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## Analysis of the Institutional Framework for Radioactive Waste Management in Bangladesh

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### ABSTRACT

Bangladesh utilizes radioactive materials and radiation sources for a wide variety of peaceful purposes in industry, medicine, agriculture, research and education. At present, Bangladesh does not have nuclear power plant (NPP), so that the radioactive waste is mainly coming from above mentioned fields. Although Bangladesh has quite good infrastructure for the management of present radioactive waste, it needs improvement especially for the disposal program of the existing and future radioactive waste. This improvement of infrastructure is an important factor for preparation of future nuclear power plant (NPP) operation. The framework for institutional radioactive waste management in Bangladesh has been analyzed in this study. The analysis has been done using several key factors based on policy and strategy, regulatory authorities and their regulations, implementing organizations, participation of stock-holders and financial system. By considering the international trends and the Bangladeshi program to utilize nuclear power, the institutional infrastructure of radioactive waste management needs to be improved. The NSRC Rule-97, for the future beneficence, will have to be revised by incorporating several missing key points on radioactive waste management such as definition of radioactive waste, classification of radioactive waste, exempt and clearance limit, storage and retrieval, NORM/TENORM waste, disposal of LILW/HLW and spent fuel.

**Keywords:** Radioactive waste, Framework, Infrastructure, Regulations, Policy, Nuclear regulatory

### 1. Introduction

The use of radioactive material in areas such as nuclear power production, medical applications, research and other industry areas, produces radioactive waste which requires safe long-term management [1]. In Bangladesh, radioactive waste and spent nuclear fuel are generated as a consequence of the peaceful use of both nuclear energy and ionizing radiation in many industries, particularly in the utilization of nuclear energy from 3 MW TRIGA

Mark-II research reactor, health care (therapy, diagnostics), research, and agriculture [2-8]. The current extent of utilization of nuclear energy and ionizing radiation in Bangladesh is comparable with that of other developing countries. The management of radioactive waste entails a range of treatment, conditioning, storage, transportation and disposal in a manner that protects human health and the environment, without imposing undue burdens on future generations.

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This objective is reflected in the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [9] ('the Joint Convention') and is also a requirement of the fundamental safety principles for waste disposal developed by the IAEA [10]. Certain radioactive waste and, above all, spent nuclear fuel contains a high risk potential, which is why strict management requirements are set out in terms of the technical, professional and financial provision of services. This is one of the reasons why the utilization of nuclear energy and ionizing radiation, as well as radioactive waste management, subjected to regulatory supervision and approval by the National Nuclear Regulatory Authority. An important solution is required for the disposal of radioactive waste in compliance with requirements for the protection of human health and the environment without excessively transferring any of the current impacts of nuclear energy and ionizing radiation utilization to future generations. In this regard, the policy and strategy on radioactive waste and spent fuel management has been drafted on 2011 based on the IAEA documents [9,10] with the following objectives:

1. To determine strategically justified, scientifically, technically, environmentally, financially and socially acceptable principles for radioactive waste and spent nuclear fuel management in Bangladesh;
2. To develop a basic system framework for the decision-making of those authorities and organizations responsible for radioactive waste or spent nuclear fuel management in Bangladesh; and
3. To communicate in straightforward way information concerning the long-term management of radioactive waste and spent nuclear fuel to organizations involved in this field and to the general public.

The strategy for disposal of radioactive wastes in a manner that adequately protects the environment and humans, takes into account a number of aspects, such as:

- existence of a national policy, technical and institutional infrastructure, and legislation;
- relevant for the safe management of radioactive waste;
- available financing schemes and financial resources;
- classification and quantification of waste according to its environmental radiotoxicity;
- mobility, waste form durability and longevity of its potential radiological impact;
- availability of technologies used for waste treatment and conditioning for disposal;
- availability of disposal site and its characteristics;
- etc.

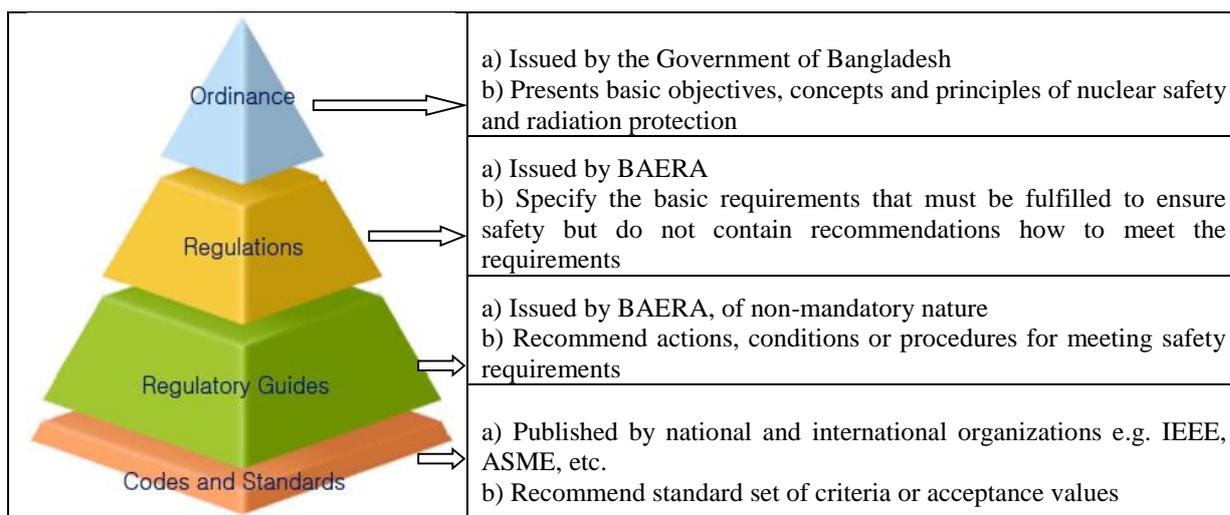
Currently, Bangladesh does not have nuclear power plant (NPP), so that the radioactive waste is mainly coming from the application of radioisotopes in industry,

medicine and laboratories. However, Bangladesh government is now planning for generation of electricity from nuclear power plant and recently they have taken a project called Rooppur Nuclear Power Plant Project (RNPP) [11]. The Central Radioactive Waste Processing and Storage Facility (CWPSF) at the Atomic Energy Research Establishment (AERE) under the Bangladesh Atomic Energy Commission (BAEC) is the only center in Bangladesh that has capabilities to treat the radioactive waste in the form of liquid [12], spent resin, combustible waste, and sealed sources. The CWPSF is equipped with compactor, chemical treatment, conditioning facilities for spent sources and also interim storage. Although Bangladesh has limited infrastructure for the present radioactive waste, it needs improvement especially for the disposal program of the existing and future radioactive waste. Many factors have to be developed in anticipation of the incoming naturally occurring radioactive materials (NORM) waste and technically enhanced naturally occurring radioactive materials (TENORM) waste along with radioactive wastes from coming nuclear power plant operation. There is no standard on the infrastructure of radioactive waste management in the world [13]; however, experience of the nuclear energy countries shows similarities on how managing the radioactive waste to ensure the safety of the public, the workers and the environment. The common institutional infrastructure at least consists of legislation, regulatory authority and implementing organization, but some developing countries may add funding system and clear involvement of the stakeholders [14]. This study analyzes the infrastructure framework of radioactive waste management in Bangladesh and the goal is to make every stake holder in Bangladesh aware of the necessity to improve the infrastructure of radioactive waste management. The paper presents some aspects on the national legislative, regulatory and operating system related to the infrastructure and safety aspects of radioactive waste management in Bangladesh.

## 2. Legislative framework

The objective of radioactive waste management is to control and account for radioactive waste, in order to protect human health and the environment now, but also to make sure we do not leave unnecessary burdens for future generations. It is unanimously recognized that a well developed regulatory system for the management and disposal of radioactive waste is a prerequisite for both public and market acceptance of nuclear energy. It has to be underlined that the continuing internationalization of the nuclear industry following terrorist attacks of 11 September 2001 influences the need for national legislation and regulatory infrastructure to be based on internationally endorsed principles and safety standards to be based on internationally endorsed principles and safety standards [15].

The structure of nuclear legislative system in Bangladesh is shown in Fig. 1.



**Fig.1** Generic structure of nuclear legislative system in Bangladesh.

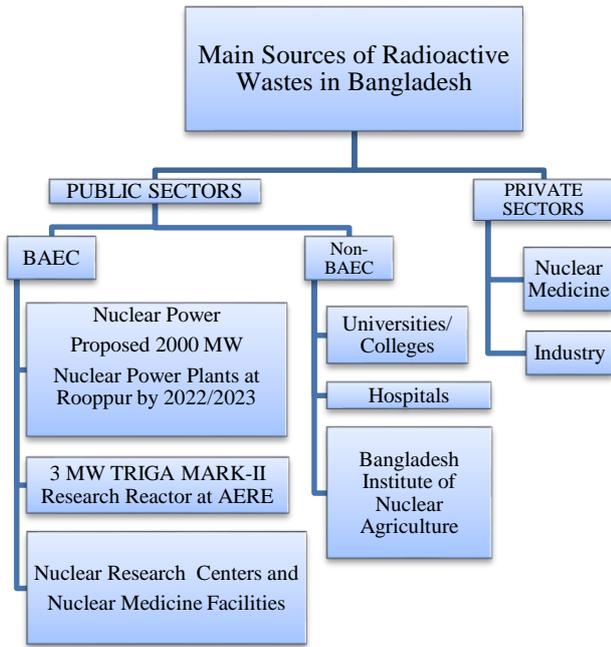
Bangladesh Atomic Energy Commission (BAEC) is the national authority for acquisition, development and application of Nuclear Science and Technology and thus is playing the pioneering role for the development of the country's nuclear research program and thus helping to achieve the cherished goal of self-reliance through national efforts and international co-operation. A Central Radioactive Waste Processing and Storage Facility has been developed at AERE for processing, safe storage and disposal of radioactive wastes. The capacity is not adequate to meet the demands for the radioactive waste storage facility of the country including the proposed power plants wastes. In anticipation of possible introduction of the nuclear energy in Bangladesh and in order to contribute to the global nuclear safety and security culture, the Government of Bangladesh has, since May 2012, issued the Act on Atomic Energy Regulatory (ten chapters) [16]. This law covers various arrangements, including the establishment of Bangladesh Atomic Energy Regulatory Authority (BAERA). The Act No. 19/2012 also stipulated some basic arrangements of radioactive waste management. The basic arrangement is accommodated in chapter V with five articles. In Bangladesh, Nuclear Safety and Radiation Control (NSRC) Rules-97 (SRO No. 205- Law/97) was promulgated to regulate nuclear and radiological practices including radioactive waste management [17]. As per NSRC Rules-97, the licensee of the radioactive waste management shall comply with the requirements of the applicable safety series published under the IAEA RADWASS Program [17].

The licensee shall not dispose of licensed material without the approval of the national nuclear regulatory authority. Moreover, the licensee shall comply with the following requirements for radioactive waste management:

- activity and volume of any radioactive waste that results from the source for which they are responsible be kept to the minimum practicable level;
- the radioactive waste be collected, transported, stored and disposed of, in accordance with the requirements of the applicable standards; and
- segregate, and treat separately if appropriate, different types of radioactive waste where warranted by differences in factor, such as radionuclide content, half-life, concentration, volume and physical and chemical properties, taking into account the available options for radioactive waste disposal.

### 3. Radioactive waste management practices

In Bangladesh, the main research facility is situated at the Atomic Energy Research Establishment (AERE), in Savar, located 45 km south-west of the capital city Dhaka, where a 3MW TRIGA Mark-II Research Reactor, Radioisotope Production Laboratories, a 14 MeV neutron generator, one Tandem Accelerator and two  $^{60}\text{Co}$  irradiators (350 kCi in 2010 and 65 kCi in 2009) form the core of the peaceful nuclear activities. In addition, there are 18 nuclear medicine centers/departments, 12  $^{60}\text{Co}$  radiotherapy facilities, two



**Fig.2** Present sources of radioactive wastes in Bangladesh.

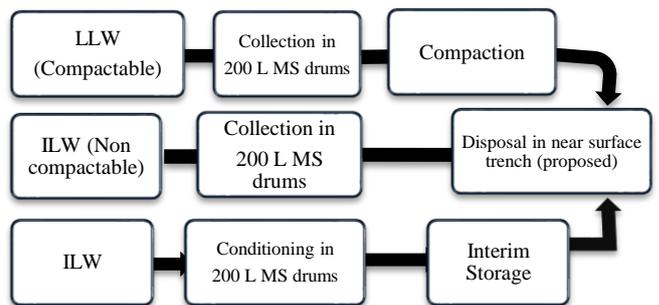
gamma-ray irradiator facilities, 11 linear medical accelerators, one Van de Graff generator, three <sup>192</sup>Ir high dose rate (HDR), two dose rate (LDR) brachytherapy units and several <sup>192</sup>Ir industrial radioactive sources in the country. These are used for a variety of purposes in research, medicine, industry and other fields.

All these activities give rise to significant amount of liquid, solid and mixed radioactive wastes including sealed radioactive source (SRS). The present sources of radioactive waste in Bangladesh are shown in Fig. 2. Proper management of spent SRS requires an established radioactive waste management infrastructure and in particular, a facility designed for the specific purpose of conditioning and subsequently interim storage of spent sealed sources.

At the present time, the CWSPF is the only center in Bangladesh that has capabilities to treat radioactive waste in the forms of liquid, spent resin, combustible waste, and spent sealed radioactive sources. Since the beginning of the nuclear activities in Bangladesh, BAEC has implemented the Radioactive Waste Management Program [2-7] with the following objectives:

- To assure that no one shall receive any radiation doses, arising from radioactive wastes, exceeding the limits of permissible value according to recommendations of the national nuclear regulatory authority, and
- To utilize the proven and safe technologies for radioactive waste management.

The overall objective of radioactive waste management is to deal with radioactive waste in a manner that protects human health and the environment at the present time and in the future without imposing excessive burdens on future generation. The general radioactive waste management scheme is shown in Fig.3 (a) and (b).



**Fig.3(a)** General waste management scheme at CWPSF (Solid Waste).

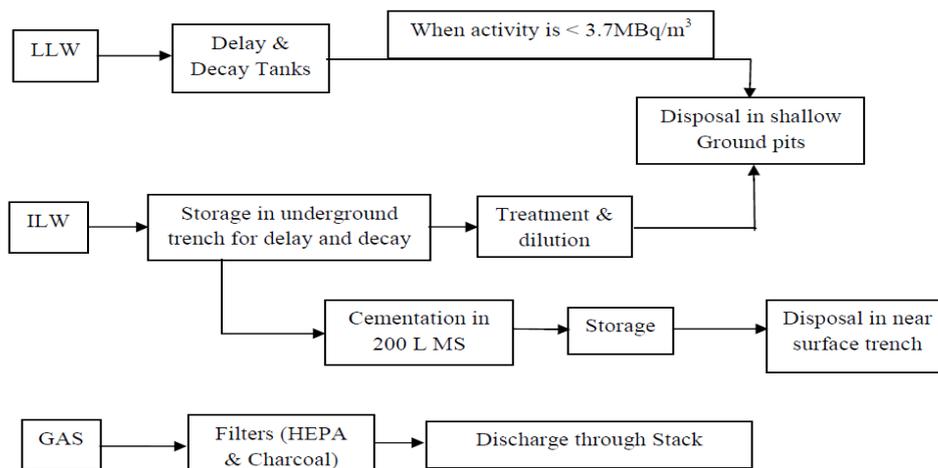


Fig.3(b) General waste management scheme at CWPSF (Liquid & Gaseous Waste).

#### 4. Analysis

##### Infrastructure

In this study, result of the analysis (based on Table 1) is discussed using references from the international trends (from IAEA and other advanced countries), and also evaluation of the common practices in Bangladesh (BAEC, waste generator and regulatory authority). Bangladesh implements the once-through nuclear fuel cycle policy for the existing research reactor as well as for the proposed nuclear power plants, so there is no reprocessing need for spent nuclear fuel (spent nuclear fuel is defined as high level radioactive waste). In Bangladesh, the general safety requirements, classification, implementing organization, fee and disposal of HLW are not well defined and as such *there is no article on the disposal for low and intermediate level waste and high level radioactive in the NSRC Rules-97*. As a result, the national nuclear regulatory authority finds difficulties to regulate the disposal of low and intermediate level waste in the country. The only solution is to revise this event by formal procedure, although this may occur in the future is the

need to classify the process is rather time consuming. The other problem that naturally occurring radioactive materials (NORM) and the technically enhanced naturally occurring radioactive materials (TENORM). This is because NORM and TENORM are not generated from nuclear or radiation activity, rather from the common industries, while according to the definition of radioactive waste in the NSRC Rules: “Radioactive waste means such waste as is created by the nuclear or radiation activity and in which radioactivity is present in excess of the prescribe limit”. At present, due to the NSRC Rules-97, the radioactive waste is only generated by nuclear or radiation activities. So the NORM/TENORM waste is in such a position that it cannot be defined as radioactive. Every country has its own classification of radioactive waste but no such classification (i.e. exempt waste [18], clearance level waste, low level waste, intermediate level waste, high level waste etc.) is included in the NSRC Rules-97, and this may cause complication in the future since in reality there are also other wastes such as long-lived waste, short-lived waste, and very low level waste, and that each has its own special treatment and disposal method.

Table 1. Technical basis for institutional framework analysis.

No.	Topics	Basis	Responsible parties
1	Legislation	Basic Laws, National structure organization to regulate and implement the radioactive waste management	Ministry of Law Ministry of Science and Technology
2	Regulatory authorities and their regulations	Organizations responsible for regulation of regulatory authority and radioactive waste management	Ministry of Science and Technology BAERA
3	Policy & strategy	National policy and strategy/institutional policy guide	Ministry of Science and Technology BAEC
4	Implementing organization	Organization responsible for implementing radioactive waste management tasks	Ministry of Science and Technology BAEC
5	Fund management body	Fund management body/organization responsible for radioactive waste management funds	Ministry of Finance Ministry of Science and Technology

### *National Organization*

The Rules of NSRC No.205/Law/97 state that the development and the use of nuclear energy has to be carried out in such a way that the safety and health of workers could be assured, as well as that of the public and besides this the environment has to be protected. This regulation does not establish specific technical criteria for the different stages of radioactive waste management such as: criteria for their classification and characteristics for temporal and definitive storage, requirements related with their treatment and conditioning, requirements for definitive storage facilities of radioactive waste and requirements for disposal of radioactive waste. To carry out the development and the use of nuclear energy, the Government has delegated power to BAEC, the "Radioactive Waste Management Body (RWMB)" and the BAERA as the Nuclear Regulatory Authority. Since BAEC as the "Radioactive Waste Management Body" performs the non-commercial activities, the commercial activities can be done in cooperation with, and/or by, private companies or state-owned enterprises. The Regulatory Authority as the independent organization has the task to control any activity using nuclear energy. The purpose of control is to prevent the workers, the public, and the environment from any harmful effect of ionizing radiation. The task of regulatory authority is administered by the following means:

- To establish regulations on the nuclear safety and radiation control.
- To issue the licenses to control that the user of nuclear energy is qualified and in accordance with the nuclear safety and radiation control regulations, criteria, standards, and guidance as well as practices.
- To do inspection to ensure that all regulations are observed in practices.

### *Regulatory Regulations*

The regulation is prepared to regulate and control the nuclear activities by the regulatory authority in compliance with the basic radiation protection requirements as described in ICRP and IAEA Basic Safety Standard and other applicable requirements. Certain necessary rules and regulations for the management of radioactive waste have been prepared; these are going to be issued in the future. Moreover, regulation on fund/financial system is essential for radioactive waste management. At present, the BAERA has a regulation on the waste management facility license fee. It means that every waste generator must pay the BAERA a fee for operation of waste management facility. However, the tariff that has been established is excluding the disposal option. If the disposal option is included, then the cost will be more expensive for radioactive waste generators to be paid, and it has been predicted in many cases that the fee for waste

management would be higher than that of for new radiation source. However, for the near future program, especially for preparation of NPP operation, regulation on radioactive waste management funding is necessary, not only to establish the fee or tariff but also the organization that manages the fund. As mentioned above, that NSRC Rules-97 does not mention the disposal procedure of low and intermediate level radioactive waste. The only way to address the problem is to improve the NSRC Rules-97, so it will provide a clear policy on the repository for radioactive waste disposal. The NSRC Rules-97 is not appropriate anymore to describe the classification and management of radioactive waste including disposal option.

### *Responsibility of Licensee*

Radioactive waste management shall be administered by the Radioactive Waste Management (RWM) Body based on the safety concern and technical capability possessed by the RWM Body and also for the ease in implementation of control. The management is administered in a non-commercial manner. For commercial activities of radioactive waste management, the RWM Body may designate a state-owned company or any private company in accordance with the proposed regulations on radioactive waste and spent fuel management. The obligation of the user generating low and medium level radioactive waste is to manage the radioactive waste within the location of the nuclear installation so that they will not pose hazards to the workers, the public and the environment, enabling further easy management by the RWM Body. The purpose of temporary storage is to reduce the radiation level of short-lived radioactive materials before transferring them to the RWM Body. It is proposed in the new regulation on radioactive waste and spent fuel management that the user generating high level radioactive waste shall be obligated to temporarily store the radioactive wastes (spent fuel) during the period not less than the life time of the nuclear power reactor.

### *Financial System*

Article 3 of the Joint Convention [9] includes a requirement on Contracting Parties 'to aim to avoid imposing undue burdens on future generations'. In addition, Article 22 requires Contracting Parties to take appropriate steps to ensure that:

- 'adequate financial resources are available to support the safety of facilities for spent fuel management and radioactive waste management during their operating lifetime and for decommissioning'; and
- 'financial provision is made which will enable the appropriate institutional controls and monitoring arrangements to be continued for the period deemed necessary following the closure of a facility'.

Since many of the activities associated with long term management of radioactive waste will take place several decades (or more) into the future (possibly after the

operators of the radioactive waste have gone out of business), it is prudent to collect the financial resources that will be needed for future operations while the waste generators are still in operation. Many countries indicated that they use various financial systems to ensure the long term availability of financial resources for their geological disposal programs. The 'polluter pays' principle is widely accepted as a governing principle for the establishment of mechanisms for financing radioactive waste management. This principle is reflected in the environmental protection legislation of many IAEA Member States. In some IAEA Member States, particularly those with nuclear power program, segregated funds have been established with the aim of providing sufficient financial means to address all expected management costs of fuel cycle wastes. Additional guarantees may be required to ensure that financing is available when needed. Special provisions may need to be made for radioactive wastes whose ownership is unknown (orphan wastes) or where the owner no longer exists (historic wastes). Where such radioactive wastes are present, the financial responsibility for their management falls to the government of the country, though it may make arrangements for the radioactive waste management body to deal with them.

These funds are also used for management of wastes

**Table 2.** Typical radioactive waste management fees.

Country	Fee per kWh	Remarks
<b>Bulgaria</b>	3% of electricity sales (nearly US \$0.9/MW·h)	Fees covering decommissioning, disposal and storage of HLW/SNF and disposal of other wastes
<b>Japan</b>	¥0.13	Fees covering only HLW and/or SNF disposal
<b>Finland</b>	Euro 0.0023	Fees covering storage and disposal of SNF
<b>Slovakia</b>	6.8% of the sale price of electricity (nearly 0.13 Sk/kW·h)	Fees covering decommissioning, disposal and storage of HLW/SNF and disposal of other wastes
<b>Spain</b>	0.8% of the retail price of electricity generated by all power stations	Fees covering decommissioning, disposal and storage of HLW/SNF and disposal of other wastes
<b>USA</b>	US\$0.001	Fees covering only HLW and/or SNF disposal

At the moment Bangladesh does not have financial system for radioactive waste management. Normally only countries with NPPs have such system. However, sooner or later the NPP program in Bangladesh must be supported by the financial system that includes fund organization (may be independent or governmental organization) and fees (for decommissioning, storage and disposal of spent fuel and other radioactive waste). Depending on the application of nuclear energy, arrangement of financial system in Bangladesh must be established to ensure that the radioactive waste and spent fuel from nuclear power plant will not be a trouble for future generation. In order to develop the

from medical, industrial and research applications. Funds and reserves are the two most common financial systems. In the former, the financial resources are usually maintained by organizations independent from the waste generators. In the Russian Federation, financing is obtained from the national budget [19]. The scope of financial system differs from country to country (e.g. some include such activities as decommissioning of nuclear facilities, and management of low level waste, while others are intended only for HLW or spent nuclear fuel). Accordingly, the activities covered by the funds vary from country to country, as follows:

- Only HLW and/or SNF disposal (Czech Republic, Japan, USA, etc.)
- Interim storage and disposal of SNF (Belgium, Finland, etc.)
- Decommissioning of nuclear power plants, as well as storage and disposal of HLW and/or SNF (Hungary, Lithuania, Spain, Sweden, Switzerland, etc.).

The annual fees that are widely used to obtain the resources kept in the funds are generally calculated and determined based on the amount of electricity or radioactive waste generated in a certain year (i.e. on the basis of the future liability associated with the waste generated in that year). Table 2 below shows the typical radioactive waste management fees [19] for some countries.

financial system for radioactive waste management, an IAEA INPRO methodology [20] is being applied.

## 5. Radioactive waste management policy & Strategy

### National Policy

Bangladesh is going to utilize the nuclear energy for electricity generation by 2022/2023 [11] and as such the Radioactive Waste Management policy had been prepared based on IAEA document [10], in the process getting approval from the government. In Bangladesh,

the radioactive waste shall be managed through, if authorized, the progresses of either:

- Return back to supplier;
- Sent to the approved radioactive waste management Centre; and
- Stored by user at appropriate storage facility (only involves a large amount of radioactive waste).

The summary of policy is given below:

1. **Recognizes:** The radioactive waste needs to be properly managed and stored at safe and secure purpose built sites to protect human health and environment.
2. **Commitment:** Safe management of radioactive waste will be ensured by Government of Bangladesh.
3. **Responsibility:** Every generator of radioactive waste shall be responsible for safe and secure management of radioactive waste and shall pay for its safe interim storage and disposal.
4. **Regulatory Control:** BAERA shall ensure safe control of all radioactive waste in the country.
5. **Ownerless waste:** Government will be responsible for bearing the cost for management of ownerless waste and orphan sources.
6. **Disposal:** Radioactive Waste Management Body/BAEC shall be responsible for safe and secure disposal of radioactive waste in the country.
7. **Funding:** The finances will be managed through Central Radioactive Waste Management Fund (RWMF) established and maintained by BAEC for the safe management of radioactive sources in the country.
8. **Import/Export:** RW shall not be imported or exported unless or otherwise approved by the Nuclear Regulatory Authority. However, returning of disused sealed radioactive sources (DSRS) to the supplier will be carried out as per BAERA regulations.

### *National Strategy*

To achieve the objectives laid down in national waste policy, strategy on safe management of radioactive waste in Bangladesh has been formulated on 2011 based on IAEA guideline [9]. The strategy is based on internationally recognized principles and approaches and locally available technological options and resources. The strategy document covers all the fundamental needs on radioactive waste management system and keeps the avenues open for accommodating any future development (s) that may evolve with time. Bangladesh has national interim radioactive waste storage and processing facility at the AERE, with cover treatment facility, generally including waste segregation, cementation and compaction.

Bangladesh is still a non-signatory country for the Joint Convention (JC) on the Safety of Spent Fuel

Management and the Safety of Radioactive Waste Management [9]. Bangladesh is making preparation on this matter. We are now making efforts to strengthen our capabilities for management of radioactive waste from Rooppur Nuclear Power Plant in near future in the light of the joint convention on the safety of spent fuel management and safety of radioactive waste management. The current priorities are:

- To begin with the site selection process for final disposal of low level radioactive waste arising from research reactor, medicine, industry, agriculture, education and research applications;
- To accomplish the radioactive waste management policy, in accordance with the IAEA recommendations, for assuring the radioactive waste are safely managed, by developing additional laws and regulations;
- To analyze and implement technologies for volume reduction and to establish programs for minimization of radioactive waste;
- To establish specific regulatory requirements for intermediate and high level radioactive waste; and
- To define the final policy related with spent fuel.

### **6. Conclusion**

The radioactive waste management system in Bangladesh is on a level comparable with that in developing countries. Bangladesh has good infrastructure of radioactive waste management for the existing radioactive waste from non-nuclear power application, however, by considering recent trends in the international community to enhance the safety of radioactive waste management, and also by considering the Bangladesh program to utilize nuclear power, the infrastructure needs to be improved i.e. on the legislation, national organizations, regulations, liabilities and radioactive waste management fund system. Nevertheless, there are certain areas that need to be addressed further:

- The Atomic Energy Regulatory Act has provided a basic legal framework in Bangladesh compatible with those of IAEA Member States, and set out the fundamental principles of the organizational system which is able to provide for all the aspects concerned with the safe management of radioactive waste and spent nuclear fuel in Bangladesh. A new amendment to the Atomic Energy Regulatory Act should remove any remaining differences between Bangladesh and other countries having nuclear power plants.
- The NSRC Rule-97, for the future beneficence, will have to be revised by incorporating several missing key points on radioactive waste management such as definition of radioactive waste, classification of radioactive waste, exempt and clearance limit, storage and retrieval, NORM/TENORM waste, disposal of LILW/HLW and spent fuel.

- The establishment of financial system for long term radioactive waste management in Bangladesh needs to be implemented to ensure that the radioactive waste will not be the burden on future generation.
- Bangladesh should be a signatory party of the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management.
- Full involvement of some important stakeholders, especially the Ministry of Environment/Ministry of Industries/Ministry of Health, on the radioactive waste management infrastructure is required since some radioactive waste has been generating from non-nuclear radioactive waste.

### Conflicts of Interest

The authors have no conflict of interest.

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