Developing Capacity for Nuclear Decommissioning: The Nigeria Experience

J. Simon
Department of Physics, Ahmadu Bello University,
Zaria, Nigeria
Email: *sjkahugu@yahoo.com*

Y.V. Ibrahim
Centre for Energy Research and Training, Ahmadu Bello University
Zaria, Nigeria

S.A. Jonah
Centre for Energy Research and Training, Ahmadu Bello University
Zaria, Nigeria

A. Asuku
Centre for Energy Research and Training, Ahmadu Bello University
Zaria, Nigeria

H. A. Adamu
Centre for Energy Research and Training, Ahmadu Bello University
Zaria, Nigeria

Abstract

Considering the growing number of nuclear facilities entering permanent shutdown, it is crucial to review lessons learned and adopt best practices to ensure effective decommissioning, dismantling, and remediation. The key to successful decommissioning lies in having competent personnel involved in the process. Therefore, organizations responsible for future decommissioning projects must prioritize the development and implementation of robust human resource management practices, policies, and training programs for all stakeholders involved. The Nigeria Research Reactor-1 (NIRR-1) is a low-power reactor located at the Centre for Energy Research and Training (CERT) in Ahmadu Bello University, Zaria. After operating for 12 years with Highly Enriched Uranium (HEU) fuel, it underwent partial decommissioning to mitigate proliferation risks by converting the fuel to Low Enriched Uranium (LEU). The decommissioning process was preceded by rigorous trainings and drills facilitated by the International Atomic Energy Agency (IAEA) and the US Department of Energy (DoE). The decommissioning preparation began with training personnel on spent fuel characterization and transport cask design and thereafter, operators were trained to be proficient in core removal and package loading operations, while the radiation protection team received comprehensive training on emergency preparedness and response. Security measures were strengthened by assembling a team comprising university guards from CERT and personnel from Nigeria's armed forces, including the police, customs, and immigration. Thanks to the extensive training and drills conducted on and off-site, the decommissioning process was executed efficiently despite Nigeria's security challenges. However, valuable lessons were learned during the preparatory phase as internal personnel transfers within the university affected trained administrative staff and security guards, leading to duplicated efforts, increased costs, and delays in implementation. Furthermore, the sustainability aspect was overlooked during the personnel training as none of the trained personnel were on internship or fellowship, which implies that none would be available to bring their experience to bear on the next decommissioning project. This will necessitate significant investment to train a new workforce. Overall, the Nigerian experience emphasizes the importance of capacity building for nuclear decommissioning and highlights the need for comprehensive training programs, considering personnel sustainability, and effective coordination among stakeholders.

1. INTRODUCTION

Effective and responsible management of ongoing and upcoming decommissioning projects, as well as the remediation of decommissioned sites, repurposing, and recycling of materials, are crucial for the sustainability and future deployment of nuclear technology [1]. The success of decommissioning, remediation, and repurposing primarily hinges on the involvement of skilled personnel. As organizations prepare for future decommissioning initiatives, they must prioritize the development and implementation of robust human resource management practices, policies, and training programs for all stakeholders. A similar scenario was encountered at the Centre for Energy Research and Training (CERT) at Ahmadu Bello University (ABU) Zaria during the conversion project of the Nigeria Research Reactor-1 (NIRR-1) from Highly Enriched Uranium Fuel (HEU) to Low Enriched Uranium Fuel (LEU). The achievement of the conversion project in 2018 was significantly influenced by the establishment of indigenous capabilities in nuclear science and technology through technical collaboration with entities such as the International Atomic Energy Agency (IAEA) and the United States Department of Energy (US DoE) [2]. This project can be considered a partial decommissioning process, entailing the replacement of the sealed HEU core with the LEU core in the reactor assembly.

NIRR-1 belongs to the category of Miniature Neutron Source Reactors (MNSRs), which are low-power research reactors designed and produced by the China Institute of Atomic Energy (CIAE) in Beijing. Originally, these reactors used HEU in the sealed core to ensure ample neutron flux for neutron activation analysis, training, and nuclear instrumentation tests [3]. However, due to concerns about proliferation and nuclear terrorism, a shift from this design became imperative [4]. The Reactor Conversion Program, formerly known as the Reduced Enrichment for Research and Test Reactors (RERTR) Program, was introduced by the US in 1978 and was managed by the Material Management and Minimization (M3) Conversion Program of the National Nuclear Security Administration (NNSA) under the US DoE. The International Atomic Energy Agency (IAEA) initiated a Coordinated Research Project (CRP) in 2006 to support states operating MNSRs in their transition to running on LEU [2]. The MNSR conversion process commenced with the quest for feasible fuel designs that could facilitate the transition from HEU to LEU without compromising overall reactor performance. Thanks to the IAEA's CRP working group, a suitable design was identified, and this design was successfully applied in converting prototype MNSRs in China, Ghana and NIRR-1in November 2018 [5].

In contrast to the bilateral management of conversion projects under the US RERTR program, the IAEA-coordinated MNSR conversion projects in China, Ghana, and Nigeria stood out for their inclusion of diverse local and international stakeholders. Effective communication among stakeholders, clear development stage clarifications, and a thorough analysis facilitated the progress of these conversions within three years. Notably, multilateral collaboration was centered around the feasibility study, analysis, and early establishment of regulatory and bureaucratic procedures [2]. Drawing lessons from the US RERTR program's conversion projects, training of key stakeholders played a central role in this effort.

2. CAPACITY DEVELOPMENT FOR FEASIBILITY STUDY

Upon the conclusion of the CRP on MNSR conversion project in 2010, a working group was established, comprising MNSR operators, the designer, and regulators. This group's mandate was to continue coordinating activities related to MNSR conversion to LEU and the repatriation of HEU to China [6]. The process of converting MNSRs involved a feasibility study to determine an appropriate fuel design for conversion. Representatives from participating countries, along with DoE and US national laboratory representatives, engaged in this study. Training encompassed the use of various codes for neutronics, thermal hydraulics, and related fields to identify qualified fuels for MNSR conversion with minimal modifications to the HEU core structure [2].

To this end, research scientists from CERT and the Nigerian Nuclear Regulatory Authority (NNRA) were trained in reactor design and safety codes, including the Monte Carlo N-Particle transport code (MCNP), REBUS, WIMSD4, PARET, PLTEMP, and RELAP. This training cascade led to the transfer of computational skills at CERT, as trained researchers shared their expertise with colleagues and students at ABU, bolstering the university's potential in manpower development for Nigeria’s nuclear power program. Nigerian scientists played a pivotal role in developing the MCNP model for NIRR-1's HEU core, which was employed for neutronics analysis and the subsequent search for

LEU fuels suitable for conversion. Collaborative publications involving Nigerian, Chinese and US counterparts underscored the advantages of human capacity building in decommissioning projects [7], [8], [9].

3. CAPACITY DEVELOPMENT FOR SPENT FUEL REMOVAL

The removal of NIRR-1's spent fuel involved a multinational team comprising entities such as the Idaho National Laboratory (INL), UJV from the Czech Republic, SOSNY from the Russian Federation, the Nigerian Armed Forces (under the Office of the National Security Adviser), and the NNRA [10]. CERT staff underwent training to become proficient in core removal, package loading operations, and licensing procedures for handling nuclear materials from the MNSR, including the irradiated HEU core and fresh HEU fuel pins. Support from the IAEA, CIAE, and the US DoE was instrumental in these efforts. Figure 1 showcases the active role of indigenous personnel during the removal of NIRR-1's HEU spent fuel and the installation of the LEU fresh core.

For the technicians and engineers from various MNSR facilities to effectively engage in core removal activities, the International MNSR Training Centre (IMTC) was established at the Ghana Atomic Energy Commission (GAEC) in Accra, Ghana. A MNSR mock-up facility was designed and set up to enable technicians and engineers to gain hands-on experience in removal activities without extensive supervision [2].

Fig. 1. CERT Engineers and Technicians Lifting an Interim Transfer Cask with HEU Spent Fuel [2]

Seizing this opportunity, a team of CERT personnel received comprehensive training sessions at the IMTC in Accra. This equipping ensured the seamless execution of core removal and package loading operations during the NIRR-1 conversion process.

4. TRAINING ON SAFETY AND SECURITY OF SPENT FUEL ONSITE AND DURING TRANSPORT

The Health Physics and Radiation Protection Section staff at CERT also underwent intensive training on radiation safety for nuclear spent fuel at IMTC in Accra and at ARGONNE National Lab in the US. This training aimed to enhance their skills in conducting leak tests on the Interim Transfer Cask (ITC) and the TUK-145/C certified Type C package used for transporting research reactor spent fuel assemblies. Personnel from ABU's security unit were also trained at IMTC in Accra and Texas A&M, USA, to comprehend their roles and responsibilities before, during, and after the discharge of NIRR-1's spent HEU fuel. Furthermore, multinational nuclear security experts organized workshops to ensure clear comprehension of the roles of both armed and unarmed security personnel during project implementation. Officers from the Nigerian Police, Customs, Immigration, and the Nigerian Military received specialized training on security concerns related to nuclear materials and the necessity of providing adequate security and clearance for the safe removal and transportation of the spent HEU fuel back to China.

Consequently, under strict military escort, the irradiated NIRR-1 HEU fuel was transported to Kaduna International Airport in Nigeria (Figure 2). A cargo plane then transported the irradiated fuel back to CIAE in Beijing, China.

Fig. 2. Reception of the TUK 145/C Cask at the Kaduna International Airport [2]

5. CHALLENGES, LESSONS LEARNED, AND IMPLICATIONS FOR SUSTAINABILITY

A significant challenge encountered during staff training revolved around administrative complexities within ABU. The redeployment of personnel within the university, without special consideration for CERT's uniqueness and the ongoing conversion project, resulted in the need for repetitive training due to the personnel reorganization. This circumstance escalated both the overall expenses and the time invested in executing the project. Sustainability was also a challenge during the training phase of the conversion project at CERT. The absence of fellowships and graduate internships for hands-on training of young scientists who would play pivotal roles in future decommissioning projects could potentially increase the long-term training costs. The conversion project for NIRR-1 took longer than necessary (around 8 years) due to disagreements among key stakeholders at ABU regarding the feasibility of converting the reactor core from HEU to LEU while maintaining its utilization. Broader consultation across various stakeholders before initiating decommissioning projects is crucial to avoid such delays.

Lessons from the Nigerian experience underline the importance of engaging a wider range of stakeholders, especially for smaller nuclear facilities within university campuses. Engagement should include personnel management units to prevent unnecessary transfers of staff and to ensure a clear understanding of nuclear facility peculiarities. Additionally, comprehensive decommissioning training should involve next-generation experts to prepare for the future, especially given the increasing number of aging reactors. Furthermore, the successful project implementation was greatly facilitated by the synergy between NIRR-1 operator, CERT, the regulatory body, NNRA, and other government key stakeholders, highlighting the necessity of early regulator engagement during decommissioning projects.

6. CONCLUSION

The conversion of NIRR-1 HEU core to LEU core and subsequent repatriation of the irradiated HEU fuel from CERT ABU Zaria Nigeria to CIAE Beijing China was a seamless process that was aided by the involvement of many key stakeholders and anchored on a thorough training of indigenous staff from CERT. The scientists, engineers, Technicians and security guards were apt in the discharge of their roles and responsibilities during the project implementation. Hence, this Nigerian experience underscores the significance of capacity development for nuclear decommissioning and highlights the need for comprehensive training programs, considering personnel sustainability, and effective coordination among stakeholders.

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