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Abstract

Bangladesh uses Category I of nuclear materials and Category 1-5 of radioactive materials in the field of research, medicine, and industries. The Bangladesh government is going to implement its first nuclear power plant under an inter-governmental agreement between the Bangladesh and Russian governments. With the emerging global nuclear and radiological terrorism by potential adversaries, enhancing nuclear security is the paramount importance for the country. In our research, we have found no established communication channels among stakeholders in order to work in a coordinated and collaborative manner for strengthening the nuclear security. This has resulted in the lack of importance of education, research, training, and knowledge management initiatives among stakeholders. The development of nuclear security policies at the national and organizational levels is also lacking, as is the development of regulatory documents, technical guidance, and action plans. Thus, we offer suggestions for creating powerful nuclear security governance to collectively tackle the nuclear insecurity dynamics. This paper also suggests establishing an institution under a public university with a global partnership for enhancing and sustainably maintaining the nuclear security regime through developing competent human resources.

I. Introduction

According to the IAEA, nuclear security is the prevention and detection of and response to theft, sabotage, unauthorized access, illegal transfer, or other malicious acts involving nuclear material, radioactive materials, and their associated facilities ***[1]***. Interest in nuclear application is expanding through the introduction of nuclear power in many states due to their needs for energy supplies, to control climate change, and to meet the requirements of development ***[2, 3]***. This growing interest in nuclear power will increase the number of reactors and the amount of nuclear materials in use. With projections of escalating demand for nuclear energy applications, probable malicious acts involving nuclear material and radioactive sources are an issue of growing concern in the global community. There is available information, which indicates that, nuclear and other radioactive materials are permeable to theft, are

unregulated, or are in unauthorized circulation. As of December 31, 2014, the ITDB recorded a total of 2,734 confirmed incidents ***[4]***. It is clear that these threats not only affect the expected growth of nuclear activities but also limit nuclear applications. So it is necessary for every state to establish prudent security measures to prevent such malicious acts and to protect nations from nuclear threat. Proper education, research, and training in nuclear security at all relevant organizations and facilities can play an important role in doing this. More research is greatly needed on emerging threats such as tunnel ***[5]***, drone, and cyber threats at nuclear facilities.

In addition, technologies and procedures are developing at an increasing rate with the introduction of new equipment and techniques. At the same time, continuous loss of qualified personnel due to retirement, carrier development, and administrative changes negatively affects the countries' capabilities to carry out nuclear security tasks successfully. The responsibility for maintaining nuclear security solely depends on each member state. There is a growing need for trained personnel in this field. A trained and knowledgeable workforce can lead to an effective nuclear security regime. Realizing the rising global trend of the nuclear power program, as well as the increasing risk of nuclear security dynamics, nuclear security experts have agreed on the necessity of a comprehensive education program to develop more nuclear security professionals. In this connection, different universities in the global community already have launched Master's degree programs in Nuclear Security. Examples are Delft University of Technology, the Netherlands ***[6]***; the UNWE, Sofia, Bulgaria ***[7]***; University of Cumbria, United Kingdom ***[8]***; University of Central Lancashire, Preston, United Kingdom ***[9]***, Master's and PhD. programs in Nuclear Security and Safeguards under the faculty of Engineering at Chulalongkorn University, Thailand ***[10]***. The duration of each Master's degree program is two years. The syllabus is based on the IAEA Education Program in Nuclear Security ***[11]***. The aim of this education program is to develop the ability of nuclear security managers to efficiently produce strategies and tactics to manage nuclear security hazards and risks within the organization.

In Bangladesh, nuclear material, radioactive sources, and different ionizing radiation producing equipment are being used in research, medical application, industry, agriculture, and mining, for economic uplift and human prosperity. The 3MWth TRIGA Mark II nuclear research reactor, central waste storage, and processing facility, Co-60 irradiator facilities, and nuclear medicine centers under the BAEC are the major nuclear facilities in the country. Other radiation producing facilities include the radiotherapy departments of 13 public and 3 private medical colleges and hospitals, BINA, industrial NDT facilities, energy explorations, and generations facilities, etc.

Furthermore, with the cooperation of the Russian Federation, Bangladesh has achieved a new milestone by starting the first nuclear power plant at the Rooppur site, which will introduce nuclear power as part of its energy mix for sustainable development of the country. In order to effectively manage this large nuclear power program and also to avoid unexpected events that might arise from the operator's or regulator's negligence, an effective national nuclear security infrastructure and follow up of international binding or non-binding instruments are the key requirements to enjoying the benefits of nuclear energy ***[12]***.

Bangladesh is very much aware of the global threat of nuclear and radiological terrorism. The country is deeply committed to fulfilling the obligations under the national framework and international treaties, agreements, conventions, and protocols with regard to nuclear security and radiological emergencies. For this, Bangladesh is actively working with IAEA, USDOE, JAEA, and FNCA to strengthen the country's nuclear security regime. As part of GTRI program of USDOE, BMI signed a contract with BAEC in March 2006 to assist Bangladesh in improving the safety and security of radioactive sources used in the country.

In order to promote nuclear energy and to operate the nuclear installations in a safe, secure, and sustainable manner, the government has given directives to the respective ministries and organizations to launch a nuclear education program for HRDs. In response to this, recently the University of Dhaka ***[13]*** and MIST ***[14]*** have initiated the first-ever nuclear engineering education programs in the country. However, there are no in-depth nuclear security education programs. There are also no trained manpower or noteworthy R&D activities in the regulatory or research establishments.

In this paper, we will state the present status of nuclear security education, research, and training activities and locate the gaps where the state nuclear security regime can be improved. This paper will suggest how to coordinate and cooperate among stakeholders for establishing effective lines of communication. In order to meet the objectives, this paper has six sections. After the introduction in Section I, Section II gives attention to on-going nuclear activities and initiatives in the country. Section III discusses existing national legal frameworks and international instruments to understand their applicability in maintaining the state's nuclear security with regard to the national, regional, and global challenges. Section IV limits discussion to the state's capacity in nuclear security education, research, and training activities. Section V underscores some suggestions for enhancing the nuclear security education, research, training, and knowledge management effort. The paper ends with an overall conclusion in Section VI.

II. Nuclear Installations and Initiatives in Bangladesh

Nuclear power was identified as a viable option for East Pakistan as early as 1960. A site was selected by considering the applicable criteria, and land for the project (260 acres) was acquired at the Rooppur site, 160 km northwest from the capital city of Dhaka. AECD, the pioneer organization of the PAEC was established in 1964 with a few R&D laboratories and a limited facility of Co-60 radioactive sources for applications in the areas of medicine and agriculture. Later in 1965, the AECD started operating a 3MV Van de Graff Accelerator. In 1971, Bangladesh achieved independence from Pakistan through the nine-month bloody liberation war and emerged as a new independent state. After independence in 1971, it considered integrating nuclear power into the long-term electricity generation-mix of the country. BAEC was established in 1973 through the promulgation of the PO-15 of 1973 [15] and started R&D activities in the areas of physical science, bioscience, and engineering. Since then, BAEC is responsible for developing and promoting nuclear activities and support for the nuclear power program in the country. These days, the cooperation of the international community has led to the daily increase of nuclear activities in the country. In the following sections, we address the current status of the country's nuclear installations and initiatives.

A. Rooppur Nuclear Power Project

The site at Rooppur on the bank of the Ganges River was selected in the early 1960s. There were four proposals by the USA, Sweden, the USSR, and Belgium to build the RNPP before 1971. After independence in 1971, a few attempts were made by the BAEC to build the RNPP. Finally, Bangladesh received a technical and financial offer from the Russia Federation to build the RNPP at a time when it was identified in the Power System Master Plan 2010 to generate 2,000 MW_e from nuclear power by 2020 and 6,000 MW_e by 2030. The two countries signed a MoU on May 13, 2009 to pave the way for exchanging nuclear technology and setting up NPPs in Bangladesh. As per terms of the MoU, the Russia Federation agreed to assist in developing the nuclear energy infrastructure in Bangladesh and facilitating implementation of Bangladesh's plan. One year later, on May 21, 2010, Bangladesh and the Russia Federation signed a five-year framework agreement on cooperation for the building of nuclear power plants for the peaceful use of nuclear energy. According to the agreement, the future cooperation between the two countries included design, construction and operation of nuclear reactors, fuel supply throughout the life span of the supplied reactors, and the return of spent fuels. The agreement also includes cooperation for nuclear waste management, personnel education, and training for operation and

maintenance of the plants. On November 2, 2011, Bangladesh signed an IGA with the Russia Federation to set up two NPPs, each with 1,200MWe capacity. In January 2013, Bangladesh and the Russia Federation signed a $500 million loan agreement to cover the feasibility studies, environmental impact assessment, site engineering surveys, preconstruction works, infrastructure development, and personnel training. Based on the site feasibility studies, an AES2006 model VVER type reactor was selected. Now negotiation is continuing to finalize the total cost of two AES 2006 VVER type plants. According to the present schedule, the first reactor will be commissioned in 2022, and in the following year, a second unit will be commissioned ***[16]***. This new nuclear power program will require stringent regulation in order to face nuclear security and safeguards challenges.

B. 3MW$_{th}$ TRIGA Mark II Nuclear Research Reactor

The 3MW$_{th}$TRIGA Mark-II Research Reactor of BAEC is the only nuclear reactor in the country. It has been operating on the campus of AERE, the largest research facility of the BAEC, located at Savar, which is about 40 km away from Dhaka. Bangladesh procured the nuclear research reactor from the USA under bilateral agreements between the US and Bangladesh governments concerning peaceful uses of atomic energy on September 17, 1981. The reactor has been designed and constructed by General Atomics of USA. Installation of the research reactor was started under a non-turnkey project, where local participation was about 50%. The reactor achieved its first criticality on September 14, 1986. The reactor was tested and commissioned fully by the end of October 1986. This may be identified as a major event in the scientific annals of the country.

Since its commissioning, the research reactor has been used for various peaceful applications in the field of nuclear science and engineering. Examples include reactor operator training and education, material characterization through neutron activation, neutron scattering, neutron radiography, and the production of radioisotopes (Tc-99m, I-131, Ho-166 and Sc-46) for medical applications. The reactor has 100 LEU fuel elements whose enrichment level of U-235 is 19.7%. However, to date, the nuclear research reactor has not generated any spent fuel because the original fuel is not completely burn out. Eventually, the generated spent fuels will be taken back to the USA per the supplier commitment. Concerning safety, during the operating lifetime of the nuclear research reactor, the reactor facility has only encountered a couple of technical incidents, which were solved locally ***[17]***.

C. Radioactive Sources and Nuclear Materials

The IAEA has categorized nuclear material and radioactive sources based upon potential health risk and use in nuclear weapons. Nuclear material has three categories, I-III ***[18],*** whereas radioactive material and sources have five categories, 1-5***[19]***. Categorization of nuclear materials is on the basis of material type (plutonium, uranium-235/233), isotope composition, radiation level, and quantity of the material. Category I nuclear materials are extremely dangerous and used for making nuclear explosive devices. The classification of each category of radioactive material and source varies from highest health risk (Category 1) to the lowest (Category 5) and considers the dangerousness of the materials and potential consequences of its use. Radioactive material and sources in categories 1-2 are truly high risk. For example, the amount of radioactivity in one gram of cobalt-60, which is a gamma emitter, is considered hazardous to someone near an unshielded source of this potency after an exposure of only a few minutes. Internal exposures to even microgram amounts of some of the radioisotopes, such as polonium-210, can be fatal. This type of radioactive material is known as radioisotopes, and they possess a different nuclear form of chemical elements. Radioisotopes can either have long or short half-lives, and the length of a radioisotope's half-life is one criterion used in determining risk level of the material for security concerns.

Bangladesh uses different categories of radioactive sources such as Co-60, Cs-137, Sr-90, Am-241, Tc-99^{m}, I-131, I-125, F-18, Kr-85, Ir-192, and Am-Be, as well as different ionizing radiation producing

equipment such as linear accelerators, Co-60 Teletherapy, Brachytherapy, medical cyclotron, Co-60 irradiator, Tc-90m generator, nuclear gauges, luggage scanners, blood irradiators, and smoke detectors, etc., ***[20]***. About 13 public and 3 private medical colleges and hospitals and about 54 commercial companies are using categories 1-5 radioactive sources in the country.

Apart from the use of radioactive sources, Category I of high-risk nuclear material (U-235) is only used in the nuclear research reactor ***[21]***. It is obvious that huge volumes of nuclear materials will also be used in the nuclear power plant if it was to be built. Appendix A lists the category of nuclear material and radioactive sources Bangladesh possesses. According to Appendix A, the highest level of security concern surrounds Category I nuclear material19.7% enriched U-235, which is used as a fuel element in the nuclear research reactor. Meanwhile Categories 1-5 of radioactive sources, organized by level of risk to health, are used in Bangladesh's medical, research, and industrial areas. In order to operate and to maintain the nuclear power plants, research reactor facilities, nuclear and radioactive materials, and sources mentioned in sub-sections A to C, nuclear security related education, research, training, knowledgeable manpower, and a strong regulatory framework are the critical issues. Proper addressing and giving due importance on these critical issues will definitely reduce the risk of nuclear security violations inside the country.

III. Legal Frameworks for Nuclear Security

BAEC was established in 1973 through the PO 15 of 1973.Now, the Government has taken the initiative to introduce the Bangladesh Atomic Energy Law, and it is expected that the measure will soon pass in the National Parliament. Additionally, in June 2012, BAER Act-2012 was passed in the National Parliament. As a result, BAERA, a semi-independent regulatory body, was formed on February 12, 2013 through the promulgation of BAER Act-2012 ***[22]***. The NSRC-1997 is still applicable under the new regulatory act until amendment by new laws.

The BAER Act-2012 is now the main, comprehensive, legal instrument for the management of peaceful uses of atomic energy and concerned matters that include the following: security of nuclear materials and radioactive sources and associated facilities, import and export control of nuclear materials and radioactive sources, ionizing equipment, SSAC, transport security of nuclear materials and radioactive sources, and civil liability for nuclear damage resulting from any nuclear event. According to the newly created BAER Act-2012, BAERA is the legal entity in charge of preparing policy, regulations, and guides on safety, security, and safeguards matters. Its sole responsibility is to regulate all the nuclear and radiological activities in the country. The prime responsibility of the nuclear facility operating organizations is to ensure safety, security, and safeguards matters in compliance with the BAER Act-2012. Apart from the BAER Act-2012 and the Chemical Weapons (Prohibition) Act of 2006, there exist some national laws concerning disarmament, non-proliferation, and the combating of terrorism and financing of terrorism which are shown in Appendix B ***[23]***.

Overall, Bangladesh has a firm commitment to peaceful uses of nuclear science and technology. The country has signed a number of international and bi-lateral agreements, protocols, and conventions related to nuclear security, which are given in Appendix C ***[23]***. Bangladesh also issues timely responses on international instruments upon receiving request or recommendations from the respective organizations. The Government as per the BAER Act-2012 protects all sensitive information related to nuclear security. The rule of punishment for infraction exists in the related legislation. All nuclear facilities are declared as KPI by the state.

IV. Nuclear Security Education, Research, and Training Activities

The Department of Nuclear Engineering at the University of Dhaka is the first of its kind for offering nuclear engineering education in the country. Its journey began in December 2012 with the enrollment of 25 students in an 18-month M.Sc. degree in Nuclear Engineering. One year later, the department created a 4-year B.Sc. major in Nuclear Engineering, enrolling another 25 students at the undergraduate level. Imitating the initiatives of the University of Dhaka, MIST established the Department of Nuclear Science and Engineering in 2015 with B.Sc., M.Sc. and PhD. programs. At both schools, curriculums are partially designed to follow the IAEA nuclear engineering education curricula [24]. BUET is also working to start Nuclear Engineering courses at the Master's level. Among private universities, BRAC University has signed an MoU with BAEC for a joint collaborative program in the area of Nuclear Science and Technology Education.

The B.Sc. and M.Sc. degrees at the University of Dhaka are 161 and 36 credit hour programs, respectively. The B.Sc. program offers a 3 credit compulsory course on nuclear safety, security and safeguards issues. The syllabus covers three nexus issues of the safety, security, and safeguards matters, and its content is given as follows:

Safety: safety principles, safety requirements, safety guides, IAEA safety standard series for regulating and operating NPP and nuclear facilities.

Security: the definition of nuclear security - threat, theft, sabotage, nuclear attacks, historical developments, international protocols, UNSCR-1373, 1540, the IAEA nuclear security document series and hierarchy, member states' obligations towards nuclear security, legal and non-legal binding instruments for member states, legislative and regulatory framework for nuclear security, the physical protection regime and its layers, graded approach, categorization of nuclear materials, PPS designs for protection of nuclear material, radiation, and associated facilities, DBT analysis, detection architecture (border, airport, seaport), regulations for nuclear material and radioactive sources during storage and transport, export and import controls, assessment methodology for nuclear security culture, insider threat analysis, cyber security, and nuclear security event response and neutralization.

Safeguards: NPT, IAEA safeguards systems, evolving safeguards implementation, safeguards agreements, additional protocol agreements, national regulatory framework for safeguards policy and regulation, nuclear material facility inspection guidance, state-level and integrated safeguards concepts, SSAC of nuclear material, safeguards reporting system, safeguards information system, safeguards verification systems, NDAs and DAs, safeguards challenges for fuel fabrication, enrichment, and reprocessing facilities, and safeguards in R&D for advanced nuclear fuel cycles.

The M.Sc. program offers an optional course on nuclear safeguards, safety, security, policy and regulation. The syllabus includes standards and regulations applied for the following: nuclear fuel cycle facilities, concepts of performance-based, risk-informed design and regulations, technical bases for assessing the environmental impacts of nuclear fuel cycle facilities under normal operation and accidental situations, institutional and international political aspects of nuclear and waste management, national laws and regulation for practice of nuclear energy, IAEA policy and regulations, national securities, and international law. Master course students complete theses on different areas of the nuclear security regime.

In a similar way, MIST offers a 3 credit compulsory course in their B.Sc. program in Nuclear Science and Engineering that emphasizes only nuclear security and safeguards issues. The syllabus is very similar to the syllabus for the Nuclear Security and Safeguards at the University of Dhaka. MIST does not include

the safety element in their syllabus. An optional 3-credit course on nuclear safeguards, safety, security, policy, and regulations are included in their 2-year M.Sc. program. Fundamentals of nuclear security and design of the PPS for nuclear facilities are incorporated in their PhD. program with a 3 credit optional course. It can be said that nuclear engineering education both at the undergraduate and graduate levels at the University of Dhaka and MIST give moderate importance to nuclear security education and research. Although both institutes offer fundamentals of nuclear safety, security, and safeguards education, their nexus issues are not truly focused. The syllabi of these courses are not well balanced. These courses should have covered the influence of human factors. Security courses are mostly considered as optional courses at the graduate level. There is a lack of experienced faculty members to run such academic courses with quality teaching. There are also no significant R&D activities present at these education, regulatory, and research establishments.

Apart from the academic and research initiatives, another important area of focus is training initiatives. BAEC mainly organizes training programs, seminars, and workshops with the cooperation of the USDOE, IAEA, and JAEA. The first ever national training program on DBT was held in Dhaka with the cooperation of the IAEA from March 7-9, 2011. The participants were from BAEC, BAERA, law enforcement communities, and radioactive source-using organizations. Under the GTRI program, the USDOE and BAEC jointly organized several seminars, workshops, and training programs for policy makers, regulator, operators, custom inspectors, and law enforcing communities to heighten awareness about the risk of the radioactive sources. A training course on search and security was held in Dhaka from September 9-13, 2012 to provide participants hands-on-training with relevant radiation detection and identification equipment to upgrade their knowledge and improve their practical skills in locating, identifying, packaging, and transporting radioactive sources, especially orphan ones. On March 10, 2013, BAEC organized a seminar on radiological security awareness in Dhaka. Another national training course on physical protection and security management of radioactive sources was held in Dhaka March 11-14, 2013. High-level decision makers from concerned ministries, regulatory authorities, civil aviation authority, radioactive source users, and law-enforcing communities participated in the seminar, and mid-level officers from the same organizations participated in the training program. In order to emphasize the importance of nuclear security culture within the organization, IAEA and BAEC jointly organized a national workshop on nuclear security culture in Dhaka June 18-20, 2013. Representatives from BAEC, BAERA, law enforcing communities, and various radioactive source-using organizations participated in this event. Stakeholders usually select participants through official nomination of the hosting organization (e.g., BAEC). Participating organizations, qualification criteria of participants, and the number of participants are usually set by the sponsored organization, like IAEA. It is noteworthy that with the cooperation of IAEA and JAEA, a significant number of staff members working at BAEC and BAERA receive various level of foreign training every year in the field of nuclear security. However, the opportunities are scant for them to disseminate their knowledge and experiences to others who are mainly responsible for responding to any nuclear security related incident in the country. There is a lack of awareness about the importance of coordination among different competent authorities in conducting courses for train-the-trainer programs. The lack of sufficient training programs, from fundamental and professional courses to various short courses differing in duration, is evident. So there are considerable lapses of nuclear security education, research, training, collaboration, nuclear security governance, and knowledge management activities to enhance the nuclear security regime in order to face global security challenges.

V. Suggestions for Enhancing the Nuclear Security Education and Research

In light of the contents of sections II-IV, some lapses are found in the maintenance of the high standard of security of nuclear installations and initiatives with regard to global initiatives. In order to enhance and

continue sustainable nuclear security, this section suggests creating nuclear security governance and establishing an institution or directorate for education, research, training, and knowledge management.

A. Nuclear Security Governance

At the state level, a nuclear security governance system is necessary to provide better security of nuclear material and other radioactive sources and their associated facilities. In order to ensure security in use, storage and transport of such material and to fight against illicit trafficking and unauthorized movement of such materials, establishing nuclear security governance is an important step. This administrative endeavor would bring opportunities for all stakeholders to work hand in hand to handle any nuclear security event through effective, legal communication channels.

In order to establish a good governance system of nuclear security that is inclusive of all stakeholders, a separate directorate/cell/unit/division can be formed under the BAERA. An independent nuclear security council as an apex body can also be considered. The main function of this unit would be to coordinate and monitor the unauthorized nuclear activities at all of the country's nuclear facilities, borders, coastal lines, seaports, and airports with the cooperation of law enforcement and concerned ministries and operating organizations. A policy for proper communication protocol among stakeholders is needed. All stakeholders may also have separate nuclear security sections/divisions that place nuclear security professionals and offer them the proper equipment to formulate, implement, and oversee specific organizational nuclear security issues.

B. Education, Training, Research, and Knowledge Management

A sustainable nuclear security regime largely depends on a proper education, research, training, and knowledge management effort. In order to develop the human resources area of nuclear security, establishing an institution for education, research, training, and knowledge management is a good choice. This institute can be formed under a public university where nuclear education and research infrastructures and faculties are available. Such an institution could offer training and professional courses to enhance stakeholder personnel's abilities to assess risks and threats by potential adversaries and instruct them how to take proper countermeasures. Upon demand, the institution could also provide a graduate level nuclear security education program with the technical and financial assistance of international organizations like IAEA, EU, and PNS. This institute could play an important role in preserving the knowledge and experience of senior experts and disseminating that knowledge to newcomers.

VI. Conclusion

Bangladesh has a good record of peaceful applications of nuclear activities. Still, security of nuclear and radioactive materials is a national, as well as global, concern. In hopes of establishing a nuclear threat free zone, Bangladesh has already signed some binding and non-binding international instruments related to nuclear security and have begun taking regular measures to fulfill those obligations. The Government has already established the semi-independent BAERA in 2013 under the BAER Act-2012.This is no doubt a significant advancement of the nuclear regulatory framework in the country. Now the regulatory authority needs to offer training programs and short courses. It must also develop nuclear security policy at the national and organizational levels and create regulatory documents and technical guidance in order to control and monitor nuclear materials, radioactive sources, and associated facilities to ensure safety, security, and sustainability. Specific guidance for DBT analysis (insider and cyber), detection and response procedures are yet to be developed, as are a work plan and operating procedures for the physical security system.

Introducing nuclear power programs for newly nuclear countries like Bangladesh is a great challenge in terms of safety, security, and safeguards matters. Although the country has been practicing nuclear services and R&D activities since 1964, formal education programs in nuclear education did not begin until 2012. In the course curricula, nuclear safety is highlighted much more than nuclear security and proliferation matters. To date, there is no specific full credit course in nuclear security or safeguards offered at the University of Dhaka or MIST. Furthermore, the importance of these matters is still not well developed in the mindset of relevant stakeholders in the country. However, limited studies, research, and training activities on nuclear security matters have been started at academic institutions, regulatory bodies, and research establishments. It is well understood that nuclear threat risks are increasing with the enlargement of nuclear activities. Enhancement of nuclear security activities is greatly needed. However, the present education, research, and training activities are not sufficient to face the global insecurity dynamics. Establishment of effective nuclear security governance with proper communication policies and coordination among stakeholders will ameliorate nuclear security infrastructure in Bangladesh. This initiative will surely increase awareness of such issues, as well as enhance the nuclear security culture among organizational employees. Furthermore, establishing a nuclear security institution under a public university, with the cooperation of the government and international organizations, can fill the gaps in education, research, and training in the nuclear security regime.

VII. Appendices

A. Security Concerns of Nuclear Material and Radioactive Sources in Bangladesh

Nuclear material	**Half Life**	**Energy Emission**	**Material /Source category**	**Application**
Uranium-235 (U-235)	700 million years	Alpha, Gamma	I	Fuel Element
Radioactive sources				
Cobalt-60 (Co-60)	5.3 years	Beta, Gamma	1/2/3/4	Brachytherapy, Radiotherapy, Teletherapy, Sterilization and Food irradiation, Industrial radiography etc.
Cesium-137 (Cs- 137)	30.2 years	Beta, Gamma	1/2/3	Treatment and thickness measurement
Iridium-192 (Ir-192)	74 days	Beta, Gamma	2	Non Destructive Testing (NDT), Industrial X-ray
Americium-241	430 years	Alpha, Gamma	3	Radiation Source
Mixture of Americium-241/Beryllium (Am-241/Be)	432.2 years	Neutron, Gamma	3	Neutron source, Well-logging
Scandium-46 (Sc-46)	83.8 days	Beta,	3	Isotope hydrology,

		Gamma		Oil refinery
Technetium 99^{m} (Tc-99^{m})	6.0 hours	Gamma	4/5	Medical diagnostic
Iodine-131 (I-131)	8.0 days	Beta, Gamma	4/5	Medical diagnostic and treatment

B. National Legal Instruments

National Laws Concerning Disarmament and Non-proliferation
Bangladesh Atomic Energy Regulatory Act (BAERA)-2012
Nuclear Safety and Radiation Control Rules (NSRC)-1997
The Chemical Weapons (Prohibition) Act -2006
National Laws Concerning Combating Terrorism and Financing of Terrorism
The Anti-Terrorism Act-2009
The Revised Anti-Terrorism Act-2012
Anti-Terrorism Rules-2013
Money Laundering Prevention Act-2012
Money Laundering Prevention Rules-2013

C. Commitments of Bangladesh to International Instruments

Relevant International Treaties/Conventions	**Bangladesh Became Party/Signed**
Convention on the Treaty on the Non-Proliferation of Nuclear Weapons (NPT)	1979
Convention on Assistance in the Case of Nuclear Accident or Radiological Emergency	1988
Convention on Early Notification of a Nuclear Accident	1988
Chemical Weapons Convention	1997
Convention on the Physical Protection of Nuclear Material (CPPNM)	2005
United Nations Security Council Resolution (UNSCR) 1540 on Non-proliferation of Weapons of Mass Destruction (WMD)	2004
International Convention for Suppression of Acts of Nuclear Terrorism ((ICSANT)	2007
Arms Trade Treaty (ATT)	2013

D. Acronyms and Abbreviations

Acronym	**Abbreviation**
AERE	Atomic Energy Research Establishment
AECD	Atomic Energy Centre, Dhaka
ATT	Arms Trade Treaty
BAERA	Bangladesh Atomic Energy Regulatory Authority
BINA	Bangladesh Institute of Nuclear Agriculture

BAEC	Bangladesh Atomic Energy Commission
BUET	Bangladesh University of Engineering and Technology
BRAC	Building Resources Across Communities
BMI	Battelle Memorial Institute
CPPNM	Convention on the Physical Protection of Nuclear Material
DBT	Design basis threat
DA	Destructive assay
EU	European Commission
FNCA	Forum for Nuclear Cooperation in Asia
GTRI	Global Threat Reduction Initiative
HRD	Human resource development
IAEA	International Atomic Energy Agency
IGA	Intergovernmental agreement
ITDB	Incident and Trafficking Database
ICSANT	International Convention for Suppression of Acts of Nuclear Terrorism
JAEA	Japan Atomic Energy Agency
KPI	Key point installation
LEU	Low enriched uranium
MIST	Military Institute of Science and Technology
MoU	Memorandum of understanding
NDT	Nondestructive test
NDA	Nondestructive assay
NPP	Nuclear power plant
NPT	Non-Proliferation Treaty
NSRC	Nuclear Safety and Radiation Control
PNS	Partnership for Nuclear Security
PPS	Physical protection system
PO	Presidential order
PAEC	Pakistan Atomic Energy Commission
R&D	Research& development
RNPP	Rooppur Nuclear Power Plant
SSAC	State system of accounting for and control of nuclear material
TRIGA	Training, Research, Isotopes, General Atomics
UNWE	University of National and World Economy
UNSCR	United Nations Security Council Resolution
USA	United States of America
UK	United Kingdom
USSR	Union of Soviet Socialist Republic
USDOE	US Department of Energy
VVER	Vodo-Vodyanoi Energetichesky Reaktor
WMD	Weapons of mass destruction

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