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Research Article

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Prospect of Internet Reactor Laboratory in Bangladesh

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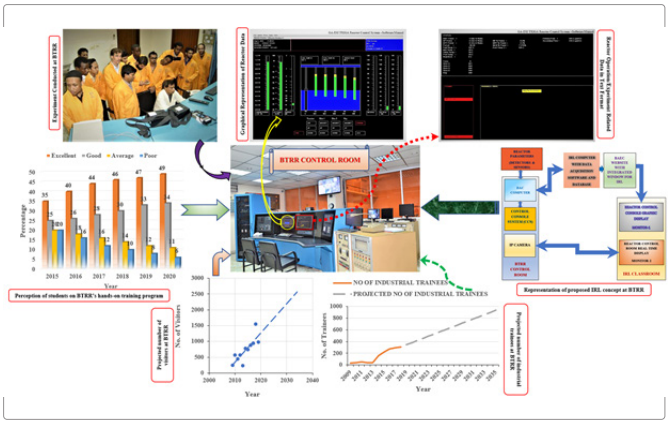
Abstract

Bangladesh Atomic Energy Commission (BAEC) has been operating a 3 MW TRIGA MK-II research reactor since 1986. The reactor has been utilized for radioisotope production, neutron beam research, training and education. Cessation of radioisotope production in 2008 due to the unavailability of TRIGA fuel has left the reactor usable for research, training and education purposes only. Over the past three decades, the reactor has been extensively used to render training and education related to nuclear science and engineering to university students, researchers and trainee reactor operators. This paper intends to present the current status of the education and training program of BAEC TRIGA Research Reactor (BTRR) as well as the prospect of IRL as a tool to impart training and education. The proposed Internet Reactor Laboratory (IRL) at BTRR is expected to facilitate training and education programs of research reactor using digital means. Internet Reactor Laboratory (IRL) can play an instrumental role in developing skilled manpower for Rooppur Nuclear Power Plant (RNPP), other proposed nuclear power plants, nuclear installations and create a new horizon in nuclear research for teachers, students and other scientific communities through distant learning method.

Keywords

Internet Reactor Laboratory (IRL); Training and education; Distant learning; Assessment

Graphical Abstract:



Highlights

- Nuclear RR plays an important role in developing skilled human resources in the nuclear engineering field and promotes nuclear research by providing education and training programs.
- Skilled manpower and research in the field of nuclear science and technology have been proposed by integrating IRL concept to BTRR's training and education programs.
- The IRL can impart training and education to the teachers, students and other scientific communities through distant learning method.
- A prerequisite software will fetch data and other reactor parameters from the Data Acquisition Computer (DAC) system of BTRR and store them in a server connected to the BAEC website.
- Access to this IRL window will enable the replication of the graphical/text display of the BTRR control console.

Introduction

Bangladesh has embarked on establishing the first nuclear power plant at Rooppur, Pabna on 30 November, 2017 following an intergovernmental agreement between Bangladesh and Russian Federation [1]. The country aims to generate 60,000 MWe by 2041 having NPP's share of 10% in the energy mix [2]. It is noteworthy that BAEC has been implementing a study project under Annual Development Program (ADP) to select the site for NPP in the southern region of Bangladesh. In addition to that, an ADP project titled "a technical study project to establish high power research reactor in Bangladesh" is implemented by BAEC [3]. So, it is evident from the government's plan that in the future there shall be a need for a skilled workforce in the nuclear field. The development of trained manpower is a prerequisite for the operation of nuclear power plants and other nuclear installations. The aim to achieve skilled human resources in the nuclear engineering field can be attained through the promotion of modern technology in research reactor education and training programs. BTRR, the sole research reactor of the country, faces impediments to delivering nuclear education on a larger scale. In addition to that, the initiative to set IRL at BTRR will provide regional countries having no research reactor with access to nuclear education for university students and researchers. At present, ten (10) research reactors are operational in South-Asia whereas, the number of educational institutes offering Bachelor, Masters and PhD degree in India, Pakistan, and Bangladesh is twenty (20), three (3) and three (3) respectively [4,5]. International Atomic Energy Agency (IAEA)'s IRL program was established in 2015 with a view to providing nuclear engineering students or related background young specialists with practical reactor physics experience [6].

The construction of RNPP has ushered in an era of nuclear science and technology in Bangladesh. So, it is imperative to put emphasis on developing skilled manpower to ensure smooth operation of nuclear power plants. Generally, around 600-800 strong highly skilled workforce is required for a typical 1000 MW nuclear power plant in a developed country [7]. However, this number should be at least four times more for a newly entrant developing country due to low workforce productivity and lack of nuclear knowledge, education and training infrastructure. According to the human resources

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development plan of RNPP, a total of 2700 personnel (including 2535 professionals) will be required to run the RNPP. Among 2535 professionals, a total of 1424 will be trained in Russia and India at different times by 2022. The professional training is scheduled for first batch (271) in 2018, second batch (251) in 2019, third batch (309) in 2020, fourth batch (507) in 2021 and fifth batch (86) in 2022.

The concept of IRL was originally developed within a U.S. Department of Energy funded research reactor consortium, through which North Carolina State University (NCSU) successfully demonstrated that an internet link could deliver practical experiments from its PULSTAR reactor to students at other universities in the U.S. This approach was implemented for the first time across international borders between the Department of Nuclear Engineering (NE) at Jordan University of Science and Technology (JUST) in Jordan and the PULSTAR research reactor at NCSU in USA [8]. In Europe, IRL project has been implemented at ISIS reactor by the French Atomic Energy and Alternative Energies Commission (CEA) and its integrated higher education institute, the National Institute of Nuclear Science and Technology (INSTN) in collaboration with IAEA. The project provides internet-based reactor experiments to students from Belarus, Lithuania, Tanzania and Tunisia [9]. In Asia, a preliminary introduction of internet reactor laboratory was launched at Kartini Reactor in Indonesia at the end of 2014 [10].

BTRR is the only research reactor of the country located in Savar, at a distance of 40 km from Dhaka. The reactor has been utilized for radioisotope production, research, training and education activities [11]. Due to the unavailability of TRIGA fuel, the production of radioisotopes (I-131 & Tc-99m generators) has been suspended since 2008 [12]. At present, the research reactor is being used for research (Neutron Activation Analysis, Neutron Scattering and Neutron Radiography), training and education activities. Students and trainees of different educational institutes receive practical experience on reactor experiments such as nuclear reactor operation, reactor thermal power calibration, measurement of core excess reactivity, shutdown margin, control rod worth calibration, neutron flux, fuel temperature coefficient of reactivity, moderator temperature coefficient of reactivity, reactor power coefficient, reactor tank constant and so on. Licensed reactor operators demonstrate the nuclear phenomena of the aforementioned experiments with the theoretical concept for visiting students and trainees. Integration of IRL concept to BTRR's training and education program shall facilitate the country to achieve its objective to develop manpower in the nuclear sector.

Description of BTRR

BAEC TRIGA Research Reactor (BTRR) was first made critical at 50 W on September 14, 1986 and was commissioned to full steady-state power of 3000 kW on October in the same year. During 1987-1990 the reactor use was mainly limited to operator training and some R & D activities. The TRIGA MK-II research reactor is a pool-type; light water-cooled and zirconium-hydride moderated reactor. Its solid cylindrical fuel element is a homogeneous mixture of Er-U-ZrH, containing 19.7% U-235. The reactor can be operated in the steady-state at a rated power up to 3000 kW. This reactor can also operate in a pulse mode with a peak power of 852 MW (with graphite dummy elements in the inner core region) and it also capable of operating under square wave mode. An inherent prompt negative temperature coefficient of reactivity of the fuel is the basic safety feature of the reactor. In addition, other passive and engineered safety systems such as high fuel clad strength, anti-siphon cooling line, Emergency Core Cooling System (ECCS), emergency purging system of the reactor hall, are also part of the design [13].

Current Status of Nuclear Education in Bangladesh

The upswing of nuclear activities in Bangladesh has necessitated the establishment of the nuclear engineering department in different universities. The aim of rendering nuclear education at graduate and postgraduate level is to prepare expert manpower for the safe operation of nuclear installation. The University of Dhaka established the first nuclear engineering department in the country in 2010 [14]. The academic activities started with the enrolment of students for Master's Program in 2012 and for Bachelor's program in the following year [15]. Military Institute of Science and Technology (MIST) established Nuclear Science and Engineering (NSE) department in 2014 and the first academic session started on 5 February, 2015 [16]. Bangladesh University of Engineering and Technology (BUET) has established the Institute of Nuclear Power Engineering (INPE) in September, 2015 [17]. Chittagong University of Engineering and Technology (CUET) established the Department of Nuclear Engineering (NE) in February 2019 [18]. Apart from dedicated nuclear engineering departments of universities, nuclear engineering courses are included in curriculum of Electrical and Electronic Engineering and Mechanical Engineering departments of different universities in Bangladesh. In addition to that, students and researchers of Physics, Chemistry and other relevant disciplines perform academic research on nuclear physics at the reactor facility.

Training and Education at BTRR Facility

The BTRR facility has been utilized for education, training and research purpose. Every year, a significant number of students perform B. Sc., Masters and PhD thesis based on research reactor facility. As Bangladesh has entered into the nuclear era due to the commencement of RNPP project, the need for nuclear education is expected to rise in the future. Meanwhile, the University of Dhaka, BUET, MIST have started offering degrees on nuclear engineering [4]. In addition to that Chittagong University of Engineering and Technology (CUET) is expected to start offering degrees in Nuclear Engineering (NE) soon. A number of private universities are expected to open a department of Nuclear Engineering in near future. Consequently, the utilization of reactor facilities for educational purposes shall increase in the future. The existing reactor facility will continue to deliver service for the next 15 to 20 years. The research reactor provides hands-on training on nuclear science and technology to university students as part of the industrial attachment program [12]. Figure 1 shows the control room of BTRR and industrial training, follow-up training, basic nuclear orientation training and so on given to the students and trainees by CRR are demonstrated in Figure 2.

Figure 1: BTRR control room.

Figure 2: Students receiving training on reactor operation and different experiments.

A significant portion of this training can be imparted through IRL platform. It will bring convenience in achieving the country's goal of developing trained manpower in the nuclear sector. The number of industrial trainees who received training in past years is presented in the Table 1.

The projection of industrial trainees at Center for Research Reactor is shown in Figure 3 [12,19].

Scientific Visit at BTRR Facility

Apart from industrial training, the BTRR facility is utilized for scientific visits of students and faculties of different colleges and schools of the country. Every year a large number of students visit the reactor facility to get an overview of reactor operation and its utilization. Through the proposed IRL window of the BAEC website, students can get an overview of the reactor facility. IRL platform can be utilized to offer online courses on basic nuclear engineering. The number of individuals who visited the reactor facility is presented in the Table 2 [19].

It can be projected from the above data that after the next 15 years the number of visitors will cross 2500. IRL initiative can play an important role to serve the purpose of the scientific visits. It is evident from the data that in the year 2020, the number of visitors at BTRR was significantly lower than that of the previous year. It is attributed to the outbreak of the COVID-19 pandemic. The purpose of scientific visits can be achieved amid the Corona pandemic implementing IRL initiative. Visitors can get an overview of the research reactor from a custom-made reactor model with animations of all auxiliary systems integrated into IRL window of the BAEC website. The number of visitors at BTRR is projected in Figure 4 by fitting the previous accumulated data trend. (Figure 4).

Proposed IRL Concept for BTRR Facility

It is possible to provide training and education related to nuclear science and technology based on reactor from BTRR using IRL concept. An interactive web window can be integrated into the BAEC website in order to pertain training and education via a digital platform. The IRL concept in context of Bangladesh should be designed to provide education at graduation level. It will enable the students of universities located at a long distance from the BTRR facility to gain experience of reactor-based experiments and to understand different reactor parameters online. There should be a mutually binding agreement between interested universities or academic institutes and BAEC to access the facilities of IRL.

To implement IRL concept, a software is required to fetch data from the Data Acquisition Computer (DAC) system of BTRR. The software will acquire a set number of data and other reactor parameters from DAC in real-time. Such data and parameters shall be uploaded to a server that will be connected to a window in the BAEC website. The access to the IRL window in the BAEC website shall be controlled by Identification IDs and Passwords to be assigned to relevant course directors (Instructors/ Lecturers) of universities by BAEC. All the reactor operational data can be visualized in graphical and text format Figure 5 and Figure 6 show the pictorial view of two way data representation.

Table 1: The number of industrial trainees received training in past years at BTRR.

Particulars	2010	2011	2012	2013	2014	2015	2016	2017	2018
Number of students awarded industrial training	31	41	50	37	162	218	273	296	307

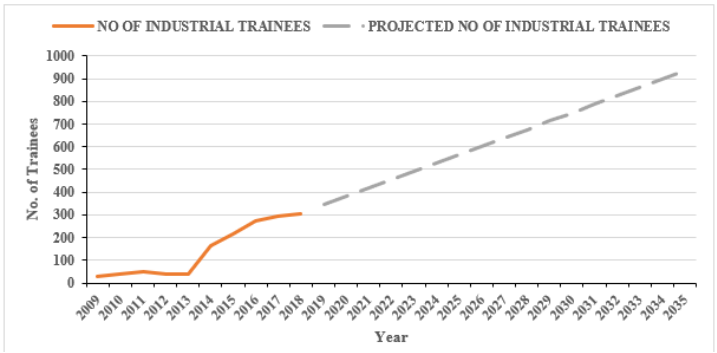

Figure 3: Projected number of industrial trainees at BTRR.

Table 2: The number of individuals visited reactor facility per year.

Particular	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
No. of Visitors	242	566	450	571	230	784	744	877	937	1551	974	345

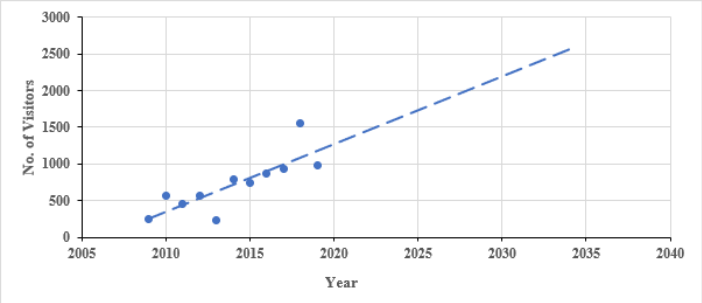

Figure 4: Projected number of visitors at BTRR.

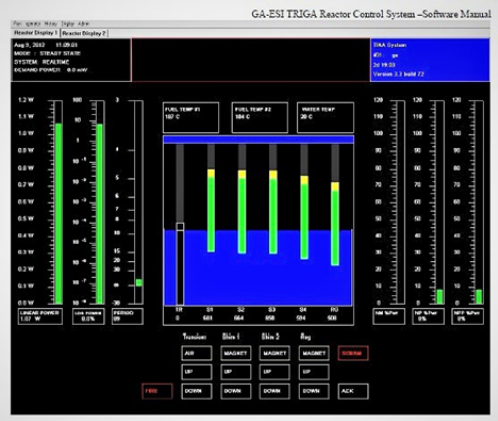

Figure 5: Graphical representation of BTRR control console data.

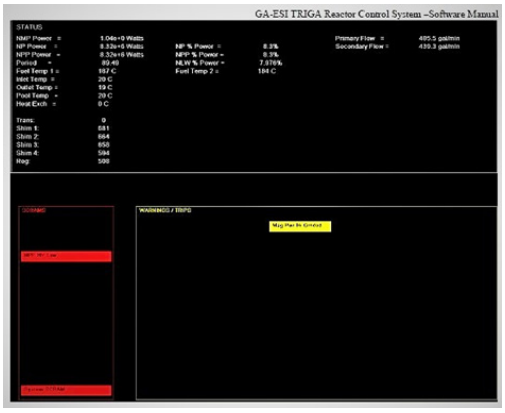

Figure 6: Reactor operation/experiment related data from BTRR control console in text format.

The software will replicate the graphical/text display of the BTRR control console through generating a graphical representation of the reactor control system comprising signals and reactor parameters. The graphical/text display will be displayed to students and instructors in the university classroom. The actual reactor control room shall be displayed to students and instructors via an IP camera system. A display system shall also be installed in the reactor control room which will display the classroom in real-time.

Proposed Training Program Under IRL Concept

Historically research reactors are being used to provide training on reactor operation. BTRR is utilized for awarding training on reactor operation through different reactor-based experiments. IRL can be used to emulate these training and experiments based on research reactor regardless of physical distance between reactor and trainees. Some of the major experiments conducted at BTRR are presented in Table 3.The flow diagram for the implementation of proposed IRL concept at BTRR is shown in Figure 7.

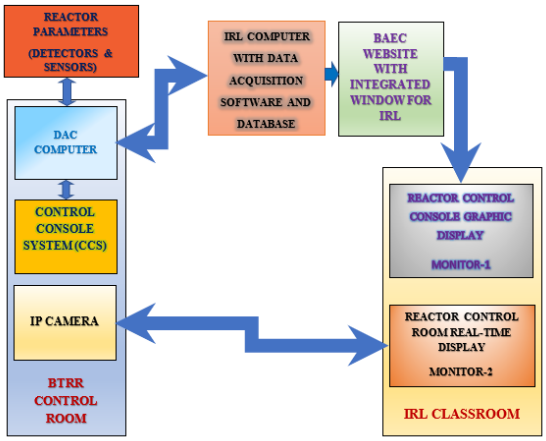

Figure 7: Representation of proposed IRL concept at BTRR.

Table 3: Experiments conducted at BTRR.

Sl. No.	Title of the experiments	Remarks on using IRL concept
1.	Facility visit and system/ equipment check of BTRR facility	Reactor operator and other staff of CRR conduct a checklist of equipment before every reactor operation. The checklist is approved by the reactor manager before the reactor is made critical. The approved checklist can be uploaded to IRL window so that the students can observe the current status of different equipment.
2.	Nuclear reactor operation	All actions related to reactor operation shall be shown to students in real-time by IP camera and all parameters of the reactor shall be showed in software.
3.	Measurement of core excess reactivity and shutdown margin of the nuclear reactor	Students in remote university classrooms can measure the parameters from the data and information displayed in graphical/ text displays installed in front of them.
4.	Thermal Power Calibration of BTRR	Same as above
5.	Measurement of the fuel temperature coefficient of reactivity	Same as above
6.	Measurement of moderator temperature coefficient of reactivity	Same as above
7.	Measurement of reactor power co-efficient	Same as above
8.	Measurement of reactor tank constant	Same as above
9.	Measurement of neutron flux	Same as above

In addition to the above-mentioned experiments, there should be a provision in IRL window of the BAEC website to create a library of videos that will explain the theoretical concept behind each experiment. Thus, the students will get the chance of learning theoretical knowledge in tandem with practical experience.

Stakeholders' Assessment of IRL Concept

BTRR has been conducting nuclear training program for university students. Students of universities receive training on reactor operation as well as experiments and their performance is evaluated by an assessment test at the end of training. The standard and quality of different training programs provided to the trainees, students and other scientific communities are ensured by giving questionnaires and getting feedback from them. Based on the assessment of these feedbacks, the CRR authority ensures the further improvement of the training programs. Feedback statistics based on the questionnaires are shown in Figure 8. It is evident from the figure that the quality of training programs offered by CRR is enhancing gradually.

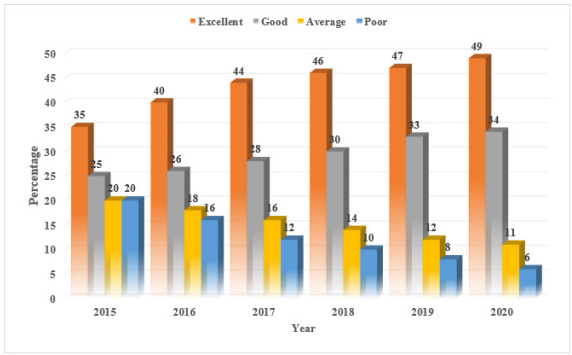

Figure 8: Perception of students on BTRR's hands-on training program.

IRL is a first of a kind concept to carry out nuclear education in context of Bangladesh. Neither the personnel of reactor facility nor the students of universities have the experience of conducting the operation of IRL. Hence, it is imperative to conduct a survey on potential stakeholders of the proposed IRL at the BTRR facility. Stakeholders are classified into three categories: the reactor personnel, students of universities and instructors of universities.

A questionnaire was prepared to solicit some information related to the actual need of IRL and its potential impact on the country's nuclear education. The survey was conducted on ten (10) universities, some of which have fully functioning Nuclear Engineering Departments and the rest of the other universities conduct courses on nuclear science and technology. Twenty (20) students from the relevant academic discipline of each university participated in the survey (Figure 9).

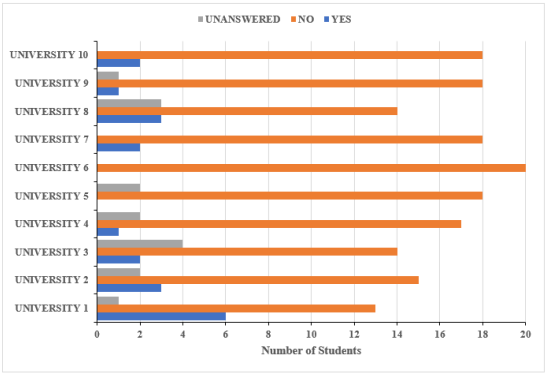

Figure 9: Familiarization of students with IRL concept.

The survey results from Figure 9 illustrated the fact that very few students were aware of the IRL concept. So, a brief overview on IRL concept had been communicated to the 200 participants of the survey (Figure 10).

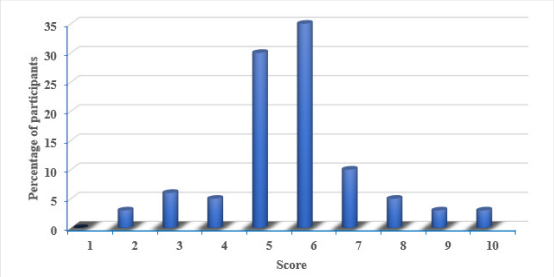

Figure 10: Can IRL be able to serve the purpose of BTRR?

The above survey data from Figure 10 were performed among possible stakeholders of IRL beneficiaries to evaluate whether IRL could serve the purpose of BTRR. It was evident from the figure that a significant percentage of participants (35%) were in favor of IRL concept and gave a score of six (6) out of ten (10). A moderate number of participants (30%) gave a score of five (5). A very few percentages of participants (14%) permitted a score of less than five (5). Above all, the majority of the participants (86%) were optimistic about the promising concept of IRL at BTRR (Figure 11).

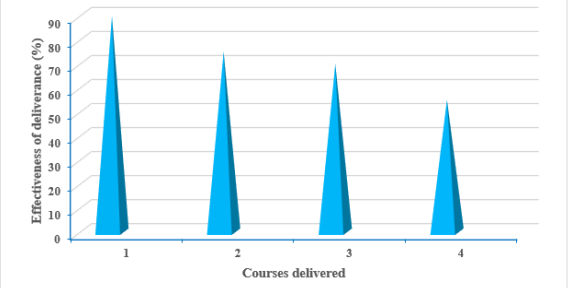

Figure 11: Field of future utilization of proposed IRL from stakeholder's perspective.

Another projection was made for future utilization of the proposed IRL from stakeholder's (students and instructors) perspectives. A number of courses were supervised and the effectiveness of the delivered courses through IRL was determined. The courses considered were Basic Orientation with a Nuclear Reactor; Nuclear Reactor Operation with Equipment Functionality Check; Understanding of Reactor Physics and Reactor Physics Experiments and marked as 1,2,3 and 4 respectively in Figure 11.

The survey was administered to derive the potential usability of IRL in the country. The result of the survey substantiates the fact that IRL will improve the usability of BTRR, if implemented.

Conclusion

The role of having an actual research reactor can't be supplanted by IRL concept completely. The objective of this publication is to articulate the prospect of internet reactor laboratory and to conduct an assessment on the viability of setting up an IRL at BTRR. The publication is not intended to cover the cost implication of implementing IRL. If the proposed IRL concept can be implemented at the BTRR facility, it will contribute towards achieving better utilization of the reactor facility. Initially, the participants had very little or no idea on IRL concept. Then, the students were delivered a brief idea on IRL concept. If IRL concept is successfully implemented, the surveyed students' remark is fairly admissible that IRL will some usability of BTRR. IRL will be pivotal in implementing the government plan of developing trained manpower in the nuclear field.

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Authors' Contributions

All authors contributed toward data analysis, drafting and revising the paper and agreed to be responsible for all the aspects of this work.

Conflict of Interest

We have no conflicts of interest to disclose.

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