NUCLEAR ENERGY AGENCY INNOVATION WORKSHOP—KEY RESULTS AND FINDINGS:

Workshop on Innovative Techniques and Technologies for Characterization and Decommissioning of Complex and Legacy Sites

C.BARR
NRC
Washington DC, US
Email: Cynthia.Barr@nrc.gov

M.BRANDAUER
EPRI
Paris, FRANCE
Email: MBrandauer@epri.com

Z.LI
OECD NEA
Paris, FRANCE
Email: Zhuoran.Li@oecd-nea.org

Abstract

The Nuclear Energy Agency (NEA) Working Party on Technical, Environmental and Safety Aspects of Decommissioning and Legacy Management (WPTES) organized an international workshop on Innovative Techniques and Technologies to Support Characterization and Decommissioning of Complex and Legacy Sites, from 29 November to 1 December 2022. This abstract provides a comprehensive overview of the workshop – including the objectives, key findings, and outlook.

1. BACKGROUND

The Nuclear Energy Agency (NEA) Working Party on Technical, Environmental and Safety Aspects of Decommissioning and Legacy Management (WPTES) organised an international workshop on Innovative Techniques and Technologies to Support Characterisation and Decommissioning of Complex and Legacy Sites, from 29 November to 1 December 2022. [1][2] Topics included innovative site and radiological characterisation, as well as decommissioning techniques and technologies. The workshop also provided information on application of existing technologies to new problems including lessons learnt, best practices and overcoming challenges associated with use of existing technologies.

Over 140 participants from various fields of expertise involved in decommissioning of complex and legacy sites, including implementers, government/regulatory agencies, academia, and researchers, participated in the workshop.[3] The workshop contributions and main discussion topics will be summarised in workshop proceedings which will ultimately provide input to a WPTES technical report to better understand (i) the state of the art in technologies and techniques related to characterisation, and decommissioning of complex and legacy nuclear sites and installations, (ii) key issues and challenges associated with implementation of technologies and techniques, and (iii) good practices and methods for implementation of techniques and technologies considering risk to workers and members of the public, and waste generation.
2. WPTES OVERVIEW

The Nuclear Energy Agency (NEA) Working Party on Technical, Environmental and Safety Aspects of Decommissioning and Legacy Management (WPTES) is the second level body under the Committee on Decommissioning of Nuclear Installations and Legacy Management (CDLM).

The WPTES focuses four areas of (i) risk management in support of decision-making, (ii) sampling, characterisation and data evaluation, (iii) innovative decontamination and decommissioning technologies, and (iv) materials management.

WPTES has been functioning actively, to fulfil its targets:
— foster exchange of information and experience between its members on issues concerned with technical, environmental and safety aspects with a view to promoting collective learning and to enhance the credibility, reliability, and auditability of both decommissioning and legacy management and thus to enhance stakeholder confidence in the process involved;
— describe good practices in the field of technical, environmental and safety aspects for decommissioning and legacy management projects, including understanding and communication of associated risks; and planning for uncertainties, with an overall aim to assist member organisations to develop robust and efficient project management processes, and examine the scope for achieving consensus on overall objectives and for developing common approaches;
— advise the CDLM on major and emerging issues in the areas of technical, environmental and safety aspects for decommissioning and legacy management, and provide appraisals of the state-of-the-art with a view to consolidating knowledge and making it transferable to a variety of different audiences.

3. WORKSHOP OBJECTIVES

The workshop objectives were:
— To better understand current state of art of technologies and techniques used in characterisation and decommissioning of complex and legacy sites (e.g., radiological and site characterisation, decontamination, dismantling, demolition, material/waste management, and risk assessment).
— To better understand challenges to successful implementation of innovative techniques and technologies including additional research, regulatory acceptance, and availability of guidance.
— To better understand how risk assessment influences decommissioning activities including characterisation, decontamination, remedial and final status survey decision-making.
— To better understand good practices and methods for implementation of techniques and technologies.
— To provide recommendations for future work of the WPTES task groups and WPTES Expert Group.
4. WORKSHOP PROGRAMME

The workshop consisted of 7 sessions under two tracks: Innovative Techniques and Technologies related to (i) characterization and (ii) decontamination and decommissioning.

The characterization track included five sessions related to characterization of (i) land, (ii) buildings, (iii) subsurface, as well as sessions on (iv) general characterization, and (v) modeling and tools. The general characterization session included presentations on the state of the art in radiation detection instruments and challenges associated with characterization of legacy and accident sites, while the modeling and tools session focused on machine learning, geostatistics, and geographic information systems combined with building information models in a common data environment to facilitate decommissioning planning and implementation.

FIG. 2. Innovative Technologies for Characterization (Vienna Environmental Research Accelerator (VERA)—left; Building Information Model showing Underground Piping and Radiological Survey Locations—right)[4][5]

The second track included two sessions on innovative decontamination and decommissioning technologies including presentations on general considerations and challenges to successful implementation of technologies, and presentations on specific application of innovative technologies such as decontamination of building surfaces, and dismantling of buildings aided by robotics, as well as presentations on remediation of soils among other topics. In total, twenty-eight technical presentations were included in the seven sessions.

FIG. 3. Innovative Technologies for Decontamination and Decommissioning (LD Safe Laser Cutting—left; Secondary Shroud with Nitrocision Technology for Wall Decontamination—right) [6][7]

Attendees also participated in break-out sessions to explore questions related to technology sharing, lessons learned and challenges and gaps in characterisation and D&D.
5. **KEY FINDINGS FROM THE WORKSHOP**

Several key takeaways resulted from the workshop. Participants discussed the need for a repository of information on innovative technologies to facilitate sharing of information and collaboration across nations and projects, which are seen as being key factors for driving innovation and sharing lessons learned on implementation of technologies. Another key finding is the importance of innovative approaches and methodologies using existing technologies, which can lead to significant benefits and significantly lower costs. Additionally, the importance of early interactions with regulators and communication of uncertainty with stakeholders was discussed. Other key findings from the workshop include the following:

---

- Several innovative technologies and techniques to aid sample collection, measurement, presentation and analysis of data were noted.
  - Gamma detection and imaging systems to support nuclear facility operation and decommissioning including support for decommissioning planning and radiation protection while reducing the number of and time of measurements (ANSTO CORIS360 and HIFAR).
  - Accelerator Mass Spectrometry (AMS) used in other applications has been applied to the nuclear industry to characterize difficult to measure (DTM) radionuclides such as Ca-41, Cl-36, H-3, C-14, and Sr-90 in different matrices (e.g., Ca-41 in bio-shield concrete). AMS has certain advantages over more traditional methods (faster measurements time) particularly if aided further by Ion Laser Interaction Mass Spectrometry (ILIAMS) to remove interfering isobars, while eliminating the need for resource intensive chemical separation.
  - Various unmanned aerial vehicle (UAV) example applications including survey of accident and uranium mining and processing sites using drones, as well as manned helicopter flights with ground truthing (DUB-GEM, IAEA/Fukushima drone project, SCK CEN/various NORM waste sites in Belgium).
  - Aerial measurements (helicopters) using gamma spectroscopy (NaI(Tl) collimated detectors) to perform radiation mapping following nuclear accidents (Chernobyl and Belgium sites).
  - Robotic equipment to facilitate video and radiation surveillance, air sampling, concrete and fuel containing material (FCM) sampling, and collection and containerization of radioactive materials under accident conditions (Chernobyl).
  - Robotic equipment (rovers, wall crawlers, pipe crawlers, samplers) to facilitate video surveillance, ultrasound, thermal, LiDAR, gamma imaging, pipework inspection, and concrete wall repair. Robotics were cold tested to overcome challenges with traversing weld seams, corroded surfaces, chemical residues, and elevated temperatures (Florida International University work at Hanford, Savannah River Site, Waste Isolation Pilot Plant [WIPP]).
  - Data management (databases), analysis methods (statistical analysis/ Bayesian methods/ geospatial analysis/ artificial intelligence/deep learning), and visualization to aid in communicating with stakeholders (Fukushima Daiichi Radwaste Analytical Data Library; remediation of Chernobyl Exclusion Zone).
  - Digital twins combined with geospatial models in a common data environment leverages data from diverse external data sets (computer aided design drawings, building information models, geographic information system data) to improve synergy between hydrogeologic and operating facility design data to facilitate decommissioning. Example applications include buried piping characterization, D&D, survey; hydrogeological investigations; subsurface characterizations; robotic inspections and survey planning; large reactor component removal; demolition takeoffs, waste estimation; and end-state modeling.
Geostatistical and other geospatial techniques are useful for conceptual site model development; survey design optimization; remediation planning and decision-making; and demonstration of compliance with clearance or release criteria. Multivariate statistics allows leveraging of data from disparate sources (e.g., geophysical and radiological survey data from field or laboratory). Uncertainty quantification is useful to inform decision-making. Several case studies were provided including Fukushima, uranium enrichment facility in Cadarache, filter room in Marcoule, and Fontenay-Aux-Roses sites.

Several innovative technologies and techniques to aid with decontamination, remediation and decommissioning were noted:
- Dismantling of reactor vessel and internals under water or in air (laser cutting aided by robotics).
- Technologies to aid with decontamination of building surfaces (Nitrocision).
- Soil characterization, treatment and management systems (Solveris, Demeterres, and FREMES).

Innovative technologies and techniques have proven to be useful:
- For decommissioning project planning (gamma imaging).
- Ensuring safety of workers (gamma imaging).
- Supporting short- and long-term assessment of risk.
- Reducing and mitigating project risks.
- In challenging locations and terrains (UAV).
- For waste characterization to support clearance or radioactive waste storage and disposal.
- With respect to remedial planning and decision-making.
- For better understanding contaminant flow and transport processes to inform conceptual site model development; locating leaks, estimating water flux, and evaluating remedial performance; and monitoring groundwater/surface water exchange over large areas with relatively small cost (geophysical data).
- In accomplishing characterization objectives compared to traditional methods.
- In characterizing sites following nuclear accidents wherein extreme radiological conditions, confined spaces, unique waste streams, and other challenging aspects are present.
- With fusion of sensors and mobile platforms, coupled with digital twins to facilitate automated change detection and provide for immersive inspection.
- For reducing the number of measurements / characterization times (gamma imaging systems using rotating masks and compressed imaging).
- For faster measurement of DTM radionuclides at lower detection limits (AMS/ILIAMS).
- With respect to supporting clearance or release of land, buildings, and materials.
- To ensure waste acceptance criteria are met.

Challenges to use of innovative technologies and techniques include:
- Sharing of information and knowledge transfer.
- Difficulty in standardizing and scaling up technologies to quality control and training requirements.
- Vertical market segmentation and end-of-life technology strategies that can lead to siloing (bottom-up approaches across multiple nations and users can lead to gains in efficiency).
- Logistical, instrumentation, deployment, and site-specific factors (terrain, biotic activity, weather) for UAV applications; lessons learned are discussed in various presentations (DUB-GEM project).
- Early communication and acceptance of stakeholders.
- Development of a regulatory framework to allow use of innovative technologies.

Observations related to innovative technologies and techniques include:
- Simple innovations, using established technologies and techniques, can lead to successful outcomes in shorter timeframes and at reduced cost.
- Innovative characterization techniques and technologies can be useful in overcoming challenges associated with hostile environments, limited access, complex facilities, and limited historical knowledge.
• In some cases, use of simpler, less precise, or less accurate technologies can lead to more efficient characterization and play an important role in furthering overall decommissioning objectives (e.g., bulk monitoring).
• Cold testing of remote and robotic equipment is important and should be performed in collaboration with the end user to improve development and deployment.
• In-situ measurements are an essential component of nuclear facility decommissioning; methods are constantly improving to address unique uses and constraints.
• It is important to recognize that there is unlikely to be one universal solution to characterization; use of multiple methods can help build confidence and lead to better decision-making.
• Simple sensors with long battery life can be deployed to 1000s of containers, for example providing large volumes of data and re-assurance in areas where person-access would be required.
• New technology deployment programs have slowed down compared to the past; industry needs to re-energize new technology development.
• National legislation and programs are needed to drive innovation.
• Demonstrations, field testing, and documentation of results are important to identifying promising technologies, building defensible project baselines, and promoting cost effective solutions.
• Policy and regulatory changes are needed to make more optimal decisions and promote sustainable waste management decisions.

6. OUTLOOK

The workshop proceedings are planned to be published later in 2023. Links to the twenty-eight presentations will be available on the workshop website: https://www.oecd-nea.org/jcms/pl_71664/innovative-techniques-and-technologies-to-support-characterisation-and-decommissioning-of-complex-and-legacy-sites. This is an important step in ensuring that the information shared during the workshop can be disseminated to a wider audience. By making the proceedings available, individuals who were not able to attend the workshop will still be able to benefit from the insights and ideas presented.

WPTES is currently accepting new members who are passionate about driving forward progress and promoting innovation in the field of decommissioning. Participation in the WPTES provides members an opportunity to come together and work collaboratively towards a common goal providing a forum for member countries to share ideas, technical insights, and best practices to further development of innovative techniques and technologies to facilitate decommissioning planning and implementation while advancing overall risk reduction.
REFERENCES


