DISPOSAL PHASE DEVELOPMENT AND RESEARCH AT WIPP

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ABSTRACT

As the Waste Isolation Pilot Plant (WIPP) neared its planned opening date in June 1998, Department of Energy (DOE) officials at the Carlsbad Area Office (CAO) redoubled their commitment to recognize the facility as a "state of the art" program. The science and engineering that earned certification of WIPP by the Environmental Protection Agency (EPA) as the world's first deep geologic repository for disposal of Transuranic (TRU) waste was recognized worldwide by the nuclear waste disposal community. CAO made this commitment by creating a new Office of Development and Research within the line organization, and dedicated many of the resources that contributed to the EPA certification to the areas of continued Research, Technology Development and Program Development. Each of these three components is described in this paper:

Research - CAO directs focused scientific research conducted by the WIPP Science Advisor, Sandia National Laboratories (SNL) that allows DOE and stakeholders to better understand and reduce the uncertainty of repository performance. Aspects of this research are applicable at other disposal facilities in both salt and hard rock.

Technology Development - CAO is directing activities to support the National TRU Program (NTP) which ensures that new technology is developed, implemented, and deployed where opportunities exist to obtain significant risk reduction, mortgage reduction, and compliance enhancement with federal and state agreements across the DOE waste operations complex. Some of this technology is available and ready for use on other forms of radioactive waste.

Program Development - CAO is aggressively seeking opportunities to deploy science and technology in private and government programs that will help them achieve the same level of success as WIPP. This success is built on a strong management infrastructure and experience obtained during the construction, permitting, compliance demonstration, and operation of the WIPP repository.

This paper summarizes current WIPP research, technology development, and institutional technology deployment. In addition, it provides updates on international initiatives. It recounts

the CAO's efforts to facilitate collaboration with national and international interests and expand theoretical and practical knowledge related to nuclear waste disposal.

RESEARCH INITIATIVES

The EPA certification of the WIPP that it meets the standards established by 40CFR191 was based on a large set of conceptual models of features, events and processes (FEPs). These were logically combined and integrated into a probabilistic calculation of the repository's performance. In this very complex ensemble of parameter measurements, mathematical modeling of properties and material behavior, and estimates of uncertainty, it is extremely difficult to quantify the degree of conservatism that the WIPP performance assessment provided. One of the primary goals of the research being conducted in the post-certification phase of the facility (disposal phase) is to reduce the uncertainty in the performance assessment and quantify the degree of conservatism.

Research is being carried out in many areas, including:

- Waste/backfill behavior in the disposal room
- Brine inflow
- Gas generation
- Actinide chemistry

These general research topics are described in the following sections.

Waste/Backfill Behavior in the Disposal Room

In the Performance Assessment (PA) for certification, DOE did not account for many of the likely advantages that would be introduced by use of MgO as backfill (to be placed along with the waste in each disposal room). Only the effect of the MgO on the solubility of actinides (should brine enter the room) was quantitatively considered. Other processes and properties that were not considered include:

- Ability of MgO to absorb free water by hydration (competing for limited water that would otherwise generate H_2 by iron corrosion)
- Strength of the waste/backfill matrix with MgO hydration
- Effect of MgO on microorganism viability

While the repository has been shown to comply with the EPA standards without including these effects, each represents an opportunity to demonstrate an increased margin of safety for the WIPP. The ability of MgO to absorb free water by hydration will compete for the limited water that would otherwise generate H_2 by iron corrosion, or generate CO_2 from microbes metabolizing organic components in the waste. Thus the presence of MgO will tend to reduce the gas generation rate. In addition, the water lost to MgO hydration will not be available for any potential actinide solubilization and hydrologic transport. Experiments are continuing to determine the reaction kinetics of the waste/backfill in relation to corrosion and microbe gas generation processes. In addition, hydration of the MgO causes it to swell, which could change the porosity and pressure in the disposal room. This effect was not considered in the PA, and experiments to quantify the effect on repository performance are also underway.

One of the major release mechanisms predicted in the WIPP's PA (and independently corroborated by the EPA in its Performance Assessment Verification Test - PAVT) was by a mechanism called "spalling". Spalling results from an event in which future inadvertent human intrusion of a sealed repository (that has reached higher than lithostatic pressures through gas generation processes) results in a tensile failure of the waste as a drill bit first penetrates the disposal horizon. As pressure releases, waste is forced up the drill hole (commonly known in the oil and gas industry as a "blowout"). In the probabilistic PA for WIPP, this scenario occurred with enough probability to make it the dominant release mechanism (but still well within the containment limits of 40CFR191). However, the conceptual model calculations assumed a very low tensile strength of the waste material. No credit for the augmented tensile strength due to the MgO backfill was taken. Experiments to estimate the strength of the waste/backfill matrix using surrogate materials are being conducted to demonstrate the degree of conservatism in the original PA.

Brine Inflow Research

In the absence of brine flow due to human intrusion penetrating possible brine reservoirs below the repository, the only brine inflow available to solubilize the actinides and generate gas comes from and through the Disturbed Rock Zone (DRZ) in the walls and floor/ceiling adjacent to the waste. As healing of the DRZ occurs, its intrinsic permeability drops, thus limiting the amount of brine that may flow into the disposal room. Experiments and measurements are being made to re-examine the properties and extent of the DRZ in actual excavations at WIPP.

Gas Generation Research

Gas generation in the WIPP PA was calculated from two processes: 1) H_2 production from iron corrosion; and 2) CO_2 production from microbial anaerobic metabolism of organic materials. Probabilistically, the first process was predicted to proceed slower than the second. Thus, more possible future states with early repository pressurization (leading to the potential for more spalling events within the 10,000 year regulatory time frame) result from the microbial gas generation process. Effects from the presence of MgO backfill along with the waste on microbe viability were not considered. Therefore, research is being conducted to determine the effect of MgO on WIPP microbe viability.

Regardless of the outcome of the experiments on microbe viability in the presence of the MgO backfill, the gas generation process due to iron corrosion will still be important. The modeling of this process in the PA probabilistically employed a range of H_2 generation rates. Experiments to confirm the bounding nature of the modeled generation rates are being conducted using simulated brine and actual waste materials at Argonne National Laboratory - West. Results to date indicate that iron corrosion diminates gas generation as the modeling predicts, and that the only significant microbial gas generation (without MgO present) is CO_2. There is no indication of methanogenesis or production of CO or H_2S.

Actinide Chemistry Research

Research in many facets of actinide behavior is being conducted to confirm the models used in the WIPP PA. These include components that can vary the controlling processes that result in mobile concentrations in brine being available for transport out of the repository. Research is being conducted by the WIPP Science Advisor, SNL at several locations around the DOE complex.

Experiments using simulated WIPP brine and actual waste matrices are being performed to test the actinide behavior related to pH/pcH (basic materials and CO_2), Eh/redox (iron, radiation, microbes), chelating/complexing agents (organics, CO_2, microbial activity), sorption (bentonite, waste solids, corrosion products, precipitates), and colloid formation (bentonite, microbes). In addition, experiments are being conducted to corroborate the models used in the PA to predict the oxidation state distribution of actinides in the expected reducing conditions of the repository. Results to date indicate that the model predictions conservatively bound the measured solubility of actinides in actual waste matrices.

TECHNOLOGY DEVELOPMENT INITIATIVES

The NTP, led by the DOE's Carlsbad Area Office, reviews and consolidates TRU waste technology needs from across the DOE complex to provide a frame of reference for evaluating the urgency of resolving specific problems. TRU waste management needs can be specific to a single site or common among several sites. The NTP assesses waste management technology development (TD) needs on a case-by-case basis, prioritizes them according to NTP goals, and then aggressively solicits funding for their conduct and subsequent deployment. This approach identifies the consequences of not fulfilling these needs (such as requirements in Site Treatment Plans and Consent Orders) and demonstrates how proposed TD projects will solve waste management problems. Once TRU waste TD programs are funded, the NTP monitors and assesses these programs to ensure that the solutions remain responsive to the TRU waste management needs.

At first blush, it might seem that as the WIPP opens, the need for TD for transportation and disposal of TRU waste might subside. This is true for those technologies that were needed to demonstrate how the WIPP could safely operate. However, the initiatives currently funded or requested are focused on benefiting the program by reducing the cost of work necessary to send waste to WIPP and by making more waste available for disposal at WIPP. A significant fraction of the existing TRU waste inventory will eventually be packaged in standard waste boxes (SWB), for which few Non-Destructive Assay (NDA) methods have been developed. The Idaho National Engineering and Environmental Laboratory, under NTP oversight, is currently developing and deploying such an NDA method which will allow any site to use it to characterize and ship waste to WIPP without repackaging into standard drums.

WIPP recently revised the schedule for initiating remote-handled (RH) waste disposal operations in 2002. Because of the accelerated schedule, many of the upcoming TD needs are related to RH

waste handling and characterization methods. NDA and robotic sampling and re-packaging of RH waste are examples that will dominate WIPP's TD efforts in the coming years.

A related paper presented at WM'99 "*Technology Development in Support of WIPP: A TRU Story*" discusses the TRU waste TD being funded in FY99 and the TD needed (and planned) in FY00. (1) It also provides a status report on over $5M of TRU research that is currently being conducted through funding from the Mixed Waste Focus Area (MWFA) and looks at future needs. It answers the following questions:

- What is currently being done?
- How and where will these TD solutions be implemented?
- What are the possible applications of TRU waste TD development to other waste types?

A related activity being conducted by CAO at WIPP is an active "soft" technology transfer program that focuses on making software developed for administrative use on WIPP available to interested parties over the internet. In benchmarking other federal technology transfer programs, CAO noted that most Federal technology transfer programs performed the following:

- Focused exclusively on transferring hard engineering technology to private sector businesses
- Sought to execute CRADAs and licensing agreements involving exclusive rights, and requiring private sector businesses to invest in technology commercialization and/or pay royalty fees
- Used traditional marketing methods, such as manned displays at conferences and trade shows, journal advertisements, and one-on-one meetings with businesses and entrepreneurs
- Concentrated on achieving a few, major transfers
- Spent significant amounts of money
- Provided the federal government with only a minimal return on investment (ROI)

CAO designed and is successfully operating a technology transfer program almost opposite this paradigm. At WIPP, technology transfer

- Focuses on transferring soft technology, such as training systems
- Seeks non-CRADA transfers involving non-exclusive rights and the waiver of fees
- Uses push marketing on the Internet to announce technology transfer opportunities
- Provides the DOE with maximum return on technology transfer investment

By challenging every aspect of a traditional technology transfer program, CAO developed a program that has enjoyed a resounding success. By the end of fiscal year 1998, the WIPP technology transfer program had completed more than 5,000 transfers, created/retained an estimated 750 jobs, and has had an estimated economic impact of $25 million in the private sector.

For a nominal investment, WIPP is:

- Creating new income and jobs in the private sector
- Helping stakeholders receive maximum return on federally-funded R&D efforts
- Helping small businesses expand their services and product lines
- Helping large businesses compete in the global marketplace
- Providing educational institutions with tools necessary to improve learning
- Helping government agencies and not-for-profit organizations improve the quality of their operations
- Demonstrating the quality of its products, people and facility to a diverse national audience
- Pioneering a technology transfer approach that complements rather than competes with CRADAs

PROGRAM DEVELOPMENT INITIATIVES

CAO's program development team actively seeks new program missions built on the management infrastructure and knowledge base established during the development of the WIPP as a deep geologic nuclear waste repository. The program development team facilitates collaboration with domestic and international interests that will enlarge the theoretical and practical knowledge related to nuclear waste disposal. A related goal is to obtain external sponsorship of activities that also further the team's mission. A recent example is a proposal to DOE's Office of Biological and Environmental Research (OBER) and CAO to use underground facilities of the WIPP to conduct experiments in very low background radiation for mammalian cell exposure studies to investigate the linear, no-threshold dose-response hypothesis. Even with ongoing disposal operations, the underground facility represents a unique asset to conduct many types of experiments that require shielding from background radiation.

An important element of CAO's program development is collaboration in domestic and international studies and experiments. These (1) provide increased assurance of WIPP facility safety and reliability, (2) advance scientific expertise and data collection in disciplines important to WIPP, (3) provide cost savings to disposal operations, and (4) expedite the acquisition of research information that furthers WIPP's mission. A recent example was an internationally attended workshop on the use of backfill materials in underground disposal units hosted by CAO in Carlsbad, New Mexico. Building on the WIPP experience, this workshop focused on the use of backfill materials to chemically slow or preclude waste mobilization, as well as to mechanically limit inadvertent disturbance.

In many areas of broad domestic and international interest, the WIPP has developed a leading expertise through its successful construction, permitting, compliance demonstration, and operation as a deep-geologic TRU waste repository. CAO's program development provides convenient access to this information by sponsoring and hosting symposia and workshops on relevant topics and by participating in both domestic and international waste management organizations and topical meetings.

Over the years leading to the successful certification of the WIPP by the EPA, several economically viable and self-sufficient outgrowth organizations have gained their start through the WIPP project. In a relatively remote area of southeastern New Mexico, these start-up organizations have greatly broadened the economic diversity of the area and brought significant external support unrelated to the WIPP to the economic health of the region.

As WIPP begins disposal operations, CAO's program development activities will continue with aggressive plans for:

- Promoting and managing international research efforts (i.e., cooperative research, decision assessment, performance assessment, and risk management with dose calculations)
- Promoting southeast New Mexico economic and program development
- Participating in and promoting a "virtual" consortium of various spin-off services that have grown out of the WIPP program

Some of the success stories of WIPP's program development activities over the past few years include:

- Participation in the DOE National Environmental Research Park program by establishing WIPP as a research park to study the biological effects on the northern Chihuahuan Desert
- Open communication with Russia on radioactive waste management and deep geologic disposal
- Collaboration with U.S. and Mexican industry and environmental protection authorities on improving the deteriorating environmental quality in border communities.
- Helping the Carlsbad Department of Development develop and privately deploy a company dedicated to technical training.

DOE's plans for continuing to assist the communities around the WIPP site in further economic diversification include the completion of a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis of the WIPP and its impact on the City of Carlsbad and Eddy County. The City of Carlsbad and Eddy County have been the primary recipients of both positive and negative impacts from the siting of the WIPP. An analysis and plan to devise a methodology and path forward for economic recovery is critical to community transition and sustainability.

A comprehensive study of the WIPP, its economic development capabilities, and capacities as it relates to the Carlsbad region will be completed by the end of fiscal year 1999. The project scope will include:

- Past, present, and projected demographics of the region quantifying the WIPP employment and procurements in Carlsbad, Eddy County, and Lea County. Projected impacts to regional businesses, local governments, school districts, and public service providers assuming gradual, moderate or rapid job reductions.
- Evaluation of the WIPP infrastructure including human resource, facility and property capabilities and capacities to meet private sector industry needs.

- An opportunity study including an assessment of the area's economic strengths. This will include, but not be limited to evaluation of non-WIPP sectors as well as potential for reuse of WIPP resources including: equipment, buildings, land, commercialization of technology, technology transfer, increased local WIPP procurement, privatization, training, education, tourism, business expansion, and new business spinoffs and recruitment.
- Identify barriers to business development and suggest strategies for their removal.
- Recommended WIPP industrial recruitment and business development targets. Evaluate ability to meet site selection factors typically evaluated by industrial/business location planners.
- Characterize capabilities to industry/business cluster markets. Develop industry and business cluster recommendations.
- Review DOE, contractor and community economic development capabilities. Evaluate and review role assignments.
- Identify barriers to WIPP/community development and suggest strategies to remove.
- Develop a community strategy that ensures a "seamless" delivery system.
- Detailed surveys of businesses, community leaders, organizations, etc.

The SWOT analysis will give DOE and the region a path forward to sound economic diversity and reduce the dependence on government funding for economic growth.

CONCLUSION

Following the EPA's certification of the WIPP, and the demonstration that the repository met the EPA's criteria based on the data and models included in the CCA, DOE recognized the need to evaluate the role of further scientific investigations. Realizing that the models and data used in the CCA calculations were quite conservative (and in many cases were over-conservative to the point of being unrealistic), the ongoing role of the scientific investigations at WIPP can be defined as being one of performing those activities which will increase the realism of the models, where this increased realism may be expected to

- significantly reduce the estimated releases
- reduce uncertainties in the computed releases
- increase the public confidence in the calculations

Note that in reference to public confidence, any new models must be subjected to peer review prior to re-certification.

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REFERENCES

1. Neilson, Sandra S., M. R. Brown, J. A. Mewhinney, and S. Jennings, "*Technology Development in Support of WIPP: A TRU Story*", in Proceedings of Waste Management '99, Tucson, AZ, March 1, 1999.