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Assessing the Feasibility of Nuclear Techniques for the Analysis and Conservation of Cultural Heritage in Katsina State, Nigeria

***[1]Emmanuel Joseph, [2]Uma Helen Emmanuel and [2]Abubakar Abdullahi**

[1]Department of Physics, Federal University Dutsin-Ma, Katsina State – Nigeria
[2]Physical Planning & Works, Federal University Dutsin-Ma, Katsina State – Nigeria

*Corresponding author's email: ejoseph@fudutsinma.edu.ng

ABSTRACT
Nuclear techniques provide non-destructive, highly precise methods for the analysis, restoration, and preservation of irreplaceable cultural heritage objects and sites. This review assesses the feasibility of applying techniques such as neutron activation analysis (NAA), X-ray fluorescence (XRF), particle-induced X-ray emission (PIXE), and gamma irradiation for cultural heritage in Katsina State, Nigeria. Katsina hosts significant tangible heritage, including the Gobarau Minaret, Durbi Takusheyi tumuli, ancient city walls, Emir's Palaces, and collections at the National Museum Katsina, which face threats from erosion, biological degradation, climate variability, and urbanization. Nigeria's nuclear infrastructure, coordinated by the Nigerian Atomic Energy Commission (NAEC), includes the Miniature Neutron Source Reactor (NIRR-1) at the Centre for Energy Research and Training (CERT) in Zaria and the Gamma Irradiation Facility (GIF) at Sheda, Abuja, offering a viable foundation for peaceful applications. Drawing on IAEA-supported global projects, this paper evaluates technical, economic, regulatory, institutional, and socio-cultural dimensions of feasibility. Opportunities through IAEA technical cooperation outweigh challenges such as expertise gaps and equipment access, making implementation promising. Recommendations focus on pilot projects, capacity building, and stakeholder collaboration to enhance heritage preservation and socioeconomic benefits.

Keywords:
Nuclear techniques,
Cultural heritage conservation,
Katsina State,
Nigeria,
NAA,
XRF,
Gamma irradiation,
Feasibility study.

INTRODUCTION

Cultural heritage embodies the historical, artistic, and identity-forming legacy of societies and constitutes a non-renewable resource requiring advanced scientific support for its survival (IAEA, 2011). In Katsina State, northern Nigeria, heritage assets reflect centuries of Hausa civilization, trans-Saharan trade, Islamic scholarship, and pre-colonial governance. Iconic sites and artifacts, however, are increasingly vulnerable to environmental and anthropogenic pressures, underscoring the need for innovative, non-invasive conservation methods.

Nuclear techniques, promoted by the International Atomic Energy Agency (IAEA), enable precise elemental analysis, provenance determination, dating, and biological decontamination while preserving object integrity (IAEA, 2011; IAEA, 2017). This review systematically evaluates the feasibility of deploying these techniques in Katsina, building on Nigeria's existing nuclear framework and global IAEA case studies. The assessment is particularly timely given recent government efforts to promote domestic tourism and monument revitalization in Katsina (e.g., Federal Government–Katsina State MoU) and Nigeria's advancement in peaceful nuclear applications.

Cultural Heritage Landscape in Katsina State

Katsina State possesses a rich tapestry of tangible cultural heritage spanning pre-Islamic and Islamic periods. Key assets include:

i. Gobarau Minaret (Gobirau Minaret): A 15-meter (50 ft) mud-brick structure in Katsina City, constructed in the late 14th–early 16th century during the reign of Muhammadu Korau. It exemplifies Sudano-Sahelian architecture and historically served as part of a central mosque and center of Islamic learning. Designated a national monument, it faces ongoing erosion from rainfall and wind (Wikipedia, n.d.; Historical Nigeria, n.d.).

ii. Durbi Takusheyi: An ancient burial site with tumuli (mounds) near Mani, containing graves of early Katsina rulers and associated artifacts such as ceramics, metals, and grave goods linked to trade networks. Some materials are preserved in the National Museum Katsina. The site holds high archaeological value for understanding elite burial practices and social structures (Gidado, 2025; Insoll, 2003, as referenced in related archaeological literature).

iii. Katsina City Walls and Gates: Remnants of 11th–16th-century earthen fortifications that highlight defensive urban planning and the city's historical role as a trade hub.
iv. Kusugu Well (Daura) and Emir's Palaces: Living heritage sites tied to foundational Hausa legends (Bayajidda myth) and traditional architecture, supporting cultural continuity and tourism.
v. National Museum Katsina (housed in Old Katsina College): A colonial-era national monument displaying terracotta, textiles, musical instruments, and archaeological finds. Organic materials here are particularly susceptible to insect and fungal damage (Katsina Investment Promotion Agency, n.d.).

These sites and collections not only sustain local identity and tourism but also require scientific characterization to inform targeted conservation. Nuclear methods excel here due to their ability to analyze complex matrices like mud-brick, ceramics, and organics without sampling damage (IAEA, 2011).

Overview of Nuclear Techniques in Cultural Heritage

Nuclear techniques are categorized into analytical and conservation-oriented approaches.

Analytical Techniques

i. Neutron Activation Analysis (NAA): Involves neutron bombardment to induce characteristic gamma emissions, enabling multi-elemental (major, minor, trace) analysis. It is highly effective for non-destructive provenance studies of ceramics and metals (IAEA, 2011).
ii. X-ray Fluorescence (XRF) and Portable XRF (pXRF): Measures elemental composition through X-ray interactions. Portable systems allow in-situ examination of large or immovable objects, such as monuments (IAEA, 2011).
iii. Particle-Induced X-ray Emission (PIXE) and Ion Beam Analysis (IBA): Accelerator-based methods providing high spatial resolution for pigments, inks, and metals, complementing XRF (IAEA, 2011).

These techniques support provenancing, authenticity verification, and degradation mechanism studies (e.g., elemental mapping of mud-brick at the Gobarau Minaret).

Conservation Techniques

Gamma Irradiation: Utilizes cobalt-60 or cesium-137 sources to disinfect artifacts by eradicating insects, fungi, and bacteria at controlled doses (typically 0.5–8 kGy for disinfection; up to 15 kGy for some materials). It penetrates deeply without chemical residues and has been successfully applied to paper, textiles, wood, leather, and parchment (IAEA, 2017; D'Orsi et al., 2024; Lungu et al., 2023). IAEA publications document extensive global applications, confirming minimal adverse effects on material properties when doses are optimized (IAEA, 2017; Cortella et al., 2011).

Nigeria's Nuclear Infrastructure and Capacity

Nigeria's peaceful nuclear program is coordinated by the Nigerian Atomic Energy Commission (NAEC), established in 1976. Key facilities relevant to heritage applications include:

i. Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria: Operates the Miniature Neutron Source Reactor (NIRR-1), commissioned in 2004, supporting NAA for trace element analysis in archaeology and materials science (History | Center for Energy Research and Training, n.d.).
ii. Nuclear Technology Centre (NTC), Sheda, Abuja: Houses the Gamma Irradiation Facility (GIF), currently under revitalization for sterilization and potential heritage disinfection applications (NAEC, n.d.; NAEC seeks presidential support..., n.d.).
iii. Centre for Energy Research and Development (CERD), Obafemi Awolowo University: Features a Pelletron accelerator for IBA techniques.

NAEC collaborates closely with the IAEA on technical cooperation projects, human resource development, and infrastructure enhancement, providing a solid base for extending nuclear applications to cultural heritage (IAEA, n.d.-b). No dedicated large-scale nuclear heritage projects exist in Katsina to date, presenting an opportunity for pioneering work.

Feasibility Assessment

Technical Feasibility

High potential of this truly exists. Portable XRF enables field analysis of monuments like the Gobarau Minaret and city walls. NAA at CERT suits museum ceramics and metals from Durbi Takusheyi. Gamma irradiation at the revitalized Sheda facility can treat vulnerable organic collections (IAEA, 2011; IAEA, 2017). IAEA training modules on portable spectrometry and irradiation protocols facilitate local adaptation.

Economic Feasibility

Moderate to high, particularly with IAEA technical cooperation grants. Initial investments in portable equipment and training yield long-term savings compared to traditional chemical methods. Benefits include enhanced tourism revenue and reduced heritage loss (e.g., through the recent FG-Katsina tourism MoU). Pilot projects can demonstrate cost-effectiveness.

Regulatory and Safety Feasibility

This is very Strong. Nigeria's Nuclear Safety and Radiation Protection framework, overseen by NAEC and the Nigerian Nuclear Regulatory Authority

(NNRA), aligns with IAEA standards. Low-dose applications for heritage minimize risks, with established protocols for public sensitization addressing any perception concerns.

Institutional and Collaborative Feasibility

Excellent. Synergies among NAEC, the National Commission for Museums and Monuments (NCMM), Katsina State Government, universities, and international partners (via IAEA TC projects) are readily achievable. Models from Ecuador, Panama, and European RER8015 provide blueprints (IAEA, 2013).

Socio-Cultural Feasibility

Promising. Community engagement ensures cultural sensitivity, while benefits such as job creation in conservation, educational outreach, and tourism, all align with national development goals.

Challenges and Barriers

Key limitations include limited interdisciplinary expertise in nuclear-heritage applications, logistical challenges for remote sites (e.g., Durbi Takusheyi), funding sustainability, and regional security/climate factors. Potential minor material changes from irradiation (e.g., on cellulose) are well-documented and manageable at optimized doses (D'Orsi et al., 2024; Lungu et al., 2023). Mitigation strategies involve phased pilots, IAEA-supported training, and awareness campaigns.

Lessons from Global and Regional Applications

IAEA-coordinated projects demonstrate success in characterization (e.g., pottery provenance via NAA in Ghana) and disinfection (e.g., Ramses II mummy, Roman wooden ship, archives in Romania and France) (IAEA, 2017; IAEA, 2023). African examples, including trace element studies on pottery, confirm applicability in resource-constrained settings (IAEA research reactor reports). These cases offer transferable methodologies for Katsina's ceramics, mud architecture, and museum organics.

Recommendations

i. Launch a pilot IAEA/NAEC-NCMM project focusing on National Museum Katsina collections and Gobarau Minaret materials.
ii. Develop protocols for portable XRF and NAA provenance studies of Durbi Takusheyi artifacts.
iii. Establish an interdisciplinary Katsina heritage-nuclear working group with targeted training.
iv. Integrate nuclear conservation into state cultural and tourism policies.
v. Conduct public sensitization on safe nuclear applications.
vi. Monitor long-term irradiation effects and scale successful pilots nationally.

CONCLUSION

Nuclear techniques offer a feasible, effective, and sustainable pathway for the analysis and conservation of cultural heritage in Katsina State. Leveraging Nigeria's NAEC infrastructure and IAEA partnerships can address degradation threats to sites like the Gobarau Minaret and Durbi Takusheyi while generating cultural, educational, and economic value. Coordinated action among stakeholders is essential to realize this potential and contribute to national heritage resilience.

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