Presentation Outline

• **Introduction**
  – Roadmaps & Research Mapping
  – Tools & Process

• **Examples**
  – Environmental Remediation
  – Waste Treatment

• **Value Proposition**
Definitions / Context

- **Roadmaps**
  - Graphical, long-range strategic plans that identify activities and schedules necessary to achieve stated goals and objectives

![Roadmap Image]

Source: Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO’s Fukushima-Daiichi Nuclear Power Station, June 12, 2015, Inter-Ministerial Council for Contaminated Water and Decommissioning Issues

---

Definitions / Context

- **Research Map**
  - A type of Science & Technology Roadmap, focused on linking underlying scientific knowledge and technological advancements for desired improvements to existing (baseline) operations

![Research Map Image]

Adapted from Irene J. Petrick, PSU, EP
Definitions / Context

- **Mapping (Process)**
  - The flexible process by which a roadmap / map is created, implemented, monitored and updated.
    - **Structured framework**
    - **Various approaches / techniques / outputs**

Technology Readiness

- **Technology Readiness Assessments**
  - An assessment of technologies and their readiness for insertion into the project design and execution schedule

- **Technology Readiness Levels (TRL)**
  - An indication of the maturity of a given technology
In Situ Groundwater Treatment System – Savannah River Site

Subsurface Contaminant Geochemistry

Study of inter-related topics: sorption-adsorption, contaminant interactions, potential treatment amendments, and long term stability of in-situ stabilized phases.

Problem: Groundwater Contamination from Seepage Basins

40 years of seepage basin operation resulted in low pH groundwater plume containing radionuclides and metals. 10 years of pump and treat had limited impact on the plume and cost over $12 million per year to operate.

Refined geological conceptual model and identified target areas of opportunity for in situ treatment deployment.

Active work with stakeholders and regulators to facilitate transition from baseline pump & treat system to innovative in situ treatment.

Development of innovative treatment reagents.

In Situ Treatment using Wall and Gate for Combined Hydrologic and Geochemical Control

Installed barriers ("walls") to block plume and force water through treatment zones ("gates"). Alkaline treatment solution periodically injected into the gate area to create permeable reactive treatment zone to immobilize contaminants.

Basic Geochemistry

Applied Lab and Field Studies

System Design and Optimization

Deployment

Savings: $300M

Solvents for Cesium Removal – Savannah River Site

Molecular Modeling

Solvent Performance Applied Studies

Performance Optimization

Deployment

First Generation Solvent

Next Generation Solvent

ARP MCU – Pilot Scale Operating Facility

Savings: $600M to $1.8B

Savannah River National Laboratory

We put science to work.
Main Processes for the Decommissioning of Fukushima Daiichi NPS

<table>
<thead>
<tr>
<th>Area</th>
<th>Main tasks conducted</th>
<th>Future tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contaminated water management</td>
<td>Purification of contaminated water using multi-vortex purification equipment, etc.</td>
<td>Completion of Phase 2 (December 2021), Present FY 2016, FY 2017, FY 2018, FY 2019, FY 2020</td>
</tr>
<tr>
<td>Isolating</td>
<td>Installation of additional equipment, etc.</td>
<td>Present FY 2016, FY 2017, FY 2018, FY 2019, FY 2020</td>
</tr>
<tr>
<td>Preventing leakage</td>
<td>Installation of additional equipment, etc.</td>
<td>Present FY 2016, FY 2017, FY 2018, FY 2019, FY 2020</td>
</tr>
<tr>
<td>Unit 1</td>
<td>Building cover decommissioning, etc.</td>
<td>Present FY 2016, FY 2017, FY 2018, FY 2019, FY 2020</td>
</tr>
<tr>
<td>Unit 2</td>
<td>Preparation of decommissioning, etc.</td>
<td>Present FY 2016, FY 2017, FY 2018, FY 2019, FY 2020</td>
</tr>
<tr>
<td>Unit 3</td>
<td>Demolition of existing building, etc.</td>
<td>Present FY 2016, FY 2017, FY 2018, FY 2019, FY 2020</td>
</tr>
<tr>
<td>Storage</td>
<td>Implementation of storage according to storage plans, etc.</td>
<td>Present FY 2016, FY 2017, FY 2018, FY 2019, FY 2020</td>
</tr>
<tr>
<td>Processing and disposal</td>
<td>Implementation of storage according to storage plans, etc.</td>
<td>Present FY 2016, FY 2017, FY 2018, FY 2019, FY 2020</td>
</tr>
</tbody>
</table>

Source: Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO’s Fukushima Daiichi Nuclear Power Station, June 12, 2015, Inter-Ministerial Council for Contaminated Water and Decommissioning Issues

Integrated Management from Fundamental/Basic Science to Practical Use

Team head: Minister of Economy, Trade and Industry
Secretary General: State Minister of Economy, Trade and Industry

Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF)

Committee for Cooperation in R&D of Decommissioning

- Two or three meetings per year
- Information sharing about R&D needs among organizations
- Information sharing about promising R&D seeds
- Coordination of R&D based on needs for decommissioning work
- Promotion of R&D cooperation among organizations
- Promotion of cooperation in human resources development among organizations

Integrated management from basics to practical use

Fundamental research - Basic research - Development for application - Practical use

Universities and research institutions
Japan Atomic Energy Agency (JAEA) - International Research Institute for Nuclear Decommissioning (IRID), etc.

Source: Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO’s Fukushima Daiichi Nuclear Power Station, June 12, 2015, Inter-Ministerial Council for Contaminated Water and Decommissioning Issues
Research Mapping Value Proposition

- Solution-oriented method for aligning R&D with operational needs
- Illustrates the integration of Science, Technology and Practical Application
- Defensible basis for an R&D investment strategy
- Flexible to support decision-makers, scientists, general public
- Opportunity for broad, transparent stakeholder consensus building
- Applicable to long-term timelines
Thank You

Questions?

SRNL: We Put Science to Work
— Begin with the outcome in mind and match the solution to the problem
Introduction

The United States Department of Energy – Office of Environmental Management (USDOE-EM) is responsible for the largest cleanup program in the world

- Large quantities of waste containing radionuclides and non-radiological hazards are being managed
- Robust multi-criteria decision-making process involving external regulation and input from stakeholders
Waste Management Strategic Considerations

Waste Hierarchy
- Prevent → Reduce → Reuse → Recycle → Dispose

Interdependence (Integrated Technical and Regulatory strategy)
- Costs, disposal needs, regulatory policies, etc. are factors for D&D, characterization, segregation, and treatment options
  - Treatment can increase volume & decrease concentration or vice versa, Potential for improper characterization?
- Waste Acceptance Criteria (store, transport, treat, dispose)?
- Volume of different categories of waste?
- Packaging and Transportation requirements?
- Plans for reactor vessels and reactor components
  - Potential Intermediate-level waste/Greater than Class C in USA? Disposal and/or storage needed?

Photos Courtesy USDOE
Disposal Options for Remediation and Decommissioning Wastes

- USDOE-EM has the option of developing on-site disposal cells, disposal at the Nevada National Security Site (NNSS) or using commercial disposal facilities
- On-site disposal has been selected as the preferred alternative for large amounts of the waste (can be combined with off-site disposal of some waste)
- Transuranic (Intermediate-level) waste is disposed at the Waste Isolation Pilot Plant
- Spent-Fuel and High-Level Waste currently being stored
Examples of On-Site Disposal of Cleanup Waste (USDOE)

Hanford Site

Fernald Site (Closed)

Idaho Site

Nevada Site (accepts off-site waste)

Oak Ridge Site

Photos Courtesy USDOE

Regulatory Context - Decision-Making Framework

- Most cleanup decisions are being developed under a US Environmental Protection Agency (USEPA) Regulatory Process
- Decision-making through formal process with continuous involvement of USDOE, USEPA, and State regulators and the public

Remedial Investigation (RI)
- Project Scoping
- Site Characterization
- Risk Assessment
- Treatability Studies

Feasibility Study (FS)
- Screening Alternatives
- Analysis of Alternatives

Selection of Remedy
- Proposed Plan (PP)
- Record of Decision (ROD)

Continuous Public Participation

Continuous Regulatory Oversight
Key Elements of USEPA Process Applied to Remediation Waste

- Risk goals rather than constraints
- Design standards for disposal facilities and treatment standards for hazardous waste forms (industrial waste) - “Prescriptive” regulation
- Modeling and characterization efforts to support decision-making
- Must meet USEPA requirements and USDOE requirements (USDOE and external regulator review processes are often conducted independently)
- Considers cleanup alternatives
- Nine criteria - Quantitative and qualitative assessment of potential impacts of different alternatives
- Following action, routine reviews (~5 year) are conducted to assess effectiveness of solution

Prescriptive Regulation – Advantages and Disadvantages

- Disposal facilities for cleanup waste are often designed to meet USEPA standards for hazardous waste disposal to address the non-radioactive hazards (“Prescriptive design-based standard”)
- Use of standardized and accepted design helps to build public confidence, but introduces challenges if it is necessary to conduct long-term safety assessment
- USEPA prescribes specific treatment approaches for hazardous wastes
- Standard approaches are not always the best option for special cases, need flexibility to consider optimal solution (e.g., grouting of ion exchange resins)
Solid Secondary Waste - Background

- Examples of solid secondary wastes and contaminants
  - HEPA Filters (e.g., Tc-99, Cr, I-129)
  - Ion Exchange Resins (e.g., Cs-137, I-129, Tc-99, Cr)
  - Activated Carbon Beds (e.g., I-129, Hg)
  - Silver Mordenite (e.g., I-129, Silver)
  - Miscellaneous Debris

- Prescriptive treatment and disposal approaches in regulations for hazardous waste (“debris” and “non-debris”) – e.g., encapsulation and solidification/stabilization using cementitious materials

- Safety assessment models for radioactive waste require numerous inputs (e.g., hydraulic conductivity, moisture characteristics, diffusion coefficients), but limited data are available

- Important to understand significance of uncertainties (inventory and properties) to help guide research priorities

Directly Link Research to Needs of the Safety Assessment (SA)

“Model Support” is a term used to describe research and other supporting activities for the SA.
### Linking initial SA results with prioritization of data collection

<table>
<thead>
<tr>
<th>Waste Form</th>
<th>Assumptions</th>
<th>Potential Data Needs</th>
<th>Vulnerabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEPA Filter</td>
<td>• Minimal credit for $K_d$ and diffusion in HEPA filter</td>
<td>• Properties of clean encapsulation material, including redox</td>
<td>• Properties based on literature</td>
</tr>
<tr>
<td></td>
<td>• Encapsulated in oxidized material with paste properties</td>
<td>• Diffusion coefficients and $K_d$ (iodine, Tc) for encapsulation</td>
<td>• Oxidizing conditions increase $K_d$ for I-129</td>
</tr>
<tr>
<td>Organic Ion</td>
<td>• Oxidized resin with no retention of contaminants</td>
<td>• Confirm material properties of final waste form</td>
<td>• Properties based on literature (mortar)</td>
</tr>
<tr>
<td>Exchange Resin</td>
<td>• Stabilized, waste form has properties of oxidized mortar</td>
<td>• Redox of final waste form</td>
<td>• Hydraulic properties</td>
</tr>
<tr>
<td></td>
<td>• $K_d$ of waste form based on weighted average of $K_d$ in waste and grout</td>
<td>• $K_d$ of resin and diffusion coefficients in waste form</td>
<td>• Oxidizing conditions increase $K_d$ for I-129</td>
</tr>
<tr>
<td>Activated carbon</td>
<td>• Stabilized waste form has properties of oxidized mortar</td>
<td>• Confirm material properties of final waste form</td>
<td>• Defensibility of $K_d$ and durability</td>
</tr>
<tr>
<td></td>
<td>• $K_d$ of waste form based on weighted average of $K_d$ in waste and grout</td>
<td>• Redox of final waste form</td>
<td></td>
</tr>
</tbody>
</table>

Diffusion coefficients can be misunderstood

---

### Organic Ion Exchange Resins – Considerations and Options

- Prescriptive treatment standard for “hazardous” resins (solidification/stabilization in cementitious materials)
- Resins dewatered and sent for treatment in hydrogen form – oxidizing conditions (favorable for I-129, not favorable for Tc-99)
- Organic resins expand posing challenge for cementitious materials (hydraulic properties of solidified matrix may not be maintained)
- Grout formulation/waste form pretreatment needs to address potential expansion and provide sufficient long-term performance (Key question: Safety assessment can help determine what is sufficient? )
- Example Options (Blending, Place in container – no pretreatment, Pretreatment to swell resin (Na or Ca form) and solidify, etc.)
Strategic Considerations Tied to Road Map for Cleanup

- How well are the wastes characterized (what is the range of uncertainty)? How could uncertainty impact transportation, treatment, storage, disposal options?

- Is treatment increasing or decreasing concentration and volume of contaminants? Will there be limitations of effluents from treatment facility?
  - Disposal facility capacity and WAC considerations (will a more robust facility be needed for smaller volume of waste or is it more effective to dispose of larger volumes?), Will it be more difficult to store and transport a higher concentration waste?

- Would prescriptive regulations be helpful or limit availability of good options? Could solidification of the waste reduce performance (e.g., activated carbon or resin stabilization in cementitious material)?

- If Tc-99 and I-129 are both present, would oxidizing or reducing conditions be more favorable? Need input from safety assessment.

- How to address “evolution” of a waste form over time (improve or degradation of properties) in safety assessment? (e.g., fracture behavior in unsaturated conditions)

Conclusions

- Variety of different approaches for D&D and remediation waste management in the USDOE-EM Complex

- Decision-making is based on multi-criteria approach with engagement of external regulators and public involvement

- Prescriptive regulations can be helpful (public perception, consistency), but can also limit optimization for special cases

- Safety Assessment helps to identify priority areas for research activities (process helps to provide sound basis for need for research)

- Many competing factors when identifying optimal waste management strategy, research inputs can help to identify and assess critical assumptions that could result in changes in the strategy
For further information, please contact:
Roger Seitz
Savannah River National Laboratory
Roger.Seitz@srnl.doe.gov

Backup Slides
**Background - Terminology**

**International Atomic Energy Agency Options for Reactor Decommissioning**

- **Immediate Dismantling (DECON)**
  - Equipment, structures, and parts of facility containing radioactive contaminants are removed or decontaminated to a level that permits facility to be released for unrestricted use or with restrictions imposed by the regulatory body.

- **Deferred Dismantling (SAFSTOR)**
  - Parts of a facility containing radioactive contaminants are either processed or placed in such a condition that they can be safely stored and maintained until they can subsequently be decontaminated and/or dismantled to levels that permit facility to be released for unrestricted use or with restrictions imposed by the regulatory body.

- **Entombment**
  - Radioactive contaminants are encased in a structurally long lived material until radioactivity decays to a level permitting unrestricted release of a facility, or release with restrictions imposed by regulatory body
  - Position paper specific to entombment being prepared
Decommissioning Considerations

Institutional
- Roles and responsibilities (government, regulator, licensee, interested parties)
- Policy, laws and regulations (health and environmental standards, worker protection, end states, risk assessment, clearance process for radioactive waste)
- Availability of
  - Funding/cost estimates
  - Experienced staff (challenge for deferred actions)
  - Waste management system (processing, storage, disposal)

Facility State
- Future use of facility or site, co-located facilities with shared infrastructure
- Type of facility and physical status
- Residual activity in facility, characterization information
- Soil and groundwater contamination outside of the buildings/structures
- Transportation of waste - proximity to disposal/storage site(s)

Example Lessons Learned
- Accurate surveys at beginning of process (well informed plans, waste planning)
- Availability of disposal options (commitment to accept waste)
- Setting expectations for final surveys and monitoring (ranges of values)
- Cost estimation reassessed as site conditions evolve
- Efficient characterization
- Effective clearance process and waste segregation (soil and potential groundwater contamination)
- Quality assurance, independent samples
- Areas where deeper contamination can occur (e.g., joints)
- Removal of surface contamination on concrete structures resulting in non-radioactive debris
- Fukushima – transparency, land use, public engagement
Building Stakeholder Confidence

- Physical models
- Graphical visualization of the subsurface
- External reviews
- Meeting requirements of DOE regulations and external regulators
- Routine public briefings (e.g., Citizens Advisory Board)
- Clear waste acceptance criteria
- Formal process to address unexpected conditions (e.g., new waste forms, monitoring results, data)