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NIRR-1'S FUEL ODYSSEY: EXPLORING BURNUP ESTIMATES, DECOMMISSIONING PLANS, AND RADIOACTIVE WASTE MANAGEMENT

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This abstract presents a detailed and comprehensive analysis of various aspects related to the Nigerian Research Reactor-1 (NIRR-1), including fuel burnup estimation, decommissioning strategies, radioactive waste management, and proliferation concerns. The study utilizes the WIMS-ANL computer code to assess the fuel burnup characteristics of both the existing Low-Enriched Uranium (LEU) fuel and the decommissioned Highly Enriched Uranium (HEU) fuel in the NIRR-1 reactor. The study focuses on understanding the fluctuation in atom density of key isotopes, namely U235, U238, Xe135, and Pu239, over the burnup time for both the HEU and LEU cores. A comprehensive evaluation of these isotopes' concentrations provides valuable insights into the reactor's operational dynamics and potential safety implications. In terms of fuel consumption, the analysis reveals that during the entire burnup period, the HEU fuel (UAL 4-Al) utilized 9.817257202 grams of U235, while the LEU fuel (UO2) consumed 12.04913749 grams of U235. Similarly, the HEU fuel generated 0.2042625596 grams of Pu239, whereas the LEU fuel produced 0.052503096 grams of Pu239. These findings contribute to a better understanding of the fuel utilization efficiency and the overall performance of the NIRR-1 reactor. The study also highlights the significance of the NIRR-1 reactor as a commercial version of the Miniature Neutron Source Reactor (MNSR) developed by the China Institute of Atomic Energy (CIAE). Operated by the Centre for Energy Research and Training (CERT) at Ahmadu Bello University, Zaria, the NIRR-1 reactor plays a crucial role in neutron activation analysis and minimal radioisotope generation. In line with international efforts to reduce the use of highly enriched uranium in civil nuclear applications, the HEU core of the NIRR-1 reactor has been converted to LEU fuel. Consequently, understanding the current LEU fuel's burnup characteristics is essential for effective fuel management and long-term reactor operation. The analysis confirms the reliability of the WIMS-ANL code in accurately estimating the fuel burnup for the potential LEU core, providing valuable insights for decision-making processes. Furthermore, the study addresses decommissioning strategies for the NIRR-1 reactor, considering its design features and core lifetime. The reactor is designed to operate at maximum flux for 2.5 hours per day, five days per week, with a core lifetime of 10 years. To compensate for the loss of reactivity due to core burnup, controlled beryllium shims are added to the top aluminum tray. This practice leads to increased fuel burnup and the accumulation of fission products throughout the reactor's operation. Considering the potential for proliferation concerns, the study examines the accumulation of fissile materials, particularly Pu-239, in the NIRR-1 reactor. The findings indicate that the accumulation of Pu-239 is insufficient to compensate for the reactivity loss caused by U-235 depletion. Additionally, the concentration of Pu-239 in the spent fuel remains below levels that raise concerns about nuclear weapon design and production. To ensure the safe and efficient operation of the NIRR-1 reactor throughout its life cycle, precise fuel burnup estimation is crucial. This knowledge helps monitor reactivity parameters, neutron fluxes, and power distributions within the reactor core. It also facilitates the estimation of the radioactive source term for safety analysis during accidental scenarios, safeguards requirements for fissile material monitoring, and the determination of cooling and shielding needs for spent fuel storage and transportation. In conclusion, this study provides a comprehensive analysis of fuel burnup estimation, decommissioning strategies, radioactive waste management, and proliferation concerns in the Nigerian Research Reactor-1 (NIRR-1) using the WIMS-ANL code. The findings contribute to a better understanding of the reactor's long-term operation, fuel utilization, and potential safety implications. The results validate the reliability of the WIMS-ANL code for fuel burnup estimation and underscore the importance of accurate fuel management for safe and cost-effective reactor operation.

Keywords: NIRR-1, Fuel odyssey, Burnup estimates, Decommissioning plans, Radioactive waste management

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