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EXPLORING THE ROLE OF NUCLEAR-BASED TECHNOLOGIES IN ENHANCING SECURITY AND COMBATING BANDITRY IN KATSINA STATE: A SCOPING REVIEW

*[1]Nura Gambo and [2]Nuraddeen Y. Adamu

*[1]Department of Physics Isa Kaita College of Education, Dutsin-Ma Katsina State
[2]Department of Mathematics Isa Kaita College of Education, Dutsin-Ma Katsina State

*Corresponding authors' email: nuragambodtm905@gmail.com

ABSTRACT

Katsina State in northwestern Nigeria faces persistent threats from organized banditry, including mass abductions, arms smuggling, and cross-border crimes. Traditional security measures have demonstrated limited effectiveness in addressing these complex challenges. This scoping review aims to evaluate the potential application of nuclear-based technologies such as radiation detection, remote sensing, and isotopic tracking in enhancing security operations within Katsina State. The review seeks to explore feasibility, identify relevant stakeholders, and assess potential risks and mitigation strategies. The methodology was applied, following Arksey and O'Malley's framework and PRISMA-ScR guidelines. Literature was sourced from databases including Google Scholar, IEEE, and ScienceDirect, along with IAEA technical reports. Studies included those focused on civilian nuclear security applications, particularly in contexts of border control, anti-smuggling, and regional surveillance. Findings suggest that nuclear-based tools such as mobile radiation detectors, gamma imaging, and UAV-mounted sensors have been successfully used in other conflict-prone or border-sensitive regions. Their integration into Katsina's security framework could improve early threat detection, enhance intelligence-gathering, and support interdiction of illicit activities. Collaboration with federal agencies and international partners is crucial for pilot deployment and capacity building. Nuclear technologies present viable opportunities for improving security in Katsina State. However, deployment must be accompanied by legal frameworks, stakeholder coordination, and public sensitization to address operational, ethical, and financial concerns. This review recommends phased pilot testing and institutional support to guide sustainable integration.

Keywords: Nuclear-based security technologies, Organized banditry in Nigeria, Remote radiation sensing, Gamma imaging surveillance, Katsina State border control

INTRODUCTION

Katsina State, located in Northwestern Nigeria, continues to face serious security threats—including armed banditry, illicit arms trafficking, and unchecked cross-border movements. These challenges are exacerbated by difficult terrain, porous borders, and limited surveillance infrastructure, all of which undermine the effectiveness of conventional policing and military interventions. To address these complex threats, there is an urgent need to explore advanced, technology-driven solutions that go beyond traditional tools. Nuclear-based technologies, such as radiation detection systems, isotope tracing, and nuclear forensics, have been successfully deployed in other global contexts to detect smuggled weapons, monitor border activity, and enhance intelligence gathering. These technologies offer strategic advantages in areas where mobility, precision, and early detection are critical conditions that align closely with the realities in Katsina.

This review examines how such technologies can be adapted to the security needs of Katsina State. Through a scoping analysis of academic literature, policy documents, and international case studies (2010–2024), the paper aims to assess the feasibility, stakeholder involvement, and regulatory considerations for deploying nuclear-based solutions in combating local security threats (Bello et al., 2024).

Nature and Dynamics of the Crisis

In Katsina State, armed groups operate across vast rural and forested areas, often striking villages, highways, and schools. These criminal syndicates are well-coordinated and frequently engage in:

Mass abductions for ransom, including school children (e.g., the 2020 abduction of over 300 students in Kankara). Cattle rustling, which has devastated the livelihoods of pastoralists and farmers. Illegal gold mining, especially in areas like Jibia and Batsari, which fuels conflict and attracts armed groups. Arms smuggling and trafficking, facilitated by porous borders with Niger Republic and weak enforcement. The attackers often use motorcycles for mobility and are sometimes better armed than local security forces. Their operations are brutal—burning homes, killing civilians, and forcing entire communities to flee (Ladan et al., 2019).

Understanding Banditry in Katsina State

Several structural and socio-economic factors contribute to the worsening insecurity in Katsina State:

i. Poverty and unemployment, especially among youth.
ii. Weak governance and lack of state presence in rural areas.
iii. Ethno-religious tensions and unresolved communal conflicts.
iv. Climate change and desertification, reducing arable land and water resources, thus intensifying farmer-herder clashes.
v. Corruption and lack of accountability within security and political structures (Audu, 2021).

Security Responses and Gaps

Despite government interventions, systemic security gaps persist. The Federal Government launched several military operations, notably:

i. Operation Sharan Daji: Aimed at flushing out bandits in the North West, including Katsina.

ii. Operation Hadarin Daji: A broader campaign targeting bandit strongholds across the region.
iii. Airstrikes and ground operations by the Nigerian Air Force and Army in affected local governments such as Safana, Jibia, and Batsari (Chukwuma & Francis, 2014).

However, these operations often face challenges such as:

i. Insufficient personnel and poor logistics.
ii. Inadequate intelligence gathering.
iii. Lack of coordination between federal forces and local vigilantes.
iv. Distrust from local communities, who sometimes feel targeted or neglected (Rufus & Ogbe, 2025).

Community-Based Responses

In response, some communities have formed vigilante groups or joined initiatives like “Yan Sakai” (a local armed group), though these sometimes engage in human rights abuses and reprisals that fuel further violence. Additionally, the Katsina State Government has attempted dialogue with bandits, offering amnesty programs and reintegration packages, though these have met limited success due to the absence of long-term strategies and inconsistent enforcement (Ladan et al., 2019).

Concurrently, the global security landscape has witnessed increased deployment of nuclear-based technologies, primarily for border security, detection of radioactive materials, and high-precision surveillance. The aim of this review is to explore how such technologies can be localized to combat organized banditry in Katsina, support law enforcement, and enhance early-warning capabilities (Bello et al., 2024).

Overview of Nuclear-Based Technologies in Security

Nuclear-based technologies have evolved beyond their traditional applications in energy and medicine to play a critical role in enhancing national and international security. Leveraging the unique properties of nuclear radiation and materials, these technologies are now integral to efforts in threat detection, border control, counter-terrorism, and emergency response. Their strategic application strengthens the capacity of nations to detect and prevent illicit activities involving nuclear and radiological materials, as well as to monitor and manage threats posed by weapons of mass destruction (WMDs), including nuclear, chemical, and biological weapons (FARUK et al., 2022).

Scientific Basis and Functioning of Nuclear Detection Technologies

To appreciate the feasibility and effectiveness of these technologies, it is essential to understand the basic scientific principles underlying their operation as follows: (IAEA, 2023).

Fundamental Principles

Nuclear detection technologies are grounded in the principles of nuclear physics, particularly the behavior of radioactive materials and their emissions. Radioactive substances emit ionizing radiation, such as alpha particles, beta particles, gamma rays, and neutrons. These emissions can be detected and measured using specialized instruments, enabling the identification and quantification of radioactive materials.

Types of Radiation and Detection Methods

i. Alpha and Beta Particles: These are charged particles that can be detected through their ionization effects on matter. Detectors like gas-filled ionization chambers and semiconductor detectors are commonly used.
ii. Gamma Rays: High-energy photons that require dense materials for detection. Scintillation detectors, which emit light when struck by gamma rays, are often employed.
iii. Neutrons: Uncharged particles that are detected indirectly. Materials like helium-3 or boron-10 are used in detectors to capture neutrons, resulting in secondary charged particles that can be measured.

Common Detection Technologies

i. Scintillation Detectors: Utilize materials that emit light when exposed to radiation. The light is then converted into electrical signals for analysis.
ii. Semiconductor Detectors: Use materials like silicon or germanium to detect radiation through electron-hole pair creation, offering high-resolution measurements.
iii. Gas-Filled Detectors: Include Geiger-Müller tubes and proportional counters, which detect ionization in gases caused by radiation.
iv. Neutron Detectors: Employ materials that undergo nuclear reactions upon neutron capture, producing detectable charged particles.

Application in Security and Border Control

In the context of security and combating illicit activities:

i. Radiation Portal Monitors (RPMs): Installed at checkpoints and borders to scan vehicles and cargo for radioactive materials.
ii. Handheld Radiation Detectors: Portable devices used by security personnel to inspect suspicious items or areas.
iii. Aerial Surveillance: Drones equipped with radiation detectors can monitor large or inaccessible areas for unauthorized radioactive sources.
iv. Spectroscopic Tools: Instruments that analyze the energy spectrum of detected radiation to identify specific radionuclides.

Relevance to Katsina State

Deploying these technologies in Katsina State can enhance the detection of illicit radioactive materials, prevent smuggling of nuclear substances, and strengthen border security. The integration of nuclear detection systems can serve as a deterrent and provide rapid response capabilities to potential threats (Rufus & Ogbe, 2025).

Gamma-Ray Spectroscopy

This technique is based on the detection and analysis of gamma radiation emitted by radioactive isotopes. Each isotope emits gamma rays at specific energies, forming a unique spectral signature. Gamma-ray detectors-commonly high-purity germanium (HPGe) detectors or scintillation detectors like NaI(Tl)-identify and quantify these energies to determine the type and amount of radioactive material present. In security applications, this enables authorities to detect and differentiate between harmless and dangerous materials in cargo, vehicles, or baggage (Harry , 2021).

Neutron Detection

Neutron-based systems detect neutrons emitted by special nuclear materials such as uranium-235 or plutonium-239. Since neutrons are highly penetrating and not commonly found in the environment, their presence is a strong indicator of illicit nuclear material. Devices such as helium-3 or boron trifluoride-filled proportional counters are often used. These systems can function passively (detecting spontaneous neutron emissions) or actively (employing an external neutron source to stimulate emissions (FasterCapital, 2025).

Isotopic Tagging and Tracking

This involves embedding traceable radioactive isotopes or stable isotopic markers into materials (e.g., fuel or metal parts) to monitor their movement. Any deviation from an expected path triggers alerts. This technology is valuable in monitoring supply chains and preventing diversion of critical materials to criminal use.

Remote Sensing with Radiation Sensors

UAVs or drones equipped with radiation detectors (gamma or neutron) are capable of surveying large areas. These sensors continuously record and transmit radiological data, allowing real-time mapping of contamination zones or illicit radioactive activity. This capability is particularly useful in inaccessible terrains like forests and mountainous regions (Fathy et al., 2024).

Used for early threat identification in inaccessible terrains

Nuclear-based technologies, particularly remote sensing and radiation detection systems, are increasingly being deployed for early threat identification in geographically inaccessible or high-risk terrains. These regions such as dense forests, mountainous zones, border areas, or conflict-prone rural communities pose significant challenges for traditional security surveillance due to limited infrastructure, poor accessibility, and the risk of ambush or environmental hazards.

By integrating aerial drones equipped with gamma-ray or neutron detectors, as well as ground-based autonomous detection units, security forces can:

Detect the presence of radioactive materials or illicit activities such as hidden weapons caches or illegal mining operations without the need for direct human intervention.

Monitor radiation signatures and environmental anomalies that may indicate clandestine nuclear activities or the use of radiological materials in criminal operations.

Provide real-time data to command centers, enabling rapid decision-making and targeted response strategies.

This capability is especially vital for border control, anti-banditry missions, and counter-terrorism operations in regions like Northern Nigeria, where terrain complexity and weak infrastructure hinder the effectiveness of conventional patrols and intelligence operations (Fathy et al., 2024).

By leveraging these technologies, authorities can proactively identify and neutralize threats before they escalate, thereby enhancing situational awareness and operational safety in areas previously considered too dangerous or remote to monitor effectively and also the applications the nuclear technology were presented in the table below

Table 1: Applications to Combating Banditry in Katsina

Technology	Use Case in Katsina
Mobile radiation scanners	Checkpoints and border crossings to detect smuggled arms
Drone surveillance	Monitoring forest camps (e.g., Rugu Forest)
Forensic tracking	Analyze arms used in attacks to trace their supply chains
Gamma imaging	Detect hidden shelters, weapons depots, or mining tunnels
Isotopic tagging	Mark and monitor fuel/oil supplies in black markets

Scope of this Review

This paper presents a review of existing literature, policy documents, and case studies to explore how nuclear-based technologies such as radiation detection and isotopic tracing—can enhance security in Katsina State. It focuses on the potential applications of these technologies for tracking weapons, monitoring borders, and combating banditry, while also addressing key challenges related to cost, safety, and regulatory frameworks. This study is a review-based analysis rather than an empirical or experimental investigation.

Research Problem

Katsina State faces persistent security threats from banditry, arms smuggling, and porous borders. Existing security measures have proven inadequate, particularly in remote and unmonitored areas. Despite the proven value of nuclear-based technologies in global security contexts, their potential application in Katsina remains underexplored. This review seeks to examine how such technologies can enhance border surveillance and anti-banditry operations, and what regulatory, technical, and operational factors must be considered for their effective deployment

Research Objectives

i. To evaluate the applicability of nuclear-based technologies for enhancing security operations and combating organized banditry in Katsina State.
ii. To analyze the feasibility of deploying these technologies to combat banditry, arms smuggling, and border security challenges.
iii. To examine how key stakeholders-NNRA, NAEC, security agencies, local universities, and international organizations like the IAEA collaborate to ensure the safe and effective use of nuclear technologies for combating banditry and securing Katsina State's borders.
iv. To identify risks (cost, safety, misuse) and mitigation strategies for sustainable adoption.

Literature Review

Johnson, (2019) in the paper challenging Traditional Paradigms: The Rise of Terror Non-States and Their Impact on International Legal Frameworks.

According to IAEA, (2024) report titled Security of Nuclear and Other Radioactive Material in Transport, the research found that Nuclear Security Series addresses prevention, detection, and response to criminal acts involving nuclear/radioactive materials, aligning with international treaties like the CPPNM and UN Security Council resolutions. These guidelines ensure consistent global nuclear security standards while complementing existing legal frameworks.

Purpose et al., (2020) in the report Human Trafficking and Migrant Smuggling Section, highlighted the significant of nuclear technology in addressing the security issues concerning human trafficking.

Rosenje & Adeniyi, (2021) in their research deterring Russian Nuclear Threats with Low-Yield Nukes May Encourage Limited Nuclear War, highlights United State nuclear policies may be reinforcing Russian perceptions and fears of Western aggression.

Ladan et al., (2019) in their articles highlighted how insecurity affect Katsina State socioeconomic of the populace.

Balogun & Pelumi, (2022) in their research Impact of Banditry on Agricultural Output in Nigeria and findings indicates that the banditry has set people of backward in terms of the agricultural activities.

Vaddi, (2021) the researcher's finding was indicates the used of arms in curtailing security situations.

According to IAEA, (2024) provide a technical guidelines on how to protect nuclear materials during transportation of the materials.

IAEA, (2023) in the report Detection at State Borders of Nuclear and Other Radioactive Material out of Regulatory Control, the report was extensively spelt out the guideline on the use of nuclear materials in curtailing the borders security challenges.

The U.S. defines homeland security as ensuring national safety from terrorism and hazards, relying heavily on advanced radiation detection technologies like gamma-ray and neutron scanners for identifying explosives and nuclear materials. These technologies use passive and active methods, such as radiographic scanning and spectral analysis, for border and cargo security. In contrast, the current study in Katsina State proposes adapting similar tools—like UAV-mounted sensors and mobile scanners to combat local threats such as banditry and arms smuggling in remote areas. While the technology overlaps, the contexts and objectives differ: national security in the U.S. versus regional crime control in Nigeria (Kouzes & Northwest, (2024)

MATERIALS AND METHODS

This study employed a scoping review methodology, guided by Tricco et al., (2018) five-stage framework and refined using the PRISMA Extension for Scoping Reviews (PRISMA-ScR) Checklist. The objective was to map the existing literature on nuclear-based security technologies and evaluate their applicability in addressing organized banditry and border insecurity in Katsina State, Nigeria.

Identifying the Research Question

The central question was: How can nuclear-based technologies be applied to enhance security operations and combat banditry in Katsina State?

Sub-questions included: What types of nuclear technologies have been used in similar conflict-prone or border-unstable regions?

What stakeholders are involved in successful implementations?

What risks and regulatory considerations arise in the deployment of such technologies?

Identifying Relevant Studies

Searches were conducted across academic databases including: Google Scholar, IEEE Xplore, ScienceDirect, PubMed and IAEA Document Archive

Study Selection

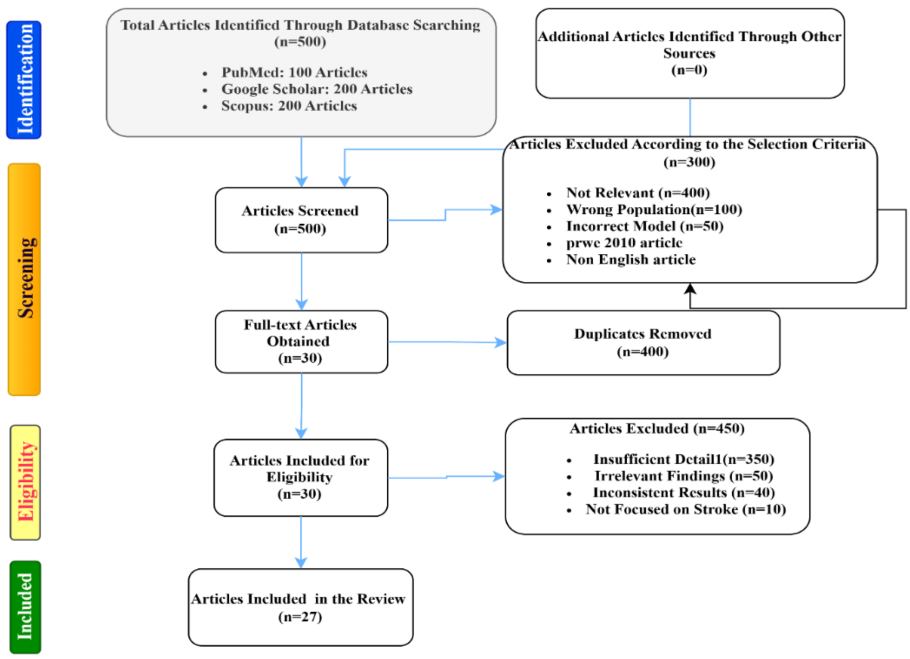
Inclusion criteria: Studies addressing civilian applications of nuclear/radiological technologies for security, surveillance, smuggling, or border control. Case studies or empirical work focused on deployment in conflict zones or resource-poor settings.

Exclusion criteria: Military applications of nuclear weapons. Theoretical discussions without applied examples and Pre-2010 publications or those outside English language.

Screening was conducted in two phases: Title and Abstract Review, Full-Text Review

Two reviewers independently assessed relevance, with discrepancies resolved through discussion.

he scoping review approach was adopted, and study selection was guided by the PRISMA-ScR (2020) guidelines. All relevant studies were identified from electronic databases and registers, and duplicates were removed prior to screening. The study selection process, including the number of records retrieved, screened, excluded, and included, is detailed in Figure using the PRISMA flow diagram. The Figure below shows the flowchart of PRISMA-ScR.



(THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL, 2024)

Figure 1: Shows the PRISMA flow diagram

RESULTS AND DISCUSSION

Comparative Case Study Design and Analytical Framework

To contextualize the feasibility of nuclear-based security technologies in Katsina State, a comparative case study approach was integrated into the review methodology. The rationale was to extract practical insights from regions that have deployed similar technologies under comparable socio-political or geographical challenges, especially where border instability, smuggling, or rural insecurity prevail (GAO U. S. Government Accountability Office, 2016).

The comparative analysis considered several key parameters, including geopolitical and terrain similarities with regions known for porous borders or rugged landscapes (such as parts of the Sahel and the Middle East). It also examined the types of technologies employed such as radiation detectors, UAV-mounted gamma sensors, isotopic tagging, and mobile scanning systems and the primary purposes of deployment, which included smuggling interdiction, surveillance of ungoverned areas, and early threat detection. Additionally, the study evaluated the institutional frameworks involved, including the role of regulatory agencies, inter-agency collaboration, and international support like that from the IAEA. Finally, outcome variables were assessed based on the effectiveness of curbing illicit trafficking, the responsiveness of local enforcement, and how well the strategies integrated into broader security operations (Rauf, 2020).

However, three major case contexts were reviewed which includes Jordan–Syria border region (UAV radiation surveillance to detect arms smuggling), Sahel region (Mali/Niger) (IAEA-assisted radiation detection at mining and border zones) and Pakistan–Afghanistan tribal border (deployment of mobile radiation portal monitors). This comparison enables a clearer understanding of how nuclear-based security measures may perform in Katsina's environment and what adaptive strategies are needed for successful implementation.

Guiding Framework: SWOT Analysis

A SWOT framework was applied to assess the viability of nuclear-based security technologies in Katsina State. Key Strengths include the proven field effectiveness of gamma-ray/neutron detectors in high-risk borders, drone-mounted sensors enabling surveillance in Katsina's remote terrain, and enhanced intelligence for proactive threat interdiction. However, significant Weaknesses exist, such as high equipment costs straining limited budgets, a shortage of specialized technical expertise for operations, and potential public resistance due to misinformation about nuclear technologies.

Critical Opportunities could facilitate implementation, including technical support from international bodies (e.g., IAEA, UNODC), multi-agency collaboration between federal regulators (NNRA/NAEC) and local security units, and research partnerships with academic institutions. Conversely, major Threats must be mitigated: criminal targeting or black-market diversion of detection equipment, sabotage/jamming of systems by armed groups, and regulatory gaps in rural enforcement that could undermine oversight (UNODC, 2025). This structured analysis informs adaptive strategies for Katsina's unique context

Feasibility Assessment of Nuclear Security Technologies for Katsina State

In this context radiation detection systems (handheld, mobile, UAV-mounted) and nuclear forensics have proven effective in environments mirroring Katsina's operational challenges:

i. Sahel Region (Niger/Mali): IAEA-supported detectors enhanced border monitoring despite resource constraints.
ii. Afghanistan-Pakistan Border: Mobile teams successfully tracked radiological materials in conflict-prone tribal areas.
iii. Lebanon: Portable detectors integrated into anti-trafficking operations amid political fragility.

Implication*:* Katsina's porous borders (e.g., Jibia/Dankama) and banditry risks make these models directly adaptable. Therefore, the Tables 2 and 3 below indicates the critical feasibility pillars and stakeholders integration frame work respectively.

Table 2: Present the Critical Feasibility Pillars

Factor	Key Finding	Recommended Pathway
Cost Efficiency	Significant initial investment required	Pursue IAEA/UNODC grants + federal co-funding.
Human Capacity	Specialized training is the top barrier	Establish NNRA/NAEC-led training hubs at Federal University Dutsin-Ma.
Regulatory Enforcement	Weak rural oversight risks safety gaps	Localize NNRA protocols for Katsina's context.
Political Commitment	Sustained buy-in essential for coordination	Align with state security initiatives (e.g., amnesty programs).

Table 3: Shows the Stakeholder Integration Framework

Actor	Role	Critical Action
Federal Agencies (NNRA/NAEC)	Regulatory oversight & policy guidance	Decentralize technical supervision to rural zones.
Katsina State Authorities	Implementation & community liaison	Mobilize traditional leaders for public trust.
Security Forces	Frontline operations & interdiction	Train 150+ personnel on detector deployment.
International Partners	Funding/technical support (IAEA, US DOE)	Pilot hotspot deployments with conditionality.
Academic Institutions	Curriculum development & localized R&D	Create nuclear security certification programs.
Local Communities	Intelligence gathering & social license	Launch transparency campaigns via radio/mosques.

CONCLUSION

In this scoping review the Table 2 indicates the present of critical feasibility pillars. Table 3 shows the role of stakeholder's integration framework. Figure 1 shows the PRISMA-ScR

However, the systematically addressed its core research objectives regarding nuclear-based security technologies in Katsina State as follows:

i. Objective 1 (Applicability Evaluation)

Nuclear technologies particularly radiation detection systems (e.g., UAV-mounted gamma sensors), isotopic tracing, and gamma imaging demonstrate strong potential for enhancing threat detection in Katsina's banditry-prone border regions. Their ability to monitor remote terrain (e.g., Rugu Forest) and track illicit materials addresses critical gaps in conventional security approaches.

ii. Objective 2 (Feasibility Analysis)

Deployment is feasible but context-dependent. Lessons from Sahelian Africa and Pakistan confirm operational viability in resource-constrained settings, though Katsina's infrastructure limitations and conflict dynamics necessitate phased implementation.

iii. Objective 3 (Stakeholder Assessment)

Effective deployment requires coordinated action across which includes: Federal agencies (NNRA/NAEC for regulatory oversight), Security forces (technical capacity building), Local communities (trust-building for intelligence sharing) and International partners (IAEA for technical support).

iv. Objective 4 (Risk Mitigation):

Key risks including equipment sabotage (e.g., drone jamming by bandits), public resistance to nuclear solutions, and maintenance costs demand proactive mitigation through community engagement and redundant systems.

Nuclear-based technologies offer a viable, though complex, pathway to enhance security in Katsina State. Radiation detection systems (e.g., mobile scanners, UAV-mounted sensors) and isotopic tracking have proven effective in comparable conflict-affected regions (Sahel, Pakistan-Afghanistan border) for detecting smuggled arms and monitoring remote terrain. However, successful deployment hinges on strategic partnerships with federal agencies (NNRA/NAEC), international bodies (IAEA), and local academia for funding and training, phased, community-sensitive implementation starting with pilot projects in high-risk zones (Jibia, Batsari) and robust regulatory frameworks to address safety, misuse risks, and rural enforcement gaps.

RECOMMENDATIONS

i. Start with Pilot Programs: Deploy nuclear detection tools (e.g., mobile scanners, UAVs with radiological sensors) in high-risk border zones like Jibia, Batsari, and Dankama.
ii. Train Security Personnel: Build capacity by training police, military, and border officials on the safe use and maintenance of nuclear-based technologies.
iii. Strengthen Stakeholder Collaboration: Facilitate coordination between federal agencies (NNRA, NAEC), Katsina State authorities, academic institutions, and international bodies like the IAEA.
iv. Develop Clear Legal Frameworks: Establish or update regulations to ensure safe, ethical, and accountable deployment of nuclear tools for security.
v. Engage and Educate the Public: Run community awareness campaigns to build trust and encourage local support for nuclear-based security solutions.
vi. Leverage Academic Partnership: Federal University Dutsin-Ma should be engaged as a key academic partner contributing local research expertise, facilitating capacity-building programs, and serving as a hub for community outreach and technical training in Katsina State.

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