Gap Analysis of the Draft Libyan Nuclear Law for Harmonization of Safety Requirements with IAEA Safety Standards

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1. Introduction

Nuclear technology's activities are diverse and vital in such that; nuclear reactors generate significant and consistent electricity while emitting minimal greenhouse gas emissions, making nuclear energy a substantial factor in decreasing global carbon footprints; the medical field uses nuclear technology for diagnostics and treatments, such as PET scans, X-rays, and radiation therapy for cancer patients; the industry uses non-destructive testing and material analysis; scientists utilizes nuclear techniques in research fields like physics and chemistry; additionally, the agriculture industry employs nuclear technology for pest control and to preserve food through irradiation, extending the lifespan of consumable goods [1].

For ensuring the safety of facilities and activities in utilizing a nuclear power program, national laws shall mandate radiation protection measures and comprehensive emergency preparedness plans for protecting human life, health, and the environment against radiation exposure. Radiation protection consists of personal protective equipment, regulated and controlled access to high-radiation areas, and continuous radiation levels monitoring. Emergency response plans are also critical, defining procedures for evacuation, medical treatment, and public communication in case of nuclear accidents. Facilities must also provide regular training and certification for employees to handle nuclear materials safely and respond to emergencies effectively. Frequent education programs will ensure the staff stays updated on the latest safety practices and technological advancements [2].

Therefore, national nuclear laws empower the safe use of nuclear energy through a robust regulatory framework that includes licensing, strict safety standards, and the establishment of independent regulatory bodies. The operation of nuclear facilities requires permits and licensing, which are only granted after extensive safety inspections. National safety standards are aligned with the international requirements established by organizations like the International Atomic Energy Agency (IAEA) to maintain a consistent and superior level of safety. Independent regulatory authorities, such as the Nuclear Regulatory Commission (NRC) in the United States of America (USA), enforce these regulations, conduct regular inspections, and ensure compliance with safety standards [3].

In this regard, many countries approach the legal regulation of nuclear energy by establishing and developing national legal frameworks that align with international standards and agreements and tackling specific local demands and restrictions. Nations such as China emphasize the peaceful use of nuclear energy and have implemented a comprehensive legislative framework by directly adopting IAEA safety standards to assure safety and innovation in terms of the utilization and regulation of nuclear energy [4]. Likewise, some countries, such as EU countries, Canada, Japan, and Korea, included international soft law measures, including IAEA safety standards, within their municipal laws to ensure compliance with international standards [5].

To establish the legal and regulatory framework for safety for the effective regulatory control of facilities and activities to a nuclear power program, the most significant legal challenges in regulating nuclear energy involve assuring compliance with international standards, protecting the threats of nuclear proliferation and security, managing radioactive waste, and evaluating the benefits and risks of nuclear energy use. Regulatory frameworks must be revised regularly to address new technology developments and arising threats [6].

Therefore, this study aims to conduct a comprehensive gap analysis of the draft Libyan Nuclear Law to ensure it complies with IAEA Safety Standards. By comparing the current draft against international best practices, the study will identify the gaps in essential areas such as radiation protection, emergency preparedness, and radioactive waste management. The aim is to develop a regulatory framework in Libya that encourages robust licensing processes, rigorous safety standards, and adequate regulatory supervision. Aligning Libya's nuclear law with IAEA standards will improve international collaboration, transparency, and nuclear safety measures within the country, assuring adherence to global safety standards.

2. Libyan approach for establishing legal and regulatory framework

2.1 Libyan nuclear program

Libya's nuclear ambitions began in the 1970s under Colonel Muammar Qadhafi. At first, it was intended for peaceful purposes. However, Libya's nuclear energy program was deferred due to the violation of international law under the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) [7]. Table I outlines the key milestones in the history of the Libyan nuclear program, showing its progression from initial membership in the IAEA to recent cooperation agreements and regulatory developments.

Table I: The history of the Libyan nuclear program [8].

Year	Event
1963	Libya became a member of the IAEA.
1970s	Libya cancels intentions to construct a 440 MW, Soviet-supplied reactor near Sidra Gulf.
1973	Establishing the Libyan Atomic Energy Establishment (LAEE).
1975	Signing a cooperation protocol on nuclear power plants (NPP) with Russia.
1977	Signing the construction contract of Tajura Nuclear Research Center (TNRC) and the NPP.
1978	TNRC construction started.
1980	Libya and IAEA reach an agreement to allow international inspection of all of Libya's nuclear sites.
1983	Tajura reactor started operation with a nominal power of 10 MW.
1986	The NPP Program stopped.
1988	Libya prohibits the production of nuclear weapons as part of an agreement intended to promote global peace.
1992	Libya disclosed all its nuclear facilities to the IAEA inspectors to prove it has no hidden nuclear weapons manufacturing project.
1996	Libya signed the African Nuclear-Weapons-Free-Zone Treaty.
2007	Libya announces pending nuclear cooperation with the USA for electricity production, water desalination, and radiochemistry.
2008	The USA-Libya Science and Technology Cooperation Agreement
2008	Re-establishing of the LAEE.
2009	Establishing of Nuclear Regulatory Office (NRO) as a part of LAEE

On December 19, 2003, Libya agreed to give up its weapons of mass destruction; after abandoning the secret nuclear program in late 2003, Libya intended to establish a nuclear power infrastructure for electricity generation, medical isotopes manufacture, and seawater desalination. Nevertheless, Libya's nuclear program's future remains uncertain since the political situation heavily influences it. If Libya achieves political stability, it may reconsider nuclear power ambitions, focusing on peaceful uses such as electricity production, water desalination, and medical isotopes. However, significant international support, investment, and robust regulatory frameworks would be required to assure compliance with international nuclear safety and non-proliferation standards.

Therefore, Libya is party to the following instruments (Table. II) in the areas of nuclear safety and security: Convention on Nuclear Safety, Convention on Early Notification of a Nuclear Accident, Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, and Convention on the Physical Protection of Nuclear Material and its Amendment. Libya has concluded a safeguards agreement and an additional protocol with the IAEA in non-proliferation and safeguards. It is worth mentioning that Libya has expressed a political commitment to the IAEA's Code of Conduct on the Safety and Security of Radioactive Sources and the Supplementary Guidance on the Import and Export of Radioactive Sources but did not make such commitment regarding Guidance on the Management of Disused. Regarding nuclear safety, Libya is not a party to the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management. It is also not a party to any instruments establishing an international regime for civil liability for nuclear damages. Libya might consider becoming a party to those instruments.

Currently, Libya's nuclear journey emphasizes the need for robust international nuclear safety and non-proliferation regimes. In this regard, the IAEA's continuing oversight of Libya's nuclear materials demonstrates the need for rigorous international control to prevent the misuse of nuclear materials. Therefore, the Libyan government recognized the importance of robust legal and institutional frameworks for managing and securing nuclear materials, particularly in countries with unpredictable political environments for ensuring nuclear safety and security.

2.2. Developing Libyan nuclear law

Establishing a comprehensive legal and regulatory framework for the management and safety of nuclear materials and activities in Libya was a critical step in the draft Libyan Nuclear Law. This legislation aims to align national nuclear policies with international standards established by the IAEA. Several international legal instruments were adopted under the IAEA auspices while developing the draft law. Also, the IAEA played an essential role in nuclear law by creating and developing international safety standards, offering guidance, and promoting international cooperation on nuclear issues. The IAEA ensures the safe and secure utilization of nuclear energy and technology, encouraging peaceful uses of nuclear energy while preventing and mitigating risks connected to its usage [9].

Table II: Libya's status vis a vis international legal instruments [10].

Agreements		
	Title	Status
ASSIST	Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency	accession: 1990-06-27
CPPNM	Convention on the Physical Protection of Nuclear Material	accession: 2000-10-18
NOT	Convention on Early Notification of a Nuclear Accident	accession: 2009-08-13
NS	Convention on Nuclear Safety	accession: 2009-08-13
CPPNM/A	Amendment to the Convention on the Physical Protection of Nuclear Material	ratification: 2006-07-19
VC/OP	Optional Protocol Concerning the Compulsory Settlement of Disputes	Non-Party
P&I	Agreement on the Privileges and Immunities of the IAEA	Non-Party
JP	Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention	Non-Party
VC	Vienna Convention on Civil Liability for Nuclear Damage	Non-Party
RADW	Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management	Non-Party
PVC	Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage	Non-Party
SUPP	Convention on Supplementary Compensation for Nuclear Damage	Non-Party
Technical Cooperation Agreements		
1403	Application of safeguards in connection with the Treaty on Non- Non-Proliferation of Nuclear Weapons	Signature: 1980-07-08
1806	Protocol Additional to the Agreement between Libya and the IAEA for the Application of Safeguards in connection with the Treaty on the Non-Proliferation of Nuclear Weapons	Signature: 2004-03-10

At first, an approach to develop the Libyan Nuclear Law is to integrate the following primary standards (Table III) in order to ensure it aligns with international best practices and the IAEA safety standards. The law covers various aspects of nuclear safety, security, and radiation protection, which are essential for the peaceful use of nuclear technology. Through addressing gaps and aligning with IAEA safety standards, the draft law aims to ensure regulatory independence, adequate safety and security measures, radiation protection, and emergency preparedness. The current structure of the Draft Law contains eleven parts as follows:

- Part I: General provisions
- Part II: The Nuclear Regulatory Authority
- Part III: Regulatory system
- Part IV: Nuclear and radiation safety
- Part V: Nuclear security and safeguards
- Part VI: Emergency preparedness and response
- Part VII: Safety and decommissioning of installations and facilities
- Part VIII: Import, export, and transport
- Part IX: Radioactive waste and spent nuclear fuel
- Part X: Civil liability and penalties
- Part XI: Final Provisions

Table III. Essential IAEA standards should be integrated into the draft Libyan nuclear law.

Category	Series No. & Title
IAEA Safety Standards Series	
Safety Fundamentals	SF-1: Fundamental Safety Principles
General Safety Requirements	GSR Part 1 (rev.1): Governmental, Legal, and Regulatory Framework for Safety, GSR Part 2: Leadership and Management for Safety, GSR Part 3: Radiation Protection and Safety of Radiation Sources, GSR Part 4 (rev.1): Safety Assessment for Facilities and Activities, GSR Part 5: Predisposal Management of Radioactive Waste, GSR Part 6: Decommissioning of Facilities, and GSR Part 7: Preparedness and Response for a Nuclear or Radiological Emergency
Category	Series No. & Title
Specific Safety Requirements	SSR-2/1 (rev.1): Safety of Nuclear Power Plants: Design, SSR-2/2 (rev.1): Safety of Nuclear Power Plants: Operation, SSR-3: Safety of Research Reactors, SSR-4: Safety of Nuclear Fuel Cycle Facilities, SSR-5: Disposal of Radioactive Waste, and SSR-6 (rev.1): Regulations for the Safe Transport of Radioactive Material
General Safety Guides	GSG-7: Occupational Radiation Protection, GSG-9: Regulatory Control of Radioactive Discharges to the Environment, GSG-16: Leadership, Management, and Culture for Safety in Radioactive Waste Management, WS-G-5.1: Release of Sites from Regulatory Control on Termination of Practices, WS-G-5.2: Safety Assessment for the Decommissioning of Facilities Using Radioactive Material, and WS-G-6.1: Storage of Radioactive Waste

Specific Safety Guides	SSG-23: The Safety Case and Safety Assessment for the Disposal of Radioactive Waste, SSG-33 (Rev.1): Schedules of Provisions of the IAEA Regulations for the Safe Transport of Radioactive Material (2018 Edition), SSG-26 (Rev.1): Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (2018 Edition), SSG-40: Predisposal Management of Radioactive Waste from Nuclear Power Plants and Research Reactors, SSG-41: Predisposal Management of Radioactive Waste from Nuclear Fuel Cycle Facilities, SSG-45: Predisposal Management of Radioactive Waste from the Use of Radioactive Material, SSG-47: Decommissioning of Nuclear Power Plants, Research Reactors, and Other Nuclear Fuel Cycle Facilities, SSG-49: Decommissioning of Medical, Industrial and Research Facilities, SSG-60: Management of Residues Containing Naturally Occurring Radioactive Material from Uranium Production and Other Activities, SSG-65: Preparedness and Response for a Nuclear or Radiological Emergency Involving the Transport of Radioactive Material, SSG-78: Compliance Assurance for the Safe Transport of Radioactive Material, TS-G-1.3: Radiation Protection Programmes for the Transport of Radioactive Material, and TS-G-1.4: The Management System for the Safe Transport of Radioactive Material
IAEA Nuclear Security Series	NSS No. 2-G (Rev.1): Nuclear Forensics in Support of Investigations, NSS No.3: Monitoring for Radioactive Material in International Mail Transported by Public Postal Operators, NSS No.4: Engineering Safety Aspects of the Protection of Nuclear Power Plants against Sabotage, NSS No.5: Identification of Radioactive Sources and Devices, NSS No.6: Combating Illicit Trafficking in Nuclear and Other Radioactive Material, NSS No.13: Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities, and NSS No.14: Nuclear Security Recommendations on Radioactive Material and Associated Facilities
IAEA Safety Reports Series	No.21: Optimization of Radiation Protection in the Control of Occupational Exposure, and No.27: Monitoring and Surveillance of Residues from the Mining and Milling of Uranium and Thorium
IAEA Glossary	Safeguards Glossary, Nuclear Safety and Security Glossary, and Radioactive Waste Management Glossary
IAEA Nuclear Energy Series	NG-T-3.14: Building a National Position for a New Nuclear Power Programme, NG-G-3.1 (Rev. 1): Milestones in the Development of a National Infrastructure for Nuclear Power, and NW-G-1.1: Policies and Strategies for Radioactive Waste Management
IAEA Conventions	Convention on Nuclear Safety, Convention on Civil Liability for Nuclear Damage, Convention on Early Notification of a Nuclear Accident, Convention on the Physical Protection of Nuclear Material, Convention on Supplementary Compensation for Nuclear Damage, Convention on Third-Party Liability in the Field of Nuclear Energy, Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, and Convention on the Safety of Spent Fuel and the Safety of Radioactive Waste Management

3. Gap analysis for harmonization with International Standards

3.1 Approaches for gap finding

The gap analysis has been systematically conducted to compare the draft Libyan Nuclear Law provisions with the IAEA Safety Standards and relevant documents. This method Included several key Steps:

(a) The draft Libyan Nuclear Law was extensively reviewed to understand its scope, objectives, and specific regulatory provisions. This review included identifying every relevant part, section, and article to map out the framework established by Libyan authorities.

(b) The Libyan Nuclear Law article was compared thoroughly with the corresponding IAEA Safety Standards elements. This comparison aimed to identify gaps, inconsistencies, and areas where the Libyan Law either meets or falls short of international standards. IAEA Safety Standards were categorized into relevant sections such as regulatory framework, radiation protection, nuclear facility safety, emergency preparedness, and radioactive waste management. Each article of Libyan Nuclear Law matched the corresponding IAEA standards, which involved a clause-by-clause analysis to ensure all aspects were covered. Gaps were detected where the Libyan Nuclear Law lacked specific provisions, had less strict requirements, or had contradictory regulations compared to the IAEA standards.

(c) Utilizing predefined templates and checklists from the IAEA and other nuclear regulatory frameworks to ensure a comprehensive review. These tools assist in methodically identifying compliance levels and areas that need improvement.

(d) Specific recommendations were developed based on the findings of the comparative analysis. These recommendations aimed to address the identified gaps, improve compliance with international standards, and ensure the robustness of the regulatory framework. Each recommendation was made to be practical and relevant to the Libyan environment.

In the gap analysis, the following information was applied to ensure a complete and accurate gap analysis:

(a) The draft Libyan Nuclear Law is the primary document defining the proposed regulatory framework for nuclear activities in Libya. This draft provided the foundation for identifying areas of comparison with international standards.

(b) The IAEA Safety Standards provide a comprehensive set of global guidelines for protecting health and minimizing risks to people and the environment from nuclear and radiation activities. These standards contain safety fundamentals, requirements, and guidance, which the Libyan Law was evaluated in comparison to [11].

(c) Other international treaties and nuclear safety and security conventions were reviewed to verify that the Libyan Law aligns with broader international obligations. These documents provided more background and guidelines for the analysis.

(d) Research papers, case studies, and articles provided additional perspectives on effective nuclear regulation and the challenges various countries face in implementing such frameworks. These sources contributed to the validity of the gap analysis findings and recommendations.

This methodology provided a comprehensive and accurate assessment of Libyan Nuclear Law in contrast to international standards, ensuring that all recommendations are reasonable and relevant and aiming to improve Libya's nuclear regulatory environment.

3.2 Results and recommendations

In order that the draft law is intended to provide a comprehensive legal framework for regulating the peaceful uses of nuclear technology in Libya, the gap analysis has identified several critical areas for improvement in the draft Libyan Nuclear Law to comply with IAEA Safety Standards and relevant global norms. The summary of the gap analysis results and recommendations are stated in Table IV.

The main elements of nuclear law are covered; however, some must be adequately addressed. Consideration should be given to revising the relevant provisions according to international standards.

The draft Law shall be organized according to Libya's existing legal drafting practices to ensure consistency and coherence. While the overall structure is generally coherent, some overlaps exist, particularly between Part IV and Part VII. Consideration should be given to merging these parts and creating a distinct section dedicated to mining. This restructuring will eliminate redundancies and enhance clarity.

Table IV. Results and recommendations

Provision	Gap	Recommendation
Part I: General provisions		
Section 1 Definitions		
	Some definitions must be more precise, and some are not used throughout the draft law.	Align definitions with IAEA glossaries. Ensure all defined terms are consistently used throughout the draft law.
Section 2 Purpose, objectives, and scope of application		
	The exclusion clause in Article 5 is not specific and allows the regulatory body to exclude exposure practices and activities.	Specify that only types of exposure, not practices or activities, can be excluded from regulatory control to ensure comprehensive oversight of all activities.
Part II: The Nuclear Regulatory Authority		
Section 1 Establishment of the authority – functions and powers		
	The reporting structure lacks clarity, potentially undermining the NRA's independence.	Specify that the NRA reports directly to the highest state authorities, such as the Parliament.
Section 2 Management of the authority		
	The qualifications and experience required for board members are unspecified. There are no clear grounds for dismissal and detailed responsibilities for safety, security, and regulatory control.	Specify the qualifications and experience needed for board members, establish clear grounds for dismissal, and ensure their independence through conflict-of-interest policies. Detail the regulatory body's responsibilities for safety and security.
Section 3 Human and financial resources		
	It permits grants, subsidies, and donations but does not explicitly prohibit donations from entities subject to the Authority's regulatory control.	Prohibit donations from entities under the Authority's control, allowing other contributions only with Prime Ministerial approval to prevent conflicts of interest and maintain regulatory integrity.

Part III: Regulatory system	
Section 1 General rules	
The draft lacks compliance with "all applicable requirements" and clarity on transporting nuclear and radioactive material. It also does not define "secure" and "protected" per IAEA standards.	To ensure comprehensive regulatory oversight, specify compliance with "all applicable requirements" and fundamental principles, including transporting nuclear and radioactive material, and define terms like "secure" and "protected" per IAEA definitions.
Section 2 Notification and registration	
The distinction between permits, licenses, and registration is not maintained, and the "magnitude and nature of the risk" is not referenced in determining regulatory control.	Maintain a clear distinction between permits, licenses, and registration, and reference the "magnitude and nature of the risk" to ensure a risk-based approach consistent with IAEA standards.
Section 3 Review and evaluation	
It needs detailed requirements for the review and assessment process. The term "conditional license" is not clearly defined.	State explicitly that the review and evaluation process applies to registration and licensing to ensure clarity and comprehensive oversight. Clearly define "conditional license," specifying the conditions and obligations.
Section 4 Licenses and permits	
The terms "license," "permit," and "approval" are inconsistently used and lack clear definitions in the law and regulations. The NRA's responsibilities regarding authorizations need delineation.	Provide consistent definitions for "license," "permit," and "approval" to avoid ambiguity. Delineate the NRA's responsibilities in granting, amending, renewing, suspending, and revoking authorizations.
Section 5 Inspection and enforcement	
It lacks clarity on the responsibility for issuing inspection standards and regulations and does not specify if facilities or activities are under another authority's control.	Define the responsibility for issuing inspection standards and regulations and specify control over facilities or activities for proper coordination. Implement a rigorous process for selecting, training, and certifying inspectors per IAEA standards.
Part IV: Nuclear and radiation safety	
Terms like "radiation workers" are unclear, and there are no specified personal dosimetry requirements as the licensee's responsibility. Calibration facility approval is not assigned to the regulatory authority.	Define "radiation workers," shift personal dosimetry responsibility to licensees, ensure continuous professional development, and assign calibration facility approval to the regulatory authority.
Part V: Nuclear security and safeguards	
Section 1 Physical protection	
The term "physical protection" doesn't cover the broader concept of "nuclear security" and lacks references to IAEA documents, material categorization, and assessment methodologies.	Rename "physical protection" to "nuclear security" to align with the law's definitions. Refer to IAEA documents for material categorization, specifically NSS No. 13, and replace "classification" with "categorization."
Section 2 Safeguards and Verification	
It fails to explicitly reference IAEA guidelines for SSAC, detailed standards for accounting, control, verification, record-keeping, and reporting, and a protocol for sensitive information protection.	Explicitly reference IAEA guidelines for SSAC, ensure accounting, control, and verification standards, and include detailed procedures for record-keeping and reporting. Establish a protocol for information protection.
Part VI: Emergency preparedness and response	
The committee's emergency preparedness and response plans exclude nuclear and radiological emergencies from malicious acts and lack representation from nuclear security stakeholders.	Ensure planning covers nuclear and radiological emergencies caused by malicious acts and includes relevant nuclear security stakeholders in the Committee. Review Part VI to reference nuclear security events.
Part VII: Safety and decommissioning of installations and facilities	
Section 1 Nuclear and radiological installations and facilities	
There is a repetition between Article 87 with Article 31 and Article 89 with Article 47. Lack of detailed criteria for each stage of the facility's lifecycle.	Consolidate Article 87 with Article 31 and Article 89 with 47 to ensure licensing covers all facility lifecycle stages. Mandate regular updates of the safety analysis report.
Section 2 Mining and processing facilities	
Article 92 does not link with general mining legislation or specify radioactive material concentrations. It lacks comprehensive coverage of activities, including closure and decommissioning.	Link Article 92 with general mining legislation to cover comprehensive safety and radiation protection requirements. Include all activities, such as closure and decommissioning.

Section 3 Decommissioning		
	It does not include detailed decommission plan requirements, specifications for financial assurance criteria for the decommissioning licensing process, or cost estimation requirements.	Include detailed decommission plan requirements to ensure alignment with IAEA standards. Include articles for accurately estimating decommissioning costs and securing economic resources to cover these costs.
Part VIII: Import, export, and transport		
	Does not consistently use the term "authorization holder" and does not outline the detailed responsibilities of all parties involved in transport.	Use the term "authorization holder" consistently and outline detailed responsibilities of all parties involved in transport to ensure all stakeholders know their duties and comply with established safety and security standards.
Part IX: Radioactive waste and spent nuclear fuel		
	Does not include articles for predisposing and classifying radioactive waste, nor does it explicitly prohibit the export of radioactive waste and spent fuel.	Include articles for predisposing and classifying radioactive waste and explicitly prohibiting the export of radioactive waste and spent fuel, aligning with international conventions and treaties on waste management.
Part X: Civil liability and penalties		
Section 1 Civil liability for nuclear damage		
	The provision fails to distinguish between "operator" and "owner," specify the operator's strict liability for nuclear damage or align with the Vienna Convention on various liability aspects.	Clarify the distinction between "operator" and "owner," explicitly state the operator's strict liability for nuclear damage, and include articles for transferring liability during transport stages.
Section 2 Penalties		
	The provision does not ensure penalties are proportional to the offense or consistent with international standards, including the CPPNM.	Ensure penalties are proportionate to the offense, consistent with international standards, and aligned with the CPPNM to deter serious offenses and reflect potential harm.
Part XI: Final Provisions		
	Article 132 lacks guidelines for orphan sources and alignment with IAEA standards. The fee structure is non-transparent, with no guidelines for transitioning licenses or a transparent appeals process.	Transfer Article 132 to the safety section and include guidelines for orphan sources per IAEA SSG-19. Ensure a transparent fee structure, provide clear guidelines for transitioning licenses, and define the appeals process.

4. Conclusion

Aligning the Libyan Nuclear Law with IAEA Safety Standards is crucial for enhancing nuclear safety and security, facilitating international collaboration and trust, establishing a clear and effective regulatory framework, and ensuring compliance with global standards. This alignment protects public health and the environment, enables Libya to participate in global nuclear programs, reduces the risk of nuclear incidents through improved regulatory oversight, and enhances transparency and compliance with international norms.

The gap analysis identified several critical areas for improvement in the draft Libyan Nuclear Law: a need for more precise definitions and terminologies to prevent ambiguities; enhanced independence for the NRA to avoid conflicts of interest; more detailed provisions for radiation protection, safety measures, and waste management; comprehensive frameworks for emergency preparedness and response; and more detailed procedures for licensing, inspection, and enforcement processes, along with clear guidelines for the transition of competences from the current regulatory body to the new NRA.

Furthermore, it is also recognized that future research will need to focus on strengthening institutional capacity through training and robust regulatory infrastructures, exploring advanced technologies for nuclear safety and waste management, developing effective public communication and engagement strategies, analyzing the economic and social impacts of adopting nuclear technology, and conducting comparative studies of nuclear regulatory frameworks in other developing countries to identify best practices and lessons learned.

In conclusion, the findings and recommendations from this study provide a structured approach for other developing nations to assess and enhance their nuclear regulatory frameworks, set a benchmark for adopting international safety standards, emphasize the importance of building institutional and human capacity to manage nuclear technology safely and contribute to the global nuclear safety culture by promoting adherence to international standards and fostering international collaboration.

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REFERENCES

[1] A. Bagher, A. Nahid, M. Mohsen, and M. Vahid, Nuclear Techniques in Agriculture and Genetics, American Journal of Bioscience, Vol. 2, No. 102, 2014.

[2] X. Xinsheng, X. Yanjun, L. Hongqiu, W. Xining, S. Sun, Y. Zhihao, L. Yinan, H. Jin, and L. Yulong, Awareness and preparedness level of medical workers for radiation and nuclear emergency response, Frontiers in Public Health, Vol. 12, 2024.

[3] B. Hu, J. Wang, and Y. Wu, Construction and improvement of the nuclear safety legal systems in China: A preliminary analysis, Vol. 44, pp. 323-330, 2014.

[4] D. Ge, Nuclear Laws for Peaceful Uses of Nuclear Energy, In Nuclear Law. T.M.C, Asser Press, pp.29-43, 2022.

[5] Y. Fukui, International Nuclear Security Law: The Use of 'Soft Law', Journal of Conflict and Security Law, Vol. 29, No. 1, pp. 129-142, 2024.

[6] S. Drobysz, A Framework for the Secure Development of Nuclear Energy: Obligations, Challenges and Possible Solutions, pp. 247-275, 2016.

[7] W. Bowen, Tracking and Assessing Nuclear Issues in Open Sources: The Case of Libya, pp. 145-163, 2006.

[8] NTI, Libya Nuclear Overview, James Martin Center for Nonproliferation Studies, 2015.

[9] J. Barkenbus, Nuclear power safety and the role of international organization, International Organization, Vol. 41, pp. 475-490, 1987.

[10] IAEA, Country factsheets: The State of Libya, 2022.

[11] IAEA, Handbook on Nuclear Law: Implementing Legislation, 2010