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ENVIRONMENTAL SAFETY IN NUCLEAR ENERGY: INTEGRATING IAEA STANDARDS WITH NATIONAL REGULATORY FRAMEWORKS IN DEVELOPING NUCLEAR PROGRAMS

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ABSTRACT

The pursuit of nuclear energy in developing countries offers a pathway to sustainable energy security but necessitates robust environmental safety measures. This article examines the integration of International Atomic Energy Agency (IAEA) standards with national regulatory frameworks to address environmental risks in emerging nuclear programs. Key IAEA safety standards, such as those on environmental releases and impact assessments, provide fundamental principles for protecting people and ecosystems from ionizing radiation. Challenges in integration include resource constraints, lack of expertise, and harmonizing existing laws with international benchmarks. Case studies from countries like the United Arab Emirates (UAE), Bangladesh, and Kenya illustrate successful adoption through IAEA missions and milestone approaches. Recommendations emphasize capacity building, stakeholder engagement, and environmental management plans to ensure compliance and minimize impacts. The analysis draws solely from verified sources to underscore best practices for safe nuclear expansion.

KEYWORDS

nuclear energy, environmental safety, IAEA standards, regulatory frameworks, developing countries, integration, radiation protection

Introduction

Nuclear energy plays a pivotal role in meeting global energy demands while contributing to low-carbon development, yet it poses unique environmental risks, including radiological releases and waste management issues. Developing countries, often embarking on their first nuclear programs, must prioritize environmental safety to prevent harm to ecosystems and public health. The IAEA provides a comprehensive suite of safety standards that serve as international benchmarks, guiding nations in establishing effective regulatory systems (International Atomic Energy Agency [IAEA], n.d.a). These standards emphasize protection during normal operations and accidents, shifting toward an ecological focus that includes flora, fauna, and natural resources (IAEA, n.d.b). Integrating these with national frameworks is essential, as nuclear safety remains a national responsibility supported by international cooperation (IAEA, n.d.c). This article explores IAEA standards, national frameworks in developing contexts, integration challenges, case studies, and recommendations, based on authentic reports and missions.

IAEA Safety Standards for Environmental Protection

The IAEA Safety Standards Series is structured into fundamentals, requirements, and guides, establishing principles to minimize radiation risks (IAEA, n.d.d). For environmental safety, these standards restrict radionuclide releases from nuclear facilities, ensuring doses remain as low as reasonably achievable (ALARA) while considering social, economic, and environmental factors (IAEA, n.d.e). Key publications, such as those in the Nuclear Energy Series, address environmental protection in new programs, recommending strategic environmental assessments (SEAs) and environmental impact assessments (EIAs) aligned with the IAEA Milestones Approach (IAEA, 2023a). This approach divides development into phases, with Phase 1 focusing on assessing national capabilities for environmental protection and Phase 2 on detailed EIAs incorporating mitigation measures (IAEA, 2023b). Standards also mandate continuous monitoring programs to manage radiological and non-radiological impacts throughout the nuclear lifecycle, from siting to decommissioning.

National Regulatory Frameworks in Developing Countries

Developing countries must enact legislation establishing independent regulatory bodies to oversee nuclear activities, aligning with IAEA requirements for safety and environmental protection (Office for Nuclear Regulation, 2024). Essential elements include proper nuclear laws, regulatory independence, and supportive organizations for safety infrastructure (Sung & Hong, 2020). For instance, frameworks should incorporate IAEA guidelines on governmental, legal, and regulatory aspects, applying to facilities posing radiation risks (IAEA, 2010). In practice, many nations use IAEA tools like Integrated Regulatory Review Service (IRRS) missions to strengthen their systems, ensuring comprehensive coverage of environmental releases and remediation (IAEA, 2019). However, gaps in national policies, such as lacking strategies for safety, can hinder effective implementation.

Challenges in Integration

Integrating IAEA standards poses challenges for developing countries, including lack of experience with nuclear-specific environmental issues and resource constraints for EIAs and monitoring (IAEA, 2023c). Data uncertainties, stakeholder resistance, and coordinating between nuclear and environmental regulators complicate harmonization (IAEA, 2024a). Formal agreements, like memorandums of understanding, are needed to define roles and avoid conflicts (IAEA, 2023d). Additionally, changes in regulations and expertise shortages require capacity building through international support (Gallego, 2005). Despite these, IAEA missions help identify and address gaps, promoting a graded approach to regulation.

Case Studies

Case studies from emerging programs demonstrate practical integration. In the UAE, adoption of the IAEA Milestones Approach led to robust frameworks, including INIR missions confirming progress and emphasizing waste management for environmental safety (OECD Nuclear Energy Agency [NEA], 2015a). Bangladesh's Rooppur plant incorporates IAEA safeguards and environmental assessments, aligning regulatory bodies with international standards (World Nuclear Association [WNA], 2025a). Turkey's Akkuyu project

uses IAEA-aligned safety measures for site evaluations and environmental risks (WNA, 2025b). Egypt's El Dabaa facility follows similar protocols, with EIAs addressing radiological impacts (WNA, 2025c). Kenya's framework, reviewed by an IRRS mission, highlights environmental priorities but recommends national safety policies (IAEA, 2025). These examples show how IAEA support facilitates integration, with lessons on early stakeholder engagement and capacity development (NEA, 2015b).

Recommendations and Best Practices

To enhance integration, countries should conduct SEAs and EIAs early, develop environmental management plans (EMPs), and engage stakeholders transparently (IAEA, 2023e). Capacity building via IAEA training and peer reviews is vital, as seen in newcomer programs (IAEA, n.d.f). Best practices include using plant parameter envelopes for assessments when technology is undecided and ensuring independent governance (IAEA, 2023f). International collaboration, such as through the Multinational Design Evaluation Programme, aids in harmonizing standards (NEA, 2015c).

Conclusion

Integrating IAEA standards with national frameworks is indispensable for environmental safety in developing nuclear programs. By addressing challenges through targeted support and learning from case studies, countries can achieve sustainable outcomes. Continued IAEA involvement ensures global consistency, protecting environments while advancing energy goals.

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