associated uncertainties, as a result of releases caused by all significant features, events, processes, and sequences of events and processes, weighted by their probability of occurrence.”

Section 10 CFR 63.114 of the regulation provides the requirements for performance assessment and states: “Any performance assessment used to demonstrate compliance with § 63.113 must:

(a) Include data related to the geology, hydrology, and geochemistry (including disruptive processes and events) of the Yucca Mountain site, and the surrounding region to the extent necessary, and information on the design of the engineered barrier system used to define parameters and conceptual models used in the assessment.

(b) Account for uncertainties and variabilities in parameter values and provide for the technical basis for parameter ranges, probability distributions, or bounding values used in the performance assessment.

(c) Consider alternative conceptual models of features and processes that are consistent with available data and current scientific understanding and evaluate the effects that alternative conceptual models have on the performance of the geologic repository.

(d) Consider only events that have at least one chance in 10,000 of occurring over 10,000 years.

(e) Provide the technical basis for either inclusion or exclusion of specific features, events, and processes in the performance assessment. Specific features, events, and processes must be evaluated in detail if the magnitude and time of the resulting radiological exposures to the reasonably maximally exposed individual, or radionuclide releases to the accessible environment, would be significantly changed by their omission.

(f) Provide the technical basis for either inclusion or exclusion of degradation, deterioration, or alteration processes of engineered barriers in the performance assessment, including those processes that would adversely affect the performance of natural barriers. Degradation, deterioration, or alteration processes of engineered barriers must be evaluated in detail if the magnitude and time of the resulting radiological exposures to the reasonably maximally exposed individual, or radionuclide releases to the accessible environment, would be significantly changed by their omission.

> (g) Provide the technical basis for models used in the performance assessment such as comparisons made with outputs of detailed process-level models and/or empirical observations (e.g., laboratory testing, field investigations, and natural analogs).”

Quality Assurance Requirements

It is important that any data that may support nuclear facility licensing review be collected under an accepted Quality Assurance (QA) program. The OCRWM *Quality Assurance Requirements and Description* [6] (QARD) establishes the minimum requirements for the QA program designed to meet the requirements of 10 CFR 60, Subpart G. The QARD contains regulatory requirements and program commitments necessary for the development of an effective QA program. Supplement III of the QARD establishes requirements for scientific investigations, including data identification, data reduction, and model development and use. Implementing documents must be based on and consistent with the QARD. Any data obtained from foreign sources not under the QARD or 10 CFR 60 requirements used to support licensing activities will have to be qualified and validated prior to use. All activities supporting an ultimate safety case for the demonstration of compliance with regulatory requirements must be done in accordance with these requirements and deemed qualified.

Yucca Mountain Review Plan Acceptance Criteria

The Yucca Mountain Review Plan (YMRP) provides guidance for the NRC staff to evaluate a DOE license application for a geologic repository [7]. It is not a regulation and does not impose regulatory requirements. As discussed above, the licensing criteria are contained in 10 CFR Part 63. Section 2.2 of the YMRP provides the review methods and acceptance criteria associated with post-closure repository performance. The acceptance criteria are not true requirements; however, the overall performance assessment approach and the supporting analyses, models, and data should satisfy these acceptance criteria such that the NRC can make a positive determination regarding safety. Thus, the YMRP acceptance criteria can be construed as indirect requirements.

POTENTIAL GNEP IMPACTS ON REPOSITORY PERFORMANCE

This section identifies those areas of the post-closure performance assessment that would be affected by implementation of the GNEP initiative, in an attempt to help guide GNEP R&D and the ultimate selection of any advanced nuclear technologies. For the most part, changes to existing modeling approaches would not be required. Those models that would essentially remain unchanged if it is decided to dispose of GNEP wastes in a repository pertain primarily to the natural repository system. These modeling approaches have been developed over a number of years using information obtained in the site characterization program to develop technically defensible models of the natural repository system. However, the inputs to the models may change, necessitating that they be re-done under the quality assurance requirements. In addition, the behavior of new GNEP waste forms within the natural system would require testing and analysis to develop technically defensible models that could be included in the post-closure performance assessment.

Features, Events, and Processes

It is not expected that disposing of wastes from a GNEP enterprise would result in new FEPs or scenarios that have not already been considered in post-closure performance assessments of the proposed Yucca Mountain Repository. However, the list of FEPs would need to be continually evaluated as the GNEP initiative evolves to ensure that any new FEPs would be identified as soon as possible.

It is also not expected that any of the GNEP waste forms would affect any of the current FEP screening justifications. However, the screening justifications would also have to be continually evaluated as the GNEP initiative evolves to determine if the justifications change. In particular, the identification of any FEPs whose justification changes from screened-out to screened-in should be identified as soon as possible so that information could be collected with appropriate formats and controls to implement those FEPs in the performance assessment.

Waste Form Characteristics

Waste form performance is a key part of the overall performance assessment model. It is likely that advanced fuel cycle facilities under GNEP would produce different HLW forms than those currently included in the TSPA (borosilicate glass). The chemical and radiological characteristics of the HLW that is produced by reprocessing will affect the composition of the material in which the HLW is solidified and packaged. All of these characteristics can affect the way the waste behaves in a geologic repository environment. Characteristics important to post-closure repository performance include the rate at which the waste form degrades when exposed to environmental conditions in the repository and the resultant radiological products that form following degradation. A more robust waste form could potentially lead to lower radionuclide release rates from the engineered barriers. However, waste form development for GNEP waste is still in the early stages of investigation and these characteristics cannot be determined until future R&D activities are completed.

The rate that contained radionuclides are made available for subsequent transport through the engineered barriers depends on the waste form degradation rate. Waste form degradation rates typically depend on the temperature and geochemical environment inside the waste package. The geochemical environment inside the waste package depends on several factors including the waste form degradation rate, the waste form degradation products that occur, the rate that waste package internal structural material degrade, the products that result from internal structural degradation, and temperature. The temperature inside the waste package depends on the waste form thermal output, which is dependent on time and the configuration of waste packages within the repository.

Degradation of the waste form makes the contained radionuclides available for subsequent transport. However, additional factors affect the rate that radionuclides are ultimately released from the waste form. These include elemental concentration limits (solubility limits) within the groundwater, elemental sorption processes (irreversible or reversible), and incorporation into secondary phases that result from waste form degradation. These processes depend on the composition of the waste form, the waste form degradation products, the geochemical environment, and the temperature.

As evident from the preceding discussion, radionuclide release from waste forms exposed to the repository environment is a series of linked coupled processes. Historically, this linking has been reflected within the performance assessment model with supporting detailed level models of the key processes developed *a priori*. These process level models must appropriately cover the range of conditions that could occur within the waste package. For example, dissolved concentration limit modeling must cover a range of environmental conditions at least as broad as what would ultimately be projected to occur within the waste package.

This further emphasizes the necessity for an integrated and iterative approach for characterizing the waste forms that could ultimately be generated by the GNEP initiative. These testing and modeling activities would ultimately culminate with a series of detailed models for each of the processes presented above. This would allow the development of source term models for use in post-closure performance assessment modeling and analyses.

Radionuclide Inventory

This section discusses radionuclide inventory considerations as related to the source term, or the assessment of radionuclide release rates from the engineered barriers. The effects of changes to the total amount of waste that could potentially be disposed of are discussed in a later section.

One of the key goals of the GNEP initiative is to reduce the inventory of radionuclides that would ultimately need to be disposed of in a geologic repository. In particular, the GNEP initiative proposes to recover from spent fuel the vast majority of actinides and burn them in advanced reactors, and to recover key fission products (Sr-90, Cs-137, Tc-99, I-129) and either store them (Sr-90 and Cs-137) or possibly transmute them (Tc-99 and I-129). Reducing the inventory of these radionuclides that would ultimately require disposal could have a significant beneficial affect on post-closure repository performance.

Spent nuclear fuel and HLW contain a large number of radionuclides, most of which are not important to post-closure repository performance. A sub-set of these radionuclides that can potentially affect repository performance is developed through a screening process. The screening includes such factors as the radionuclide inventory within the waste, radionuclide half-life, elemental solubility, mobility within the natural barriers, and the radionuclide toxicity (i.e., the dose conversion factors). This screening would have to be done specifically considering wastes from GNEP, since the inventory and proportions of radionuclides would be different from those considered under current Yucca Mountain conditions.

The first step would be to identify the radionuclide inventory that would ultimately require disposal in a repository. This depends on the recycling and recovery processes, and would evolve concurrently with the evolution of the GNEP concepts. Laboratory and demonstration tests conducted early in the development could be used to develop a broad suite of radionuclides for consideration. This list could be shortened as the GNEP initiative begins to focus on specific technologies that will be implemented along with system level performance assessment analyses that identify which radionuclides are truly important to system performance. Beginning with a broad suite of radionuclides for consideration in post-closure performance assessments early on would ensure that important radionuclides would not be missed possibly requiring additional testing and modeling at a later date.

Elemental solubility and mobility constraints would be obtained from existing information regarding elemental solubility, complemented with additional testing as needed. Radionuclide toxicity values (i.e., as reflected in dose conversion factors) have been developed for all radionuclides currently important to repository performance and additional information exists in the literature for additional radionuclides that may need to be considered.

Radionuclide inventory in each disposal canister and ultimately in each waste package will have to be determined. This information will also evolve as the GNEP recycling and recovery concepts, waste form development, and repository design concepts evolve. Early assessments could assume configurations and canister loadings consistent with the assumptions and inputs currently being used in the Yucca Mountain TSPA (e.g., for the high-level waste canisters and co-disposal waste packages). A range of loadings could also be considered and refined as additional information becomes available.

Thermal Effects

A potential benefit, identified as a goal of the GNEP initiative, is a reduction in the thermal output of the waste that would ultimately be disposed of in a repository through the removal of the vast majority of actinides and key fission products. These potential benefits have been quantitatively described in sensitivity analyses [5] [8] and the potential overall impacts on the repository have been summarized [3] [4].

Thermal effects depend on several factors including the thermal output of individual waste canisters and waste packages; waste package loading within the emplacement drifts; emplacement drift spacing; the amount, duration, and efficiency of ventilation; and the thermal-hydrologic behavior of the host rock. Thermal effects have had a significant influence on the current design for a proposed repository at Yucca Mountain. A significant amount of testing, modeling, analysis, and design has been conducted over the past twenty years to quantify these effects. The repository design now enhances thermal benefits and mitigates potential deleterious effects. Analysts have developed methodologies that appropriately model the long-term thermal behavior of the repository for inclusion in a performance assessment.

Models that predict the coupled thermal-hydrologic behavior within Yucca Mountain are well advanced and these models themselves would not be affected significantly by the disposal of wastes generated from the GNEP initiative. However, the inputs to these models and the resulting thermal response could be affected. These inputs are design related and again include waste package thermal output, waste package loading within the emplacement drifts, emplacement drift spacing, and ventilation. These factors combine together and result in an imposed thermal perturbation on the ambient repository system and a corresponding thermal behavior within the host rock.

The removal of actinides and key fission products will reduce the thermal output of the waste per MTHM of reprocessed CSNF. However, the amount of radionuclides that can be loaded into the waste form has a significant affect on the waste form thermal output. Waste form performance requirements may limit the radionuclide loading. Thus, one of the first steps would be to identify how much waste could be physically loaded into the waste forms, defining the thermal output of the individual waste canisters. This step would be a key component of characterizing the waste form as discussed above.

Once the waste form thermal output is determined, parametric studies could be undertaken to optimize the repository design for disposal of the GNEP waste forms to satisfy repository design requirements and goals. Such parametric analyses could utilize simpler models (e.g., 2-D, conduction only) for initial optimization followed by multi-scale thermal-hydrological modeling to complete the optimization. Once the optimized design is selected, the thermal-hydrologic model would be fully developed to be consistent with the selected repository design, utilizing all available information.

Repository Capacity

A stated potential benefit of the GNEP initiative is that only a single repository would be needed over the next century [9]. A widely recognized requirement to realization of that objective at the Yucca Mountain site is a change in federal law. The Nuclear Waste Policy Act “prohibit[s] the emplacement in the first repository of a quantity of spent fuel containing in excess of 70,000 metric tons of heavy metal or a quantity of solidified high-level radioactive waste resulting from the reprocessing of such a quantity of spent fuel until such time as a second repository is in operation.” [10] Legislation to repeal the 70,000 MTHM limit has been introduced in Congress but has not been agreed to by either the House or the Senate [11]. Removing this limit through legislation would be necessary to dispose of all the spent nuclear fuel from both existing and future reactors at Yucca Mountain, regardless of the technical constraints [12]. Besides legislative changes, several additional factors would affect the amount of waste that could ultimately be disposed of in, or the capacity of, a repository at Yucca Mountain. These factors include physical space, waste form thermal characteristics, thermal management strategy, and post-closure repository performance.

The Yucca Mountain sub-surface repository design has been developed for the disposal of 70,000 MTHM of CSNF and high level waste. The sub-surface repository design does not preclude the flexibility to be expanded to accommodate greater quantities of spent nuclear fuel (up to 119,000 MTHM of CSNF) [13]. However, meeting the goal of needing only one repository over the next century could ultimately require further expansion of the repository.

The accommodation of an increased capacity within the existing sub-surface repository design or within an expanded sub-surface repository would require revisions to models and analyses in several areas: infiltration, unsaturated zone flow and transport, unsaturated zone thermal-hydrology, and emplacement drift seepage. The overall modeling approach and methods would not be affected. Rather the initial and boundary conditions would change, necessitating required revisions to the models. Additional field investigations would likely not be required, except perhaps in the case of an expanded repository footprint where additional data covering this area may be needed to bolster the technical defensibility of the models for the new areas.

The maximum repository capacity could ultimately be limited by two factors. The first is simply that the available area to locate a repository becomes fully utilized. Additional field investigations and modeling could result in the identification of additional expansion areas. Secondly, the radiation dose that a potential receptor may receive depends on the total inventory of waste disposed of in the repository. An increase in capacity may be limited by the individual protection standards at 10 CFR 63.113, which are independent of the amount of waste disposed of.

CONCLUSIONS

GNEP has the potential to make significant changes to the types of wastes that are disposed of and the radionuclide inventories in the waste. Plans for repository facilities may be reconfigured to accommodate these new waste forms. These changes are likely to directly affect post-closure performance assessment modeling for a repository.

Ultimately, the post-closure performance assessment would have to be revised in accordance with the requirements at 10 CFR 63. The entire systematic performance assessment revision would consist of: 1) evaluating the features, events and processes (FEPs) that might affect performance of the geologic system with consideration of the GNEP wastes, 2) modifying the modeling hierarchy used in the performance assessment to include revised FEPs and scenarios, 3) revising the input and boundary conditions of models based on characteristics of the GNEP nuclear wastes and any associated re-design, 4) collection of required specific data (half life, decay products, chemical solubility, dissolution, and absorption) of radiochemical species introduced by GNEP technologies, 5) collection of information on waste characteristics and waste packages, and 6) revision of models, as necessary.

Post-closure performance assessment should be an integral part of the GNEP program with models developing in an iterative and integrated manner. Performance assessment can initially be at a scoping level to focus research and development, but should strive to ultimately comply with regulatory and quality assurance requirements. All activities including testing, modeling, and analyses should strive to comply with licensing-related quality assurance requirements so that all data would be available for ultimate use in a compliance demonstration.

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