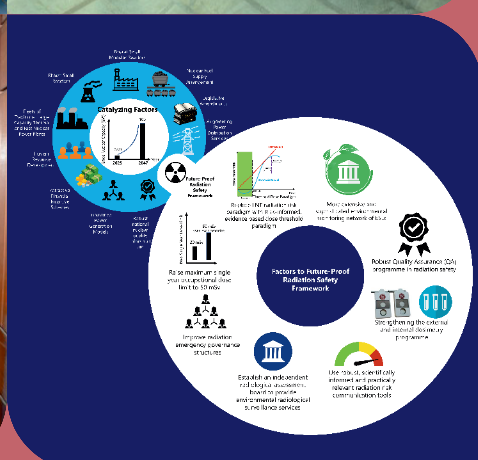
INDIAN NUCLEAR SOCIETY NEWS

QUARTERLY BULLETIN OF
INDIAN NUCLEAR SOCIETY



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FROM PRESIDENT, INDIAN NUCLEAR SOCIETY

INS President Speech for INSAC-2024 on "Regulatory Framework for Nuclear Renaissance"

Honourable Shri Vivek Bhasin, Director, BARC, Shri B.C. Pathak, CMD NPCIL, Shri D.K. Shukla, Chairman AERB, Shri A.P. Garg, Convener, INSAC-2024 and Shri Satyawan Bansal, Vice-President INS and Co-convener, INSAC-2024, Distinguished invitees, invited speakers and delegates, Members of the Executive Committee of INS, Members of Organizing and Advisory Committees of the conference, Life members of Indian Nuclear Society, Industry representatives, Media persons, Students, Ladies and gentlemen, On behalf of the Indian Nuclear Society and on my own behalf, I extend a warm welcome to you all. Special words of welcome are due to outstation delegates who are participating in big way in the conference.

INS is indeed proud to host this conference on the theme, **Regulatory Framework for Nuclear Renaissance**, which to my mind is a sequel to the last year's successful internation conference. INSIC-2023, on the theme, **Nuclear for Clean Energy Transition.** It is worth noting that INSIC-2023 took place on the backdrop of COP28 declaration to triple nuclear energy by 2050.

Nuclear renaissance rests on four important pillars:

The first is undoubtedly the access to technology which includes accelerated growth of nuclear power by Gen III and III+ nuclear reactors, rapid progress in innovative nuclear technologies like Small Modular Reactors, Nuclear Hydrogen, Breeder reactors etc and also life extension and management of aging nuclear reactors. This basket also includes accelerator-based technologies which may help to sustain carbon neutrality after 2050. These issues were addressed in INSIC-2023. It is important to note here that the nuclear renaissance is not just more nuclear power, it is also cleaner and safer power. Here comes the role of robust regulatory framework, which is the second important pillar of nuclear renaissance.

For over 60 years, nuclear regulatory framework has helped to produce safe nuclear power, thanks to the nuclear safety data for normal as well as abnormal operating conditions including the worst disasters: Chernobyl and Fukushima. The question that is currently being asked is whether the regulatory framework evolved over the years can help realise the so-called nuclear renaissance.

Last year, I was reading an interesting article by Ted Nordhaus and Adam Stein with an explosive title, **"Will Washington halt the global renaissance of nuclear power"** with a subheading, **"Hopes to slash emissions with nuclear energy are being dashed by US regulator"**. Many of you must have read this article.

The backdrop of this article is as follows: The US congress mandated NRC to provide a modern, streamlined licencing process for the new small reactors in the advanced stages of development. Nordhaus and Stein write, "*Instead, the NRC staff simply cut and pasted the existing rules for large conventional reactors into a mammoth 1200 -page regulation for new reactor type. The excess of precautions so extreme that observers have longed quipped that NRC's view of nuclear safety is that the safest reactor is one that never will be built.*"

Many countries view NRC licensing as the regulatory gold standard. For this reason, Nordhaus and Stein argue that *global progress in lowering carbon emissions may ultimately be determined not by fossil fuel companies, climate activists, or elected representatives, but by deeply conservative regulatory agencies.*

Interestingly very similar views were articulated in 1955 as one may read from the book, Nuclear Regulation: A Historical Perspective by James Quirk and Katsuaki Terasava. - Safety is indispensable to progress. At the same time, if it is too restrictive or inflexible, it would discourage rapid growth of nuclear technology.

There have been discussions on the licensing and permitting reforms to accelerate nuclear energy deployment. I do not intend to go through the details of the arguments and discussion. One troubling issue is the cancer risk from low-dose radiation and use of the statistical model. Another point is the emergency response adapted after the Fukushima disaster. Many have questioned the scale of evacuation-more than 160,000 people were displaced. Evacuation stress and disruption are estimated to have contributed to several thousands of early deaths. Many have called for development of early assessments and protocols of radiation risks and the scale of evacuation.

In Indian context, AERB has been doing impeccable job in nuclear regulation. Given the importance of a robust nuclear regulatory framework in accelerating the growth of nuclear energy, Indian Nuclear Society approached Shri D.K. Shukla, Chairman AERB with a request to conduct a joint conference on regulatory framework. He and his colleagues responded promptly and enthusiastically to this proposal. INSAC-2024 is a result of this intense collaboration. I thank Shri D.K. Shukla and his colleagues of AERB for making this happen. I am confident that INSAC-2024 will provide a platform for deliberation on the nuclear safety and security as we embark on massive expansion of nuclear power.

While I have described two main pillars of nuclear renaissance, let me also add that the other two pillars are capacity building and public outreach. As regards the public outreach, Indian Nuclear Society has been conducting public outreach in a big way. In last one year, we conduced over 15 outreach programs at places like Jammu, Srinagar, 4 schools and CDRI at Lucknow, Amravati, Dharwad, Hubbali, Sindhudurg. so on and so forth. Recently, INS has instituted Foreign Travel Grant Scheme to partially support foreign travel of students in the nuclear science and technology area. In this conference, we have invited over 30 engineering students form Mumbai and nearby areas so that they understand the challenging issue of energy transition and regulatory framework; and may decide to take up career in nuclear areas. INS has also entered into cooperation agreements with American Nuclear Society, French Nuclear Society and Japanese Nuclear Society.

Finally, I extend my most warm and hearty welcome to all delegates once again and wish them memorable stay and stimulating deliberations on one of the most important issues of nuclear renaissance.

Thank you one and all.

Prof. B.N. Jagatap
President, Indian Nuclear Society

REPORT OF INSAC-2024 ON "REGULATORY FRAMEWORK FOR NUCLEAR RENAISSANCE"

The Annual Conference of Indian Nuclear Society (INSAC-2024) was organized during 19th to 21st November 2024 in DAE Convention Centre, Anushaktinagar, Mumbai - 400094 in association with Atomic Energy Regulatory Board (AERB), Mumbai on 'Regulatory Framework for Nuclear Renaissance'. The conference brought together esteemed experts and stakeholders to discuss the important topics in the conference. This report summarizes the key discussions, presentations, outcomes of the conference, highlighting the challenges, opportunities and recommendations for shaping an effective regulatory framework in support of safe and sustainable development of nuclear energy. With affirmative support declared by Government of India for speedy growth of nuclear in India, conducive development for collaboration by global leaders for aiding capacity addition and likely scenario of private participation in expanding nuclear in the country, nuclear industry in India stands at a critical juncture. The situation certainly warrants moving from business-as-usual style to mission mode for executing the projects to meet the goals mandated in the plan. In time of renewed interest in nuclear energy, it is but natural for all the stakeholders to discuss and evolve a robust regulation for nuclear safety. In that respect, organizing the conference is timely and rewarding.

The twenty invited talks were distributed across six technical sessions, allowing for in-depth exploration of specific areas. The six technical sessions covered the following topics.

- **Leadership for Safety and Resources:** In this first session there were one keynote talk and three invited talks. This session focused on bringing out the importance of strong leadership in fostering a safety-conscious culture within nuclear organizations and the effective management of resources to support safety initiatives. Regulatory process is said to be evolving and is truly a journey to attain maturity in regulatory culture to address newer challenges. It was asserted that while regulation is necessary but is not an impediment as commonly viewed by designers and operators. It was stated that over the last four decades, AERB with its built-up resources has been recognised as a knowledge organisation of international standard and it maintains high level of professionalism. It was pointed out that India has adopted a stringent radiation dose limit that diverges from international standard. It was also argued that aligning India`s dose limit with ICRP standard could be a game changer for rapid expansion of nuclear in India. The need for standards for nuclear material and the need for approving alternate to nuclear grade material was emphasised.

- **Public Safety and Industry Excellence:** There were three talks in this session. The session explored the relationship between public perception of nuclear safety and the industry's pursuit of excellence. The talks addressed communication, transparency and the industry's efforts to continuously improve safety performance. For an effective and timely response during the severe nuclear accident it was emphasised that it is prudent to establish a robust Emergency Preparedness and Response (EPR) framework for assuring public protection in spite of defence-in-depth concept applied in the design. Such a practice also takes into account socio-economic considerations and non-radiological hazard associated with response action for doing more good than harm. This goes in a long way in building public confidence on regulatory actions, which should be taken without fear and favour in an honest and impartial manner. Presentation also highlighted the key challenges & gap areas at various administrative levels and recent initiatives taken by Ministry of Home Affairs (MHA).

- **Addressing Safety Challenges and Culture:** There were four invited talks in this session. The session discussed about safety reviews that has been evolving concurrently with the development of technology. AERB is preparing to address the expectations of a robust yet flexible regulatory process that can boost timely deployment of Nuclear Power Plants (NPP) with advanced technologies in multiple units. The session had a presentation on challenges faced in safety evaluation during the first commissioning trials of 700 MW PHWR in Kakrapar. Multi-tier reviews were carried out as a part of the consenting process, by the Site Evaluation Committee (SEC), Project Design Safety Committee (PDSC), Advisory Committee for Projects Safety Review (ACPSR) and the Board of AERB. There were in fact no set Regulatory guidance or acceptance criteria available for the first-of-its-kind systems and features which posed many challenges. It is generally accepted that there are lots of advantages in adhering to safety requirements but some requirements of safety and security are contradictory. The challenge is to identify, analyze and evaluate such contradictory requirement and provide adequate security/safety measures to minimize the risk of unauthorized removal of nuclear/radioactive material and/or sabotage to the vital areas. The session emphasized that safety culture plays all important roles in regulating safety. The culture towards radiation safety, which comprises core values, behavioural traits, conduct, leadership & commitment for safety, and transparent reporting of issues, plays a key role in ensuring compliance to the requirements and protection of occupational workers from ionizing radiation following the principle of ALARA (As Low As Reasonably Achievable). Licensees are expected to identify and address the low level non-compliances before they become part of culture and result in pile up effects, which may warrant regulatory action.

- **Radiation Safety in Healthcare & Food Industry:** This session had three talks. The session discussed about addressing radiation safety and occupational exposure that require a multi-pronged approach and unfailing commitment of management. Valuable guidance on this is available from documents developed at international level. Nurturing radiation safety culture in healthcare, encompassing all stakeholders and every action, is essential to improve the protection and safety of patients and workers exposed to radiation. Use of radiation has seen a rapid increase in its use in research, medicine and industry, with many benefits to the society. They are used in medicine to diagnose illnesses, to kill harmful bacteria in food and to extend the shelf life of fresh produce, many radioactive materials (Bq to MBq range) are being used for experiments and drug discovery, no. of consumer products, such as smoke detectors and exit signs, radiation has useful applications in agriculture, archaeology (carbon dating), space exploration, law enforcement, geology (including mining), and many others. RRCAT has also developed a 10 MeV, 15kW food irradiation Linac which has an energy filtering system to remove electrons above 10 MeV as required by food irradiation regulations. The Linac is also suitable for industrial applications including sterilization of medical devices for high throughput.

- **Regulatory approach to ensure safety of new entrants:** This session had one keynote talk and four invited talks. This session discussed the importance of nuclear fuel cycle that is expected to act as a catalyst for the growth of nuclear. Introduction of MOX fuel as an accident tolerant fuel in advanced reactor was discussed. The need for updating regulatory framework to meet the challenges in safety review of advanced fuel cycle was discussed. In the recent times, with nuclear renaissance in the backdrop of global climate control, a regulation of new and emerging technologies was discussed along with their associated challenges in their regulations. In its journey of attaining maturity in safety regulation, AERB has traversed a long path from its evolution and is gradually moving towards concept of higher level technology neutral requirements and technology specific aspect covered as necessary. The talk also highlighted the international developments for dealing with challenges posed by new and emerging technologies. Nuclear regulatory bodies follow graded approach in regulation of nuclear & radiation safety. This approach allows regulatory bodies to decide the scope & stringency of regulatory controls for facilities & activities in a coherent manner and thus brings effectiveness & efficiency in regulation without compromising safety. This approach allows AERB to determine whether regulatory controls are warranted if there is low risk involved and where the regulatory controls are actually needed. On engagement of stakeholders, AERB has developed regulatory guidelines through REGDOCs with a view that requirements and guidance covered are 'clear' and 'easily understandable' to the stakeholders and which adequately reflect regulatory expectations. One of the important functions of regulatory guidelines is to establish communication and consultation with interested parties throughout the lifetime of the facility or duration of the activity to both inform and obtain the views of the public and other interested parties. The session discussed The Atomic Energy (Amendment Act), 2015 which has expanded the definition of 'Government Company' to stimulate the expansion of India's nuclear power generating capacity in the medium to long term framework through the joint venture model. Therefore, PSUs are now participating in joint ventures with NPCIL (or BHAVINI). There are also possibilities of foray of private players in the nuclear sector, in the coming days, which may necessitate amendments in the governing legal statutes. In future, different entities may be made responsible to build, own, operate and decommission a nuclear power plant. The requirements related to organizational change of management of the project from one entity to another during the consenting stages also assume significance.

- **Global Synergy in safety, Research & Manufacture:** This session had three invited talks. The session discussed about major international conventions and agreements present and comprehensive framework for ensuring safe and sustainable expansion of nuclear power. Convention on Supplementary Compensation for Nuclear Damage (CSC) facilitates a framework for compensation in case of nuclear accidents, ensuring economic relief and share liability among countries that have ratified the CSC. The CSC thus supports global expansion of nuclear power while addressing potential public safety risks. These conventions together provide a holistic approach and best practices to global nuclear safety and security. India has ratified all the major international conventions on nuclear safety and security and has made political commitments as required. The session further adds a flavour on the way forward which can strengthen the safety research based on Phenomena Identification and Ranking Table (PIRT) to close the existing research gap areas for newly designed and aged plants on a priority basis. Introduction of robust V&V methodology for indigenous analysis tool qualifications, usage of research network among DAE units and National Institutes, establishment of database for a systematic research and usage of evolving frontier technologies like AI based tools for a speedy regulatory decision making, especially with respect to operational safety needs time-bound regulatory decisions. The session further discussed about objective of implementing Quality Management System during manufacturing to assure that stated requirements for manufacturing of Structures, Systems and Components (SSCs) are complied with and adhered to and SSCs of required quality are produced. The contract document of NPCIL provides Quality Assurance requirements with respect of items to be manufactured. It is the responsibility of each organization participating in the manufacture of item(s) to establish and implement the Quality Assurance Programme (QA Programme) to the satisfaction of NPCIL (contract) and this is stated in the contracting document.

- Dr A. Rama Rao

INVITED TALKS OF INSAC-2024

1. 'Leadership and Management for Safety' by Shri D. K. Shukla, Chairman, AERB
2. 'Regulatory Framework for Nuclear Safety' by Shri S. B. Chafle, Executive Director, AERB
3. 'Strengthening Resources and Expertise in Regulatory Body' by Shri S. A. Bhardwaj, Former Chairman, AERB
4. 'Scaling of Nuclear Power, the Regulatory and Supply Chain Imperatives for India's 2047 Goals' by Dr. D. K. Aswal Director, HS&E Group, BARC
5. 'Public Trust through Stakeholder Engagement' by Shri A. P. Garg, Director, Directorate of Regulatory Affairs & External Relations, AERB
6. 'Emergency Preparedness and Response Framework and Challenges Ahead' by Shri Kapil Deo Singh, Head, Division of Radiation Protection & Environment, AERB
7. 'Key Issues and Challenges - Nuclear and Radiological Emergency - National Perspective: Roles and Responsibilities of stakeholders' by Shri S. K. Ghosh, Former Head, Division of RI, AERB & Former NDMA
8. 'Safety Review Experience of Three Stage Indian Nuclear Program: Lessons for the Future' by Shri S. Harikumar, Head, Nuclear Projects Safety Division, AERB
9. 'Experiences in Safety Review and Licensing of 700 MW PHWRs' by Dr. Mayank Verma, Project Review Coordinator, Nuclear Projects Safety Division, AERB
10. 'Safety and Security Interface Challenges' by Shri Fredric Lall, Former Director, Nuclear Projects Safety Division, AERB
11. 'Role of Regulatory Body Influencing Licensees for Strengthening Radiation Safety Culture' by Shri J. Koley, Head, Operating Plant Safety Division, AERB
12. 'Global Initiatives to Foster Radiation Safety in Healthcare (Infrastructure)' by Dr. N. Ramamoorthy, Former Outstanding Scientist, BARC / DAE
13. 'Growth of Radiation Application in Medicine and Industry: The Regulatory Perspective' by Dr. Pankaj Tandon, Head, Regulatory Interface & Stakeholder Engagement Section, Directorate of Regulatory Affairs & External Relations, AERB
14. 'Radiological Safety in Food Radiation and Indian E-Beam Technology: A Step towards Improved Radiological Safety and Atmanirbhar Bharat' by Shri Jishnu

Dwivedi, Director, Technology Development and Support Group, RRCAT

15. 'Advances in Nuclear Fuel Cycles towards Sustainability' by Shri Kailash Agrawal, Former BARC & IAEA

16. 'Challenges in Regulation of New and Emerging Technologies' by Shri S.C. Utkarsh, Head, Nuclear Safety Analysis Division, AERB

17. 'Application of Great Approach in Regulation of Nuclear and Radiation Safety' by Shri Vivek Piplani, Head, Nuclear & Industrial Facilities Inspection Section, DRI, AERB

18. 'Development of Regulations and Guidance and Stakeholders' Participation' by Dr. R.B. Solanki, Head, Regulatory Documents Section, RDD, AERB

19. 'A Critique on Legal and Regulative Framework for Nuclear Renaissance' by Shri Soumen Sinha, Head, International Cooperation & Management Support, DRA&ER, AERB

20. 'Global Synergy for Nuclear Safety and Nuclear Security Towards Nuclear Renaissance' by Shri Deepak Ojha, Head, Division of Regulatory Inspections, AERB

21. 'Safety Research in Regulatory Decision Making for Water Reactors: Current Status and Way Forward' by Dr. Deb Mukhopadhyay, Project Manager, Isotope Production Reactor & Head, AHWR Division, BARC

22. 'Quality Management System and Regulatory Oversight during Manufacturing Stages of Nuclear (NPP) Components' by Shri A. Ramu, Executive Director, QA, NPCIL

PANEL DISCUSSIONS OF INSAC-2024

- **Panel Discussion – 1:**

Balancing the Regulatory Processes for Posting Rapid Growth of Nuclear Energy While Ensuring Public Safety and Trust by the Panelists Shri R. Raghavan, Shri S. B. Chafle, Shri K.K. Vaze, Shri J. Koley which was chaired by Shri S. K. Chande.

The panel emphasised the need for rapid growth of nuclear to fight climate change with clean power. It was suggested to use nuclear more as a source of energy rather than as a source of power. It was reiterated that today the industry is better placed to take up the challenges of new technologies in nuclear. There was a general consensus that procurement process in the department must be made simpler, simpler terminologies should be used to explain practices in nuclear operation and more transparency should be brought in the programs of DAE.

It was also suggested to make changes in the safety review process and consenting process by the regulatory body. To speed up the process it was suggested to involve regulatory review only at higher level and that lower level review must be left to the designers. Several examples were cited in support of the suggestion. The panel discussed how the regulatory reviews have kept pace with the growth of nuclear in India right from early 1980s. The panel suggested to explore the need for rule-based review and speed up standardising the design and design practice.

- **Panel Discussion-2:**

Innovations in Regulatory Approaches for Next-Generation NPPs and New Entities in the Nuclear Landscape by the Panelists Shri S.A. Bhardwaj, Shri U.C. Muktibodh, Shri A.P. Garg, Shri S. Harikumar, Dr. R. S Yadav chaired by Shri G. R. Srinivasan.

This panel involving manufacturing industry suggested speedy regulation, risk informed decision making, performance based regulation, early engagement of the regulator and the owner of the plant, one step licence, digital transformation, digital documentation, AI based data analysis, collaborate and harmonize, digital twin and so on. Panel cited the importance of time and cost overruns and need to put up complete safety basis to the regulator. Regarding time taken in the regulatory process, it was stated that the first design would take longer time as new technologies pose newer challenges.

The panel stated the importance of public acceptance and the positive yet decisive role played by AERB in this respect. While accepting new technologies, it was cautioned to be more selective. In this contest applicability of AI based systems was discussed and felt that AI can be used effectively for accident management. The panel also discussed about technology neutral regulation with examples. The panel also discussed about exclusive zone in the context of newer technologies being adopted in Gen III+ and future Gen IV reactors.

Broadly the message was that NPCIL and future public sector units and private partners must closely collaborate to meet the target set by GoI to add capacity to the grid and at the same time scrupulously adhere to all the AERB guidelines to obtain regulatory consent from very early stage to avoid delays and cost overruns in the projects. AERB on its part would evolve the regulatory framework for advancements in the design, construction, erection and operational stages of on-going and future projects.

Note: Readers may visit the following link to listen to the above talks and the panel discussions: **https://www.insac2024.org/video-gallery.php**

LIST OF POSTERS OF INSAC-2024

Sr. No.	Title	First Author
01.	Seismic margin assessment and fragility analysis of a nuclear power plant pressure vessel	Dr. Ravi Kiran Akella
02.	CFD analysis of the hot and the cold stream injection into large containment cells	Mr. Asif Ahmad Bhat
03.	Study on solid waste categorization for muck cleaning spent filters generated at reprocessing plant, Tarapur	Ms. Riya Gupta
04.	Tools qualification: changing horizons	Mr. Yogesh Suresh Nirgude
05.	Moving towards deterministic evaluation of in-vessel retention strategy in light water reactors	Mr. Ganesh V
06.	Experimental demonstration of fuel bundle cooling from top flooding during SBO	Mrs. Garima Singal
07.	Comparison of single and multi-parameter models for criticality safety assessment of metal system	Mr. Rajnish Kumar
08.	Replacement of reactor recirculation piping within narrow space of primary containment of TAPS-1&2, NPCIL	Mr. Vinay Thattey
09.	Upgradation of Computer based systems for life extension of Nuclear Power Plants	Ms. Jaya Choudhary
10.	Navigating nuclear safety and security: Transparency, training and technological challenges	Mrs. Sumathi Ellappan

11.	The importance and preparedness for handling of early phase of nuclear emergency in Indian NPPs	Mr. Amit Kumar
12.	Forecasts of atmospheric wind profile with an ARIMA technique based model	Dr. Roopashree Shrivastava
13.	pyDOSEIA: A python package for radiological impact assessment during long-term or accidental atmospheric releases	Dr. Biswajit Sadhu
14.	Different schemes for numerical solution of 1D advection diffusion equation: A comparative study.	Ms. Anmol Batra
15.	CELAS based Heavy Water in Air Monitor for PHWRs	Dr. Anita Gupta
16.	Effect of source cage orientation on dose distribution of blood irradiator	Mrs. Jyoti Garg
17.	Thermo-structural analysis of guide tube during a postulated severe accident in a PHWR	Mr. Rajaganesh Shivaraman
18.	Experimental research for severe accident management in SFRs	Mr. Hemanth Rao Ellapu
19.	Decision support system for assessment of protective action recommendation during off-site emergency exercises	Mr. Anup Yadav
20.	Thermal analysis of a typical radioactive material transport package for fire exposure as per regulatory requirement	Dr. Seik Mansoor Ali
21.	Additional postulated initiating events to be considered for a natural circulation based reactor	Dr. Satish Kumar Gupta

22.	Siting small modular reactors in India: re-thinking regulations on the exclusion zone	Mr. Anirudh Chandra
23.	Review of power profile effect on thermal margin evaluation	Mr. Vivek Popat
24.	Regulatory perspective on licensing framework for claiming compensation under civil liability regime	Mr. Soumen Sinha
25.	Regulatory research needs to support deployment of advanced nuclear reactors as captive power plants for industries	Ms. Rupsha Bhattacharyya
26.	Development of regulatory framework for emerging technology based nuclear power plants in India	Dr. Rajendrasinh Bahadursinh Solanki
27.	Scope of hydride based moderator use in advanced nuclear reactors and its challenges in development	Dr. Ananta Borgohain
28.	Use of thermoelectric generators (TEG) in nuclear reactors	Mr. Mahesh Bhagwandas Bajaj
29.	Medical cyclotron facilities (MCFs) in India: a regulatory inspection based safety performance assessment	Mr. Suvadip Roy
30.	INES rating scheme for NPPs events based on defence in depth degradation	Ms. Jyoti Kumari
31.	Challenges in speedy deployment of Nuclear Energy and Preparedness of Indian Industry	Mr. Nijam Mahamad Nadaph
32.	Application of graded approach in regulation of facilities and activities	Mr. Vivek Piplani

33.	Regulatory challenges for age-old nuclear facilities	Dr. Nandkumar L Sonar
34.	Regulatory challenges for assessment of new nuclear reactor designs	Dr. Ananta Borgohain
35.	Expanding nuclear energy capacity - Radiation safety	Mr. Virendra Kumar Gupta
36.	Experimental investigations on station black out and passive decay heat removal system performance of 700 MWe IPHWR design	Dr. Ritesh Bagul
37.	Estimation of source term during start-up operations of a typical PHWR-700 based NPP	Dr. Subrata Bera
38.	Improvement in primary containment ventilation system to reduce the range of blind LOCA in 700 MWe IPHWR	Mr. Ankush Yadav
39.	Internal Safety Review of 700 Mwe PHWRs in NPCIL	Mr. Jagannad B L
40.	Insights into the Methodology for Determination of CCPs in 700 MWe PHWR	Mr. Vivek A. Kale
41.	Insights from safety review process for emergency diesel generators used in Indian NPP	Dr. Dhanashree Vyawahare
42.	Experiences in safety review and licensing of PDHRS in 700 MWe PHWRs	Mr. Ashutosh Dixit
43.	Cooling of end bundle during LOCA+LOECCS in old 220 MWe PHWR	Mr. Ramesh Kumar

Note: Abstracts of the selected three posters which received the best poster award are reproduced in the next chapters of the newsletter.

EXPERIMENTAL RESEARCH FOR SEVERE ACCIDENT MANAGEMENT IN SODIUM BASED FAST REACTORS

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INTRODUCTION

Despite of very low probability, severe accidents in Sodium cooled Fast Reactors (SFRs) need to be analyzed for safety evaluation and formulating effective Severe Accident Management strategies. Many uncertainties exist in the severe accident analysis of SFRs and experimental data is scarce to validate the models. Moreover, enhanced safety requirements from the new safety criteria demand thorough investigation of the complex phenomena associated with severe accidents in SFRs. An extensive R&D program has been taken up at Safety Engineering Division, FRTG, IGCAR to study various key phenomena. Dedicated facilities are set up and experimental programs are chalked out to address various gap areas related to severe accident progression and effective mitigation in SFRs. The knowledge gained from these experimental studies help in developing Severe Accident Management Guidelines (SAMG).

METHODS

The experimental program focuses on two important areas

i) Studies on Molten Fuel Coolant Interaction (MFCI), and safe retention of debris bed

ii) Investigation of consequences of sodium fire in containment for Radiological Impact Assessment

To support the MFCI studies, two techniques viz. Aluminothermy Reaction and Cold Crucible Induction Melting (CCIM) were developed for generation of corium at high temperatures up to ~ 2400 oC. The melt generation systems were integrated to dedicated sodium systems. Several experiments were conducted at various melt - coolant inventories to investigate the fragmentation of simulated corium (melt mixture of ceramic+metal, metallic melt) in sodium. A real-time X-ray imaging system was deployed for in-sodium visualization of MFCI as shown in Fig. 1. Energetics of the MFCI were monitored using in-sodium dynamic pressure sensors. Fragmented debris for each experiment were retrieved from sodium and debris characteristics was assessed for defining bed signature. Experiments on debris bed coolability were conducted in a 1:4 scale reactor vessel with core catcher and decay heat exchangers using water as simulant. For assessment of consequences of sodium ejection through PFBR top shield during HCDA, a scaled setup with actual leak paths was used. Sodium slug impact at bottom of the model top shield was generated experimentally and the ejected sodium was quantified for assessment of its burning potential.

RESULTS AND DISCUSSION

X-ray images from the MFCI experiments in sodium showed fragmentation of the simulated corium within short travel in sodium (Fig. 2), indicating the chances for direct corium impingement on core catcher are very remote. The dynamic pressure pulse during the melt-sodium interaction observed to be very less confirming the non-energetic MFCI in SFRs. The debris generated comprised majority of small size particles, which were observed to solidify almost instantaneously indicating formation of debris in solid phase with adequate porosity for ensuring long-term coolability. Simulated experiments in 1:4 scale main vessel with water successfully demonstrated establishment of natural convection from the heat generating debris bed on the core catcher to the decay heat exchangers confirming effective post-accident heat removal. Experiments on sodium leak through top shield of PFBR during HCDA

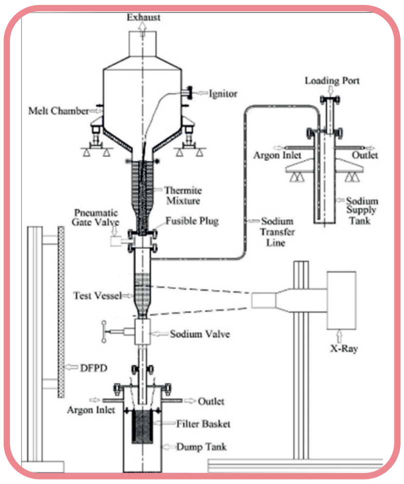

Fig.1: Experimental setup for MFCI in sodium

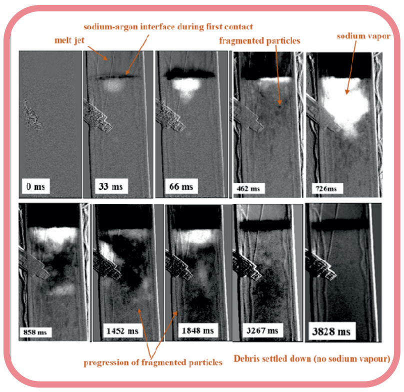

Fig.2: Fragmentation of simulated corium in sodium

Fig. 3 Experiments on sodium release from top shield during HCDA

indicated the chances for instantaneous sodium combustion in the containment to be very remote. The quantity of ejected sodium though the leak path-1 found to be 3 times lesser. The sodium temperature at the exit of the leak path was lesser than the required temperature for instantaneous combustion (Fig. 3).

CONCLUSIONS

A dedicated experimental R&D program is underway at IGCAR for phenomenological understanding of severe accidents and validation of safety features in SFRs. However, gap areas still exist for meeting the enhanced safety requirements as per the emerging safety criteria. Benchmark experiments with prototypic corium consisting of actual fuel composition in sufficiently large scale is necessity for realistic estimation and extrapolation of the results to the future reactor designs.

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2) Hemanth Rao, E et al., Investigation of molten fuel coolant interaction with simulated corium in sodium, Annals of Nuclear Energy 206(2024):110640

INSIGHTS INTO THE METHODOLOGY FOR DETERMINATION OF CRITICAL CHANNEL POWER IN 700 MWE PHWR

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INTRODUCTION

Regional Overpower Protection System (ROPS) is one of many first of a kind features in 700 MWe IPHWR which enables reactor trip on local overpower. The trip set points (TSPs) of the ROPS detectors are determined so as to prevent fuel dry-out or melting. For any reactivity device (RD) configuration, the reactor power at which the minimum Critical Heat Flux Ratio (mCHFR) in any coolant channel falls below 1.1 or fuel melting occurs is called the critical channel power (CCP). Determination of CCPs for different RD configurations/flux shapes is a pivotal step in ROPS design. Steady state calculations of CCPs were done earlier for nominal and selected skewed core configurations [1]. Use of steady state equations to determine CHFR in coolant channels gives conservative values of CCP since it is assumed that the thermal-hydraulic state immediately follows the neutronic/power changes without any delay. In actual transient, the thermal-hydraulics lags the power changes depending on the time scale of the transient. The present exercise has been performed using in-house computational code REDAC to determine the CCPs for slow LORA transient for selected reactivity device configurations. The steady and transient CCP values have been compared for the same configurations, highlighting the degree of conservatism in the steady state approach.

METHODOLOGY

Determination of CCPs involves estimation of CHFRs and fuel temperatures for all the coolant channels. The transient coolant transport equations (continuity, momentum and energy) coupled with the transient 1-D fuel heat conduction equation are solved numerically in REDAC using validated algorithms and the available state of the art correlations [2]. For the transient simulation, the power is increased with time (starting from 100%FP) based on a known power history corresponding to the slow Loss of Regulation Accident (sLORA) [3]. Only thermal hydraulic calculations are performed, i.e. evolution of bulk power and power distribution is used as an input (imposed externally), without solving neutronics. With respect to the initial conditions, two approaches are used for the transient simulations.

Approach 1: In a conservative and simpler approach, the reactor starts with the given steady distorted configuration at t = 0 and subsequent slow power rise is imposed in a transient thermal-hydraulic simulation to arrive at the minimum CCP.

Approach 2: In this approach, the shape change form nominal to a given distorted configuration is imposed on the thermal-hydraulics solver as a part of the transient itself. This saves the detailed space-time kinetics calculations while still approximately accounting for the time dependence of power distribution.

TABLE 1: COMPARISON OF THE STEADY VS TRANSIENT CCP VALUES

Case Number/Configuration	Minimum CCP (%FP) and (Channel Number)		
	Steady State Calculation	Transient Calculation	
		Approach 1	Approach 2
Nominal: All ARs IN, CRs OUT, All ZCC @ 44%	130.24 (L-15)	163.49 (K-8)	No shape change
AR IN, CR OUT, ZCC-4,11 @ 0%, rest 40%	121.64 (M-11)	144.80 (M-11)	144.93 (M-11)
AR IN, CR OUT, ZCC-5,12 @ 0%, rest 70%	104.74 (D-12)	108.12 (D-11)	109.05 (D-11)
AR IN, CR OUT, ZCC-3,10 @ 0%, rest 90%	110.27 (S-11)	119.27 (S-11)	119.75 (S-11)
AR IN, CR OUT, ZCC-1-4,8-11 @ 0%, rest 90%	100.44 (R-6)	101.00 (R-6)	104.00 (R-6)

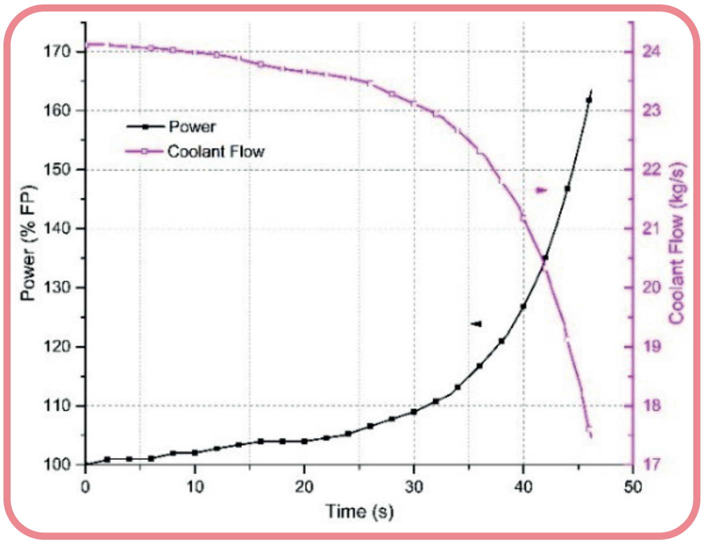

Fig. 1: (a) Variation of power and coolant flow for transient simulation,

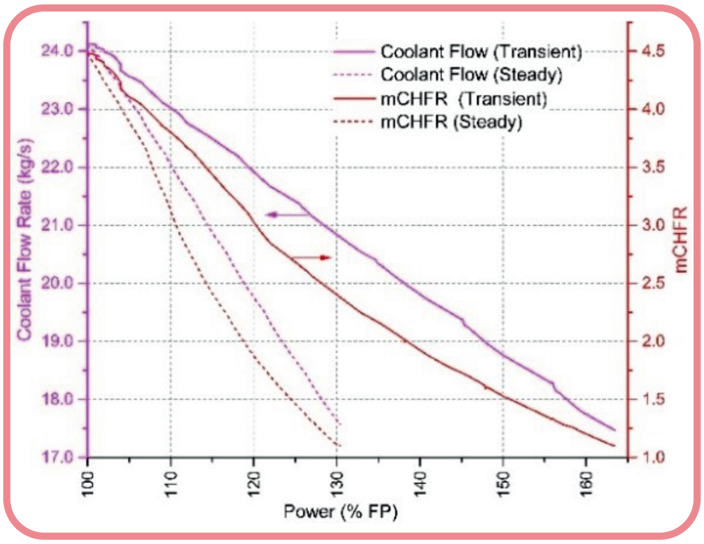

Fig. 2: (b) comparison of mass flow rate and mCHFR reduction in steady vs. transient cases for one channel (nominal configuration)

RESULTS AND DISCUSSION

Table 1 shows the values of CCP for steady and transient simulations for selected reactivity device configurations. It is observed that the CCP values obtained for transient analysis are higher than the corresponding steady state values. This is due to the delay in attaining a given thermal hydraulic state in the transient case compared to the fuel/coolant state associated with steady state simulation at the same power. Consequently, the CHFR decreases slowly (or the fuel temperature rises slowly) for the transient simulation compared to the steady state simulation. However, it is noted that for highly distorted configurations, the difference between the steady vs. transient mCCPs is very small.

The differences associated with steady vs transient approach can be illustrated by considering a single channel. Figure 1(a) shows the variation of the normalized channel power and coolant mass flow rate with time for channel K-8 in nominal core configuration. Figure 1(b) shows the variation of mass flow and mCHFR with power for the steady and transient cases. At the same power level, the mass flow rate and mCHFR values are higher for the transient case than the steady case. mCHFR drops rapidly with power for steady state analysis and CCP is obtained at a lower power level (130.41 %FP) compared to the transient analysis (163.49 %FP).

CONCLUSIONS

It is observed that the CCP values

obtained from the transient simulations are higher than the corresponding steady state values. This is due to the delay in attaining a given coolant thermal-hydraulic state for the transient case at a given power level. However, this difference (between steady and transient CCP) is small for highly distorted configurations; even when the change of shape is considered a part of the transient. Slower the rate of power rise, closer the value of transient CCP to its steady state value. Hence the slowest possible transient and all possible distorted configurations should be considered while arriving at the mCCP. It is also necessary to account for the modelling and input uncertainties for transient analysis. In absence of extensive case coverage and explicit uncertainty modelling, conservative approach based on steady state is recommended.

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PYDOSEIA: A PYTHON PACKAGE FOR RADIOLOGICAL IMPACT ASSESSMENT DURING LONG-TERM OR ACCIDENTAL ATMOSPHERIC RELEASES

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INTRODUCTION

Nuclear energy is a key clean energy source, with over 420 plants operating globally. Radiological impact assessments (RIAs), however, are essential for evaluating radiation exposure during routine releases and ensuring compliance with international safety standards. Several RIA software tools have been developed [1,2,3,4], each contributing valuable method for assessing radiological impact. Yet, many of these tools are not open-source, which can limit accessibility and adaptability. In response, pyDOSEIA, a Python-based package, aims to simplify the RIA process by offering an open-source alternative, with enhanced flexibility for both novice and advanced users, while also supporting machine learning applications.

METHODS

The pyDOSEIA package, developed in Python, streamlines radiological impact assessments by providing tools to calculate radiation doses based on local meteorological data, radionuclide properties, and exposure pathways. It features four key modules: META (meteorology), RADUTIL (radiation utilities and conversion factors), RADAR (dose assessment and reporting), and DOCS (dose summaries). The package accommodates both short-term and long-term release scenarios, using the Gaussian plume model for dispersion calculations. Additionally, pyDOSEIA includes the INGEN tool, which streamlines input generation by guiding users through scenario-specific questions, making it accessible even to those with limited expertise. Figure 1 presents a flowchart detailing the various modules within pyDOSEIA.

RESULTS AND DISCUSSION

The benchmarking of the pyDOSEIA software, particularly its META and RADAR modules, was validated against established studies on radiological dose assessments [5,6,7,8]. The META module's computations of dilution factors (χ/Q) closely align with values reported in the literature under various atmospheric conditions. The RADAR module accurately estimates radiation doses across multiple exposure pathways, with minor discrepancies attributed to differences in Dose Conversion Factors (DCFs). Furthermore, plume-shine doses for radionuclides such as Ar-41 and Xe-135 showed close agreement with previous studies. Parallel processing was successfully integrated, significantly reducing computation times.

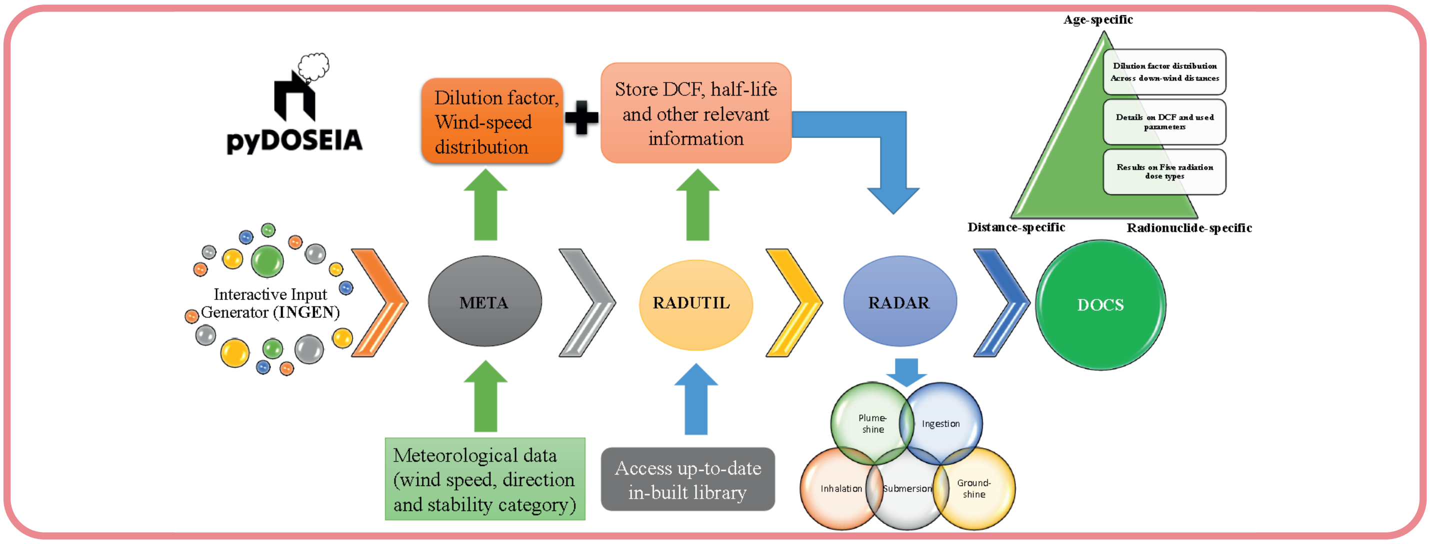

Fig 1: Simplified pyDOSEIA flowchart illustrating the INGEN module for interactive input generation and the four other key modules of pyDOSEIA: META, RADUTIL, RADAR, and DOCS.

CONCLUSIONS

In conclusion, pyDOSEIA is a Python-based software package designed for the efficient and user-friendly computation of radiation doses and dilution factors, supporting various exposure pathways and release scenarios. Its parallel processing capabilities, and compliance with IAEA guidelines, make it a robust tool for radiological impact assessments and future applications in machine learning.

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FUTURE-PROOFING INDIA'S RADIATION SAFETY FRAMEWORK FOR A GROWING NUCLEAR ENERGY PROGRAM

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Abstract:

India's goal of achieving 100 GW of nuclear power by 2047 requires a future-proof radiation safety framework that is scientifically robust, operationally efficient, and publicly trusted. This article discusses key elements of such a framework, their challenges and opportunities. A key challenge is the uncertainty surrounding low-dose radiation risks. While high-dose protection is well established, low- dose regulations need refinement based on emerging research. Adopting a Adaptive Radiation Safety (ARS) principle for low doses while retaining ALARA for high doses can enhance both safety and efficiency. Institutional reforms are equally crucial. Reassessing nuclear power plant classification based on environmental monitoring data will enable risk-informed regulation. Establishing a Radiological Assessment Board (RAB) can strengthen independent radiation monitoring, emergency preparedness, and regulatory oversight. Additionally, improving dosimetry programs, emergency response mechanisms, and quality assurance will reinforce safety at every level. To complement all the above, transparent risk communication and continuous environmental monitoring will help address misconceptions and build confidence in nuclear energy. By integrating scientific advancements, regulatory clarity, and public engagement, India can develop a resilient, internationally credible radiation safety framework, ensuring its nuclear ambitions are both safe and widely accepted.

Keywords: radiation safety, nuclear energy, low dose radiation, nuclear regulations, environmental monitoring, emergency response

Introduction

India has created an aspirational goal of installing 100 GW of nuclear power by 2047 [1]. Achieving this milestone will require not only cutting-edge technology and forward-thinking policies but also a deep commitment to safety at every level. One of the most important aspects of this journey is ensuring that our radiation safety framework-designed to protect people and the environment from the effects of nuclear radiation-is robust and ready for the future.

In today's rapidly evolving world, the rules and systems we use to manage radiation risks must keep pace with scientific discoveries and technological advancements. This means updating how we understand radiation effects, improving our methods to monitor and control radiation exposure, and making sure that our safety practices are both reliable and adaptable.

In this article, we will explore the key ideas and strategies needed to modernize India's radiation safety framework. By focusing on scientific insights, innovative technology, and smart regulatory reforms, we can build a system that not only meets today's challenges but is also prepared for the growing demands of tomorrow's nuclear energy program. (See Figure 1 for a visual summary.)

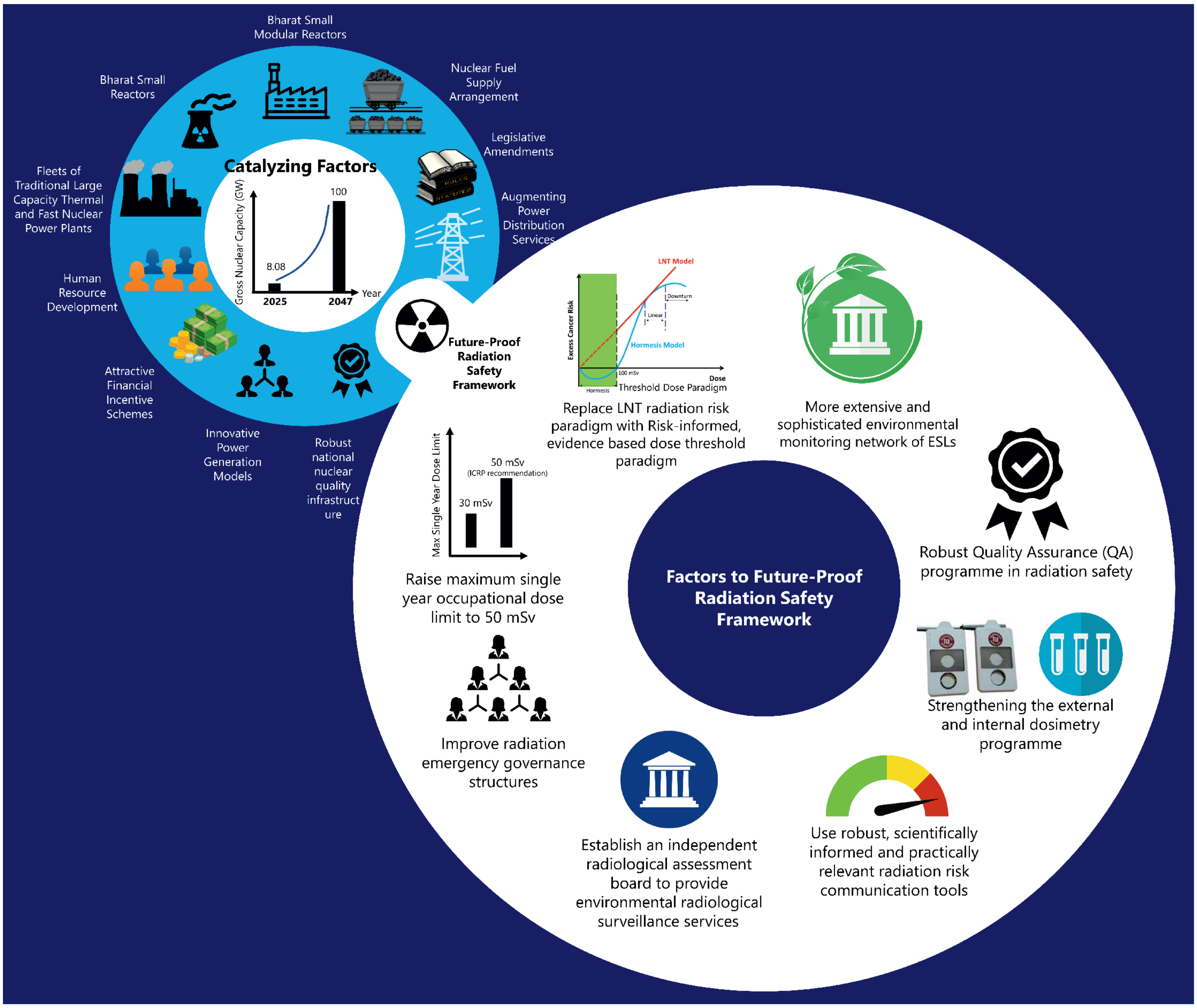

Figure 1. A comprehensive illustration of how India's drive toward 100 GW of nuclear power intersects with the need for a resilient, future-ready radiation safety framework. The blue outer circle (left side) represents the key catalysts propelling India's nuclear ambitions—ranging from advanced reactor technologies (e.g., Bharat Small Modular Reactors), nuclear fuel reprocessing capabilities, and human resource development initiatives to evolving legislative and policy reforms. The timeline from 2025 to 2047 underscores the progressive milestones India aims to achieve in expanding its nuclear power capacity. The white inner circle (right side) details the strategic measures required to strengthen and modernize India's radiation protection system. These include:

- Refining risk models by transitioning from the Linear No-Threshold (LNT) approach to an Adaptive Radiation Safety (ARS) model for low-dose exposures.
- Raising the maximum single-year occupational dose limit to 50 mSv, in line with emerging scientific evidence and international standards.
- Enhancing environmental monitoring networks to provide real-time, sophisticated assessments of radiological conditions, ensuring more accurate Emergency Information Systems (EIS).
- Instituting robust quality assurance (QA) programs and improving internal and external dosimetry protocols to maintain high standards of worker andpublic safety.
- Strengthening emergency governance through clear, well-practiced response mechanisms that can be rapidly activated if needed.
- Establishing an independent radiological assessment board for unbiased oversight, encompassing environmental monitoring, public communication, and regulatory compliance.
- Adopting science-based, practical risk communication tools to foster public trust and dispel misconceptions about nuclear energy.

Together, these factors highlight the dual imperative of advancing nuclear technology while ensuring that safety measures remain agile, evidence-based, and widely trusted, ultimately paving the way for a secure and sustainable nuclear future in India.

Radiation risk models and Science of radiation

Radiation safety is built on a foundation of science-specifically, how ionizing radiation interacts with living organisms and what happens as a result. When it comes to radiation's effects on the body, scientists generally place them into two categories. First, there are deterministic effects, like radiation burns or acute radiation syndrome, which only happen above a clear dose threshold. Then, there are stochastic effects, such as cancer, which don't follow a predictable pattern and are believed, in theory, to occur even at very low doses. At high levels of radiation exposure, the risks are clear-cut. The effects are well understood, reproducible, and predictable. That's why radiation safety protocols aim to keep exposures As Low As Reasonably Achievable (ALARA) -a principle designed to minimize harm [2]. But what about low doses -say, levels at or below 100 millisieverts (mSv)? This is where things get complicated [3, 4].

Radiation doses in this range are similar to what people naturally receive in many parts of the world and are common in nuclear facility operations. Unlike high-dose effects, the biological impact of such low levels isn't easy to pin down. Scientists often use the Linear No-Threshold (LNT) model to estimate cancer risk, which assumes that even the tiniest dose increases cancer risk in a straight-line fashion, with no completely safe threshold [5]. But this idea is far from universally accepted. Many researchers argue that LNT is overly cautious and isn't fully backed by real-world data [5, 6]. In fact, numerous studies suggest that the relationship between radiation dose and cancer risk isn't as simple as a straight line. Some findings even hint at possible adaptive responses, where low-dose exposure might trigger protective mechanisms in cells. Despite these debates, the LNT model remains the backbone of radiation protection policies worldwide [7, 8].

The problem? Applying the same strict safety rules for both high-dose and low-dose exposures can lead to unnecessary restrictions, inflated fears, and impractical regulations [6]. While minimizing exposure is a good idea at high doses, blindly applying the same approach to very low doses may be impractical going forward. Perhaps it's time for a more balanced, evidence-driven rethink of radiation protection- one that acknowledges both scientific uncertainty and practical realities.

But, if we're going to rethink radiation protection, we need more than just new regulations or risk models-we need a deeper scientific understanding of how ionizing radiation interacts with biological systems. That means moving beyond the conventional idea that radiation risk is always tied directly to dose. Instead, scientists are calling for a multi-scale approach [9] -one that looks at radiation effects from the tiniest atomic interactions all the way up to population-wide health impacts.

At the most fundamental level, radiation first interacts with our bodies at the quantum and atomistic scale-where high-energy particles collide with biomolecules like DNA. Understanding exactly how radiation deposits energy, forms radicals, and disrupts molecular structures could provide unprecedented insights into the earliest biological effects of exposure [9]. This kind of precision would help explain how different types of radiation damage DNA, trigger repair mechanisms, and influence cellular behavior.

Zooming out from the molecular level, researchers are also investigating how cells respond to low-dose radiation. Interestingly, some studies suggest that small doses might actually activate repair mechanisms or even stimulate beneficial biological responses [10, 11] - contradicting the traditional view that all radiation exposure is harmful. By integrating these findings into systems biology, which looks at how cellular changes affect the whole body, scientists may uncover non-linear dose-response relationships-including possible thresholds below which radiation has little to no harmful effect. Some even speculate that at very low doses, radiation might have hormetic effects [11], meaning it could stimulate protective biological responses.

The final piece of the puzzle is

epidemiology-large-scale studies tracking radiation-exposed populations over long periods. These studies could provide the hard data needed to validate alternative dose-response models and challenge long-standing assumptions about low-dose risks. The more we integrate molecular research with real-world health data, the closer we get to a science-backed reassessment of radiation safety.

Traditionally, much of this research in India has been led by the Department of Atomic Energy (DAE), but expanding these efforts to more universities and independent research labs could accelerate progress. A broader scientific community tackling these questions would bring fresh ideas, diverse expertise, and faster breakthroughs. Ultimately, this multi-scale, multi-stakeholder approach could pave the way for a new understanding of radiation risks-one based on solid scientific evidence rather than outdated assumptions.

System of radiation protection

Moving from scientific to operational perspective, for scientific advancements in radiation biology to truly matter, they need to translate into real-world safety policies-ones that balance both risk and practicality. As nuclear energy and radiation-based technologies expand, our operational approach to radiation protection must evolve alongside emerging scientific evidence and operational needs. For decades, radiation safety has been guided by the ALARA principle. While this makes sense for high doses, its rigid, one-size-fits-all application often leads to overly cautious restrictions-especially at low doses, where the actual risks remain uncertain. These conservative regulations can create operational roadblocks without necessarily improving safety.

Until a global scientific consensus or breakthrough is achieved in low dose research, what if we tailored our operational approach instead? A new concept-Adaptive Radiation Safety (ARS)-could provide a more flexible and practical way to manage radiation risks at low doses (below 100 mSv). Instead of relying on strict dose limits, ARS would allow for risk-informed decision-making, where protective measures are based on real-world evidence rather than outdated assumptions. Under this model, ALARA would remain in place for high doses, where strong precautions are necessary; and ARS would guide low-dose radiation work, ensuring that safety measures are commensurate with actual risks. This shift could make radiation work more efficient, cost-effective, and practical, particularly in fields like nuclear reactor maintenance and decommissioning. Reducing unnecessary conservatism would mean fewer project delays, optimized costs, and smoother execution of nuclear programs-all without compromising safety.

Another critical step toward modernizing India's radiation protection framework is updating the maximum annual dose limit for special activities from 30 mSv to 50 mSv [12]-a standard already endorsed by global bodies like the IAEA and ICRP. This adjustment would provide greater operational flexibility in high-radiation tasks, especially for: (i) Decommissioning aging nuclear reactors (ii) Major repair and maintenance work and (iii) Life-extension projects for reactors nearing the end of their lifespan. Currently, the lower dose limit acts as a constraint that lead to prolonged shutdowns, increased manpower requirements, and operational inefficiencies. Raising it to 50 mSv would allow for better workforce planning, reduced downtime, and more effective execution of high-radiation tasks, all while maintaining stringent safety oversight.

Environmental monitoring

When one talks about radiation safety, most people think of protecting workers inside nuclear facilities. But just as important is monitoring radiation in the environment-the air, water, and soil around nuclear power plants (NPPs). This kind of surveillance helps ensure that nuclear operations remain safe not just for plant workers but also for the public living near these facilities. That's why environmental monitoring is a core pillar of nuclear safety worldwide. It allows scientists to track radiation levels before, during, and after a plant's operation, ensuring public health, regulatory compliance, and environmental protection. In India, this responsibility falls to Environmental Survey Laboratories (ESLs), which operate at every nuclear power plant site [13].

Each ESL is managed by the Bhabha Atomic Research Centre (BARC), the R&D unit of India's DAE, but the lab staff work directly within NPP sites operated by the Nuclear Power Corporation of India Limited (NPCIL). This arrangement ensures that ESLs function with a level of independence while maintaining close coordination with plant operators. Before an NPP starts operating, ESLs conduct baseline environmental studies to measure natural background radiation levels. Once the plant is running, they continuously monitor the atmosphere, water bodies, biota and soil within a 30 km radius, ensuring that radiation emissions remain well within regulatory limits. Over the years, these rigorous monitoring programs have repeatedly confirmed that Indian nuclear power plants do not pose a significant radiological risk to the environment or the public [14]-a very important factor in maintaining trust in nuclear energy.

As India's nuclear energy program grows, including the potential entry of private players into reactor deployment, environmental monitoring will need to scale up as well. This means:

- Expanding the network of ESLs to cover new and upcoming nuclear power plants.
- Building a highly skilled workforce to manage the increasing number of monitoring labs.
- Upgrading monitoring technology, including real-time radiation detection systems, advanced data analytics, and state-of-the-art sample analysis techniques.
- Strengthening oversight and

transparency, ensuring that monitoring remains independent, scientifically rigorous, and aligned with international best practices.

Dosimetry

As India ramps up its nuclear energy program, the number of occupational radiation workers will grow significantly. Keeping track of their radiation doses-both external (from sources outside the body) and internal (from radioactive material inside the body)—is critical for ensuring safety and regulatory compliance. To meet this challenge, India's National Occupational Dose Registry System (NODRS) will need a major upgrade.

This system records radiation exposure data for nuclear workers, ensuring that doses remain within safe limits [15]. But with a growing workforce, this registry must expand its infrastructure, increase the production of personal dosimeters, and improve efficiency in dose tracking—possibly through automation. A larger and more advanced monitoring network also means training additional personnel to handle dosimetry operations, data management, and compliance with safety regulations.

While external radiation exposure is relatively easy to measure, internal exposure-from inhaled or ingested radioactive materials-requires more sophisticated monitoring techniques. As more workers enter the nuclear sector, India will need to modernize its internal dosimetry program. This includes:

- Expanding bioassay programs to analyse radioactive substances in bodily fluids.
- Enhancing whole-body counting facilities to measure internal contamination.
- Improving real-time exposure tracking, particularly for workers handling high-risk materials like volatile radionuclides.

An increasing nuclear workforce also presents an opportunity for a large-scale health study on radiation exposure. By tracking workers' health and radiation doses over time, India could gain valuable insights into the long-term effects of low-dose radiation exposure. This could contribute to global research efforts-such as the Million Person Study (MPS) in North America [16]- and provide scientific evidence to refine radiation safety regulations.

Emergency response

When it comes to radiation safety, one of the most critical pillars is Emergency Preparedness and Response (EPR). As India expands its nuclear program, strengthening existing EPR mechanisms will be crucial to ensure swift and effective responses in case of an emergency.

India has a well-established nuclear emergency response system [17], which has successfully managed past radiological incidents-such as the Mayapuri incident in 2010. The Crisis Management Group (CMG) at the DAE has been the country's apex decision-making body for nuclear and radiological emergencies since 1987, coordinating responses across multiple government agencies. However, as the nuclear sector grows-including possible private sector participation-gaps in coordination and governance need to be addressed to keep pace with new challenges.

India's current emergency response framework involves multiple organizations, including DAE, CMG, the National Disaster Management Authority (NDMA), and the National Executive Council (NEC) [18]. However, one major shortcoming is that NDMA-India's top disaster management body-does not have direct representation in CMG. This could lead to delays and inefficiencies in large-scale nuclear or radiological emergency responses. To strengthen India's nuclear emergency framework, three possible solutions could be considered:

- Immediate Fix: Include NDMA Representation in CMG: A simple yet effective solution would be giving NDMA a seat at CMG. This would enable faster coordination, better alignment of disaster management strategies, and a more unified decision-making process in nuclear emergencies.
- Intermediate Solution: Create a Nuclear Emergency Sub-Committee under NEC: Establishing a dedicated Nuclear Emergency Sub-Committee within NEC could streamline inter-agency coordination, ensuring technical expertise and disaster management efforts are well-integrated.
- Long-Term Vision: Establish an Independent Nuclear Emergency Preparedness Board: For a comprehensive and future-ready approach, India could consider setting up a dedicated agency under DAE-similar to the U.S. National Nuclear Security Administration (NNSA) or the Federal Emergency Management Agency (FEMA). Such an organization would oversee nuclear emergency response assets, enhance training for first responders, upgrade radiation monitoring capabilities and ensure long-term sustainability of emergency preparedness

Quality assurance

As India's nuclear program expands, the need for a strong Quality Assurance (QA) framework in radiation safety becomes more essential than ever [19]. More nuclear facilities mean stricter regulatory compliance, increased public scrutiny, and a higher demand for accurate radiation monitoring. Ensuring reliability and consistency in radiation protection, environmental monitoring, and emergency preparedness is key to maintaining safety and public confidence.

With new nuclear power plants and radiation-based industries coming up, standardizing radiation monitoring protocols across ESLs and other facilities needs to be a priority. Uniform sampling and measurement methods, regular calibration of radiation detection instruments, and inter-comparison exercises will ensure that radiation data remains consistent and credible. Without these measures, discrepancies in monitoring could weaken regulatory oversight and erode public trust.

Radiation detection systems and instruments such as survey meters, gamma spectrometers, neutron detectors, and airborne particulate monitors, must undergo continuous calibration and quality control. Regular testing and certification to national and international standards-such as those set by BARC and the National Physical Laboratory [20]—will help maintain accuracy. Automated quality control systems can further improve efficiency by enabling real-time performance monitoring and reducing the risk of unnoticed failures that could compromise safety.

As the nuclear sector grows, reliable dose assessment models and exposure pathway analysis will also become increasingly important. Computational models used for public dose assessments must be rigorously validated using site-specific environmental data and probabilistic simulations to predict radiation dispersion in the event of an accident. Regular updates to dose coefficients and environmental transfer factors will further enhance the accuracy of exposure assessments. Managing the vast amounts of radiation data generated by an expanding nuclear program requires secure, cloud-based databases for real-time access, regulatory reporting, and cross-verification. AI-driven anomaly detection and blockchain integration could play a vital role in identifying inconsistencies and ensuring data integrity, preventing regulatory lapses and misinformation.

With a growing workforce, enhancing training and competency frameworks for radiation safety personnel is equally essential. A certification-based training program, international knowledge exchange (through organizations like IAEA, ICRP and EURATOM), and hands-on calibration workshops will help build a skilled workforce. Simulation-based training using virtual and augmented reality can further strengthen preparedness for radiation dose assessment and emergency response. Finally, a rigorous QA approach to emergency preparedness is critical. Stress testing of early warning systems, full-scale emergency response drills, and standardized response protocols will improve India's ability to manage potential nuclear incidents. As nuclear installations increase, seamless multi-agency coordination and real-time data integration will be key to maintaining a robust radiation safety framework.

Radiation safety education

As India charts an ambitious path toward a 100 GW nuclear energy target, one of the biggest hurdles will be public perception. While nuclear power has historically enjoyed greater acceptance in India than in some other countries, resistance remains—especially at the local level. The "Not-In-My-Backyard" (NIMBY) mindset can lead to opposition against land acquisition and infrastructure projects, resulting in delays, legal battles, and rising costs [21]. To prevent these roadblocks, proactive public engagement is essential.

Global experience has shown that effective risk communication is crucial for gaining public trust in nuclear energy. Many countries now make public outreach a mandatory part of nuclear project approvals, ensuring that transparency and dialogue are built into the process. However, communicating nuclear risks is uniquely challenging. Radiation, probability, and long-term safety concerns are complex topics, and explaining them in a way that is both scientifically accurate and reassuring to the public requires careful strategy.

A key aspect of successful communication is tailoring information to different audiences. For individuals with a scientific background-such as students, technical professionals, and science enthusiasts-nuclear risk communication can be more analytical. Discussions can cover topics like reactor safety, radiation dose-response relationships, and quantitative risk assessments. Public seminars, expert panels, and technical reports can provide these groups with in-depth insights. In the long run, incorporating nuclear energy and radiation safety into school and university curricula could ensure a more informed society. For those without a science background, such as local communities and policymakers, communication must be clear, relatable, and engaging. Complex concepts can be simplified using analogies, visual aids, and interactive formats like community workshops and Q&A sessions. For instance, comparing radiation exposure from nuclear plants to everyday sources-such as medical X-rays or natural background radiation-can help demystify nuclear risks and put them in perspective.

Regardless of the audience, effective communication should follow a few fundamental principles. Information must be accurate without being sensationalized, risks should be presented in context rather than isolation, and trust must be built through transparency and early community engagement. A multi-platform approach-including social media, traditional news outlets, schools, universities, and NGOs-can ensure that credible, science-backed information reaches a wide audience.

Institutional reform

As India expands its nuclear energy program, it must also update its institutional and regulatory framework to improve clarity, optimize resources, and build public trust. One key area of reform is how NPPs are classified based on their environmental impact. Currently, Indian NPPs fall under the "Red" category-grouped with highly polluting industries like coal plants and chemical factories. However, this classification is outdated and does not reflect modern nuclear safety standards [22]. Unlike traditional polluting industries, NPPs operate under strict safety regulations, emit minimal radioactive discharge, and have little conventional environmental impact. A more accurate classification-such as "Orange" or even "Green"-would better reflect the reality of their operations. Historical data from ESLs can support this change. These laboratories continuously monitor radiation levels around NPPs and consistently show that radiation remains well within safe limits-often comparable to natural background levels.

Changing how NPPs are categorized is not just a technical issue; it's also about public perception. Many people have exaggerated fears about radiation, often due to misinformation. Explaining radiation exposure from NPPs in comparison to natural sources (like cosmic rays or radon in the air) and medical sources (like X-rays) can help reduce unnecessary fear. Additionally, regulatory agencies must clearly state that radiation levels at or near natural background levels pose no meaningful health risk. This clarity would provide a strong scientific basis for rethinking hazard classifications.

Another important institutional reform is the creation of a dedicated Radiological Assessment Board (RAB) within the DAE). This board would function like other specialized entities within DAE, such as the Nuclear Recycle Board (NRB) and the Heavy Water Board (HWB), but with a specific focus on radiation safety and emergency preparedness. The RAB would oversee and expand ESLs to ensure independent radiation monitoring, not just around nuclear plants but also in public spaces. It would provide radiation safety services for industries, hospitals, and research facilities, while also strengthening emergency preparedness in coordination with disaster management agencies. Additionally, it would handle the calibration and quality control of radiation detectors and safety instruments to ensure high operational standards.

By creating an independent government body dedicated to radiation monitoring and safety, India can improve transparency, regulatory efficiency, and public confidence. Separating nuclear operations from radiation safety oversight would reinforce credibility, making India's nuclear governance more resilient as the country moves toward greater use of nuclear technology in power generation, industry, and medicine.

Conclusion

To summarize, as India aims for 100 GW of nuclear power by 2047, a stronger and more adaptable radiation safety framework is essential. This means advancing scientific research, refining regulations, and engaging the public with transparency. One major challenge is the uncertainty surrounding low- dose radiation risks. While high-dose protection is well established, low-dose regulations require a more nuanced, evidence-based approach. Investing in experimental and epidemiological research can help refine dose-response models. A balanced strategy-applying ARS for low doses while retaining ALARA for high doses-could enhance both safety and efficiency. Institutional reforms are equally crucial. Reassessing the classification of nuclear power plants based on real environmental monitoring data would ensure a more accurate, risk-informed approach. Establishing a Radiological Assessment Board (RAB) could further strengthen radiation monitoring, emergency response, and regulatory oversight. Enhancing dosimetry programs, improving emergency preparedness, and maintaining strict quality assurance standards would reinforce radiation safety at every level. Finally, public trust is key.

Transparent risk communication and robust environmental monitoring will help dispel misconceptions and build confidence in nuclear energy. By embracing these reforms, India can develop a resilient, science-driven, and internationally credible radiation safety framework-ensuring that its nuclear expansion is both safe and widely accepted.

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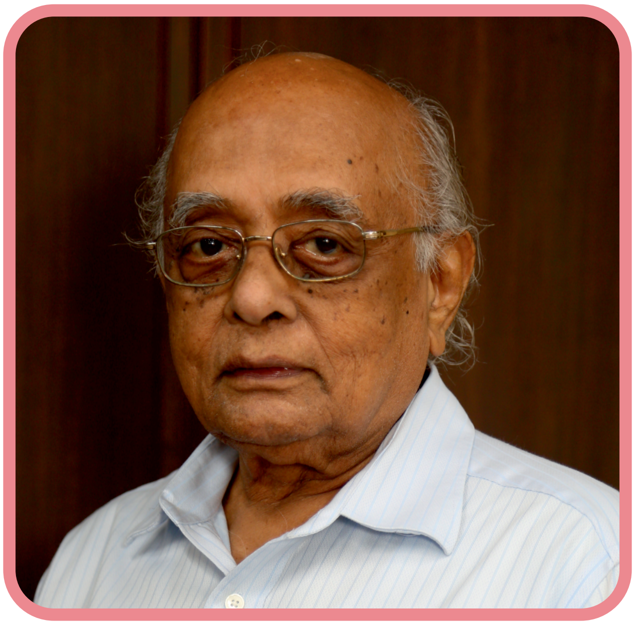
REMEMBERING DR. R. CHIDAMBARAM



DR. R. CHIDAMBARAM

(1936-2025)

Dr. Rajagopala Chidambaram was born on 12th November 1936. His early education was in Meerut and Chennai. He completed B.Sc. with honours in physics in 1956 from Madras University. He obtained M.Sc. in physics in 1958. He then obtained Ph.D. from IISc in 1962. He was awarded D.Sc. Degrees (h.c.) from thirty Universities from India and abroad. He had more than 200 research publications in refereed journals and all his research work has been in India.

He joined Bhabha Atomic Research Centre (BARC) and rose to become the Director of the Centre in 1990. He was Chairman, Atomic Energy Commission from 1993 to 2000. He was the Principal Scientific Adviser to the Govt. of India and the Chairman of the Scientific Advisory Committee to the Cabinet from 2001 to 2018. Dr. Chidambaram made important contributions to many aspects of India's nuclear technology. He was Chairman of the Board of Governors of the IAEA during 1994-95. During 1990-99, he was a member of the Executive Committee of the International Union of Crystallography, the last three years as its Vice-President. He was Chairman, Board of Governors of IIT Bombay (1994-97), IIT Madras (2008-2011), IIT Jodhpur (2018-2023) and IIT Delhi (2021-2023) and Member, Space Commission (2009-2014).

Dr. Chidambaram was a Fellow of all the major Science Academies in India and also of the National Academy of Engineering and The World Academy of Sciences Trieste (Italy). He had received many awards and honours, notable among them are the C.V. Raman Birth Centenary Award of the Indian Science Congress Association in 1995, the Distinguished Materials Scientist of the Year Award of the Material Research Society of India (MRSI) in 1996, R.D. Birla Award of the Indian Physics Association in 1996, Homi Bhabha Lifetime Achievement Award of the Indian Nuclear Society (2006), The Lifetime Achievement Award of the Indian National Academy of Engineering (2009) and the C.V. Raman Medal of the Indian National Science Academy (2013). Lifetime Achievement Award of A.P. Akademi of Sciences (2014), Lifetime Achievement Award of the Council of Power Utilites (2014). Dr. Chidambaram was awarded Padma Shri in 1975 and the Padma Vibhushan, the second highest civilian award in India, in 1999.

Among other significant contributions, his major contributions have been in the 1974 Peaceful Nuclear Explosion Experiment and the tests of 1998 at Pokharan.

Biography of Dr. Chidambaram, India Rising – Memoir of a Scientist was published and released by Penguin India in 2023. Dr. Suresh Gangotra, member of Executive Committee of Indian Nuclear Society (INS) is the co-author of this biography.

Dr. Chidambaram, who left us on 04 Jan 2025 was associated with the activities of the Indian Nuclear Society. He was Chairman of INS Board of Trustees for more than 10 years (July 1995 to November 2005). He was the President of the Society for the years from November 2001 to November 2005. We also take pride that he was conferred with INS Homi Bhabha Lifetime Achievement Award in November 2006. We place on record his service to the nation, and to the INS in particular.

- Dr S. Gangotra

INS ELECTION NOTICE

INDIAN NUCLEAR SOCIETY

Project Square, Anushaktinagar, Mumbai – 400094
Trust Registration No. F- 12326 (Bombay) dated 23.03.1988
E- mail: indiannuclearsociety@gmail.com Phone: +91-22- 6929 8327
Website: https://www.ins-india.org

NOTICE FOR THE ELECTION OF THE EXECUTIVE COMMITTEE FOR THE TERM 2025-2027

Notice is hereby given for the Election of the Executive Committee of Indian Nuclear Society for the term 2025- 2027 through online secure digital ballot. Elections are to be held for the following posts at Head Office:

Post	No. of vacancies
President	One (1)
Vice – President	One (1)
Secretary	One (1)
Joint Secretary	One (1)
Treasurer	One (1)
Joint Treasurer	One (1)
Member	Twelve (12)

A. ELIGIBILITY:

As per Rule 8 of the Rules of the Indian Nuclear Society, any person who has been a member of the Society for a minimum period of two years and is not in arrears of payment of subscription, is eligible to contest the election. In the present context, only those who have been members as on 31-03-2023 or earlier and are not in arrears of the payment of subscription as on 31-03-2025, are eligible to contest the Election. **As per Article 5.3 of the** Constitution of the Indian Nuclear Society, **"The term of the Executive Committee shall be for a period of two years. President, Secretary and Treasurer shall not be either President or Secretary or Treasurer for more than two terms continuously or cumulatively (total period not exceeding beyond 4 years). No Members of the Executive Committee shall receive honorarium, remuneration or any compensation for the services rendered by him to the Society.".**

B. SCHEDULE

Sl.No.	Programme	Day and Dates
1	Start of Filing of Nominations	Wednesday, 16 April, 2025
2	Last Date for Receiving Nominations	Thursday, 1 May, 2025
3	Announcement of Valid Nominations	Saturday, 3 May, 2025
4	Last Date of Withdrawal of Nominations	Saturday, 10 May, 2025
5	Final list of Contestants	Sunday, 11 May, 2025
6	START OF ONLINE VOTING (@)	Friday, 16 May, 2025
7	CLOSE OF ONLINE VOTING	Tuesday, 20 May, 2025
8	Counting (Online tabulation) & Announcement of Results ($)	Wednesday, 21 May, 2025

*(@) Instructions for Online Voting will be mailed by **Online Election** Agency.*
The Online Voting will remain open from 10:00 am on 16-05-2025 to 23:59 pm on 20-05-2025.
($) The contestants or their authorized representatives are welcome during the declaration of results at 11:00 am.

Nominations for various posts as listed above should be submitted in the prescribed nomination form only. The nomination form along with instructions and the format for candidate's profile is attached herewith and would also be available for download on INS website www.ins-india.org. The incomplete nomination form or wrong declaration may lead to rejection of the nomination.

Mumbai: 01-April-2025

(Ashok Kumar)
Returning Officer, INS Election 2025
Email: inselection2025@gmail.com

INDIAN NUCLEAR SOCIETY

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Website: https://www.ins-india.org

NOMINATION FORM
INS EXECUTIVE COMMITTEE FOR THE TERM 2025-2027

NAME OF THE POST		
CANDIDATE'S PARTICULARS	NAME	
	POSTAL ADDRESS	
	INS MEMBERSHIP NUMBER	
	MOBILE NUMBER	
	EMAIL ID	
	*** I hereby declare that I have NOT been either President or Secretary or Treasurer for more than two terms continuously or cumulatively (total period not exceeding beyond 4 years).**	
	DATE	SIGNATURE
PROPOSED BY	NAME	
	POSTAL ADDRESS	
	INS MEMBERSHIP NUMBER	
	MOBILE NUMBER	
	EMAIL ID	
	DATE	SIGNATURE
SECONDED BY	NAME	
	POSTAL ADDRESS	
	INS MEMBERSHIP NUMBER	
	MOBILE NUMBER	
	EMAIL ID	
	DATE	SIGNATURE

*** Applicable for the post of President, Secretary or Treasurer only and not applicable for all other posts.**

PROFILE of the CANDIDATE
INS Elections for the term 2025-2027

Membership Number: ____

Name: ____

Please paste your recent passport size photograph # here.

Date of Birth: dd/mm/yyyy	d	d	/	m	m	/	y	y	y	y

About the Candidate: (**Not more than 150 words**)

I have read the instructions for the nomination.

Signature of the Candidate

The soft copy of the photograph should be sent along with the scanned copy of the above. The JPEG/JPG file should be of 300 x 300 pixels.

Instructions for filing of the Nominations

1. Nominations are to be submitted along with the Profile in the prescribed form only.
2. Nominations are to be submitted for each post separately.
3. Nomination is to be proposed by a member and seconded by another member who are eligible to Vote.
4. Nomination Forms either incomplete or with wrong declarations are likely to be rejected.
5. Completed nomination forms should be sealed in an envelope marked with "INS ELECTION 2025" and should reach on or before the last date of receiving the nomination, i.e. 01-May-2025 by post/courier in the INS Office at Project Square, Anushaktinagar, Mumbai 400094. The envelopes containing the nomination form can also be handed over in person in the INS Office between 10:00 am to 05:00 pm on working days.
6. *Nomination Forms received after the last date of receiving the nominations will be rejected.*
7. Withdrawal of the nomination should be submitted either in writing to the INS Office or by email (entered in the nomination form) to inselection2025@gmail.com before the last date of withdrawal of Nominations.
8. The soft copy of the photograph along with the scanned copy of the profile should be sent to the Returning Officer at inselection2025@gmail.com. The photograph should be in JPEG/JPG file of 300 x 300 pixels.

GLIMPSES OF INSAC-2024


INSAC-2024
CORE
Energy Systems Limited
BALDOTA
LARSEN & TOUBRO
ECIL
TEMA
INDIA PVT. LTD.
ROSATOM
Pyrotech
kirloskar
Oil Engines
APAR
pla
advancetech


Chief Guest: Shri Vivek Bhasin, Director, Bhabha Atomic Research Centre
of Thanks
Shri Satyawan Bansal, Vice President, Indian Nuclear Society
in association with
ATOMIC ENERGY REGULATORY BOARD
INSAC-2024
"Regulatory Framework for Nuclear Renaissance"


INDIAN NUCLEAR SOCIETY


"Book Release"


INDIAN NUCLEAR SOCIETY'S ANNUAL CONFERENCE
(INSAC-2024)
REGULATORY FRAMEWORK FOR NUCLEAR RENAISSANCE
November 19-21, 2024
In association with
INSAC-2024
ATOMIC ENERGY REGULATORY BOARD


INSAC-2024


RF-03
Regulatory perspective on Licensing Framework for claiming compensation under Civil Liability regime

Republic Day Celebration on 26th January 2025 in the Presence of
Chief Guest Shri K. Mahapatra, Director, DCSEM, DAE.