Evaluative Report of Bhabha Atomic Research Centre

1 Name of the CI

Bhabha Atomic Research Centre (BARC), Trombay, Mumbai

2 Year of establishment

1957

3 Is the CI part of the university

Yes

4 Names of programmes offered

Programmes	Name of programme	Location	Area of Specialization
PG	M.Tech. in Engineering Disciplines of : Mechanical ,Chemical, Computer, Electronics, Electrical, Instrumentation, Radiological Safety, Metallurgical and Civil	BARC TS Mumbai	Nuclear Engineering
	M.Tech. in Engineering Disciplines of: Mechanical ,Chemical, Electronics and Electrical	BARC TS Hyderabad	Design, Operation and Maintenance of Nuclear Fuel Cycle Facilities
	M.Tech. in Discipline of: Exploration Geosciences	BARC TS Hyderabad	-
	M.Sc.(Engg)	BARC	-
M.Phil.	M.Phil. in disciplines of: Physical Sciences, Chemical Sciences, Life sciences and Mathematical sciences	BARC TS Mumbai	-
Ph.D.	Ph.D. in disciplines of: Physical Sciences, Chemical Sciences, Engineering Sciences, Life Sciences, Health Sciences, Strategic Studies and Mathematical Sciences	BARC	-
PG Diploma	Post Graduate Diploma in disciplines of: Mechanical, Chemical, Computer, Electronics, Electrical, Instrumentation, Radiological Safety, Metallurgical, Civil, Physical Sciences, Chemical Sciences and Life Sciences	BARC TS Mumbai	Nuclear Engineering
	Post Graduate Diploma in disciplines of: Diploma in Radiation Medicine, Diploma in Radiological Physics and Diploma in Medical Radio Isotopes Techniques	BARC Mumbai	-
	Post Graduate Diploma in disciplines of: Mechanical ,Chemical, Electronics and Electrical	BARC TS Hyderabad	Design, Operation and Maintenance of Nuclear Fuel Cycle Facilities
	Post Graduate Diploma in Nuclear Engineering & Science in the discipline of: Exploration Geosciences	BARC TS Hyderabad	-

Please see Appendix 1 of the profile for further details.

5 Interdisciplinary programmes

Subject of research leading to Ph.D. is inter-disciplinary in many cases. M.Tech. programme in Radiological Safety Engineering run by BARC is also an inter-disciplinary programme.

6 Courses in collaboration with other universities, industries, foreign institutions, etc.

Ph. D. students can have two guides with one of them from a collaborating institution with whom HBNI has a formal MoU. In addition, students can also attend credit courses offered at collaborating institutions. For a list of collaborating institutions, please see Para 2.4.10 of 'Criteria-wise Inputs'.

7 Details of programmes discontinued, if any, with reasons

NIL

8 Examination System

Semester system

9 Participation of the department in the courses offered by other departments

This question is not applicable to BARC. CIs of HBNI have no rigid boundaries. In many cases, research and development work pursued in BARC are inter-disciplinary in nature.

10 Number of teaching posts sanctioned, filled and actual (Professors/Associate Professors/Asst. Professors/others)

Please see para 24 of the Profile.

11. Faculty profile with name, qualification, designation, area of specialization, experience and research under guidance

Please see Appendix 1

12. List of senior Visiting Fellows, adjunct faculty, emeritus professors

Please see para 26 of the 'Profile'.

13. Percentage of classes taken by temporary faculty – programme-wise information :

NIL

14. Programme-wise Student Teacher Ratio :

For delivering lectures in PG-Diploma, M. Tech. and pre Ph. D courses student to teacher ratio is 1: 2.7. Maximum number of PhD students and M.Tech. students allotted to each faculty is limited to eight and five respectively as per UGC rules.

15. Number of academic support staff (technical) and administrative staff: sanctioned, filled and actual

Please see para 24 of the 'Profile'.

16. Research thrust areas as recognized by major funding agencies

In pursuit of the peaceful uses of Atomic Energy, power generation based on nuclear energy assumes first and foremost place and BARC has achieved many milestones in this area. A well planned programme for the progressive expansion for the tapping of atomic energy for electricity keeping in view of the country's future requirements for increased power generation capacity and available resources has been under implementation. A strong R&D base in BARC has been established and functions as a back bone for the smooth transition of the research and development activities to the deployment phase and thereby realising the Department of Atomic Energy's mandate. To ascertain availability of nuclear power to future generation of India, an elaborate R & D program is being pursued in BARC in thorium based fuel cycle and associated nuclear reactors. Many technologies of strategic importance have been mastered in BARC to meet developmental needs. Indigenous technology development in the areas of fuel reprocessing, enrichment, production of special materials, computers, lasers and accelerators represent a whole spectrum of activities necessary for realising full potential of our energy resources to meet future energy needs. Radiation Technology and Isotope Applications represents another prominent area of the peaceful uses of Atomic Energy in health care, agriculture, industries, hydrology and food preservation where self- reliance has been accomplished.

Funding in all these areas of R&D activities in BARC is provided by the Department of Atomic Energy. Please see para 3.1 of the 'Criteria-wise Inputs' for further details.

17. Number of faculty with ongoing projects from a) national b) international funding agencies and c) Total grants received. Give the names of the funding agencies, project title and grants received project-wise.

Full funding is received from the Department of Atomic Energy and all the faculties are involved in one or more projects. Details of ongoing projects and grants for BARC put together are given in Appendix 2.

18. Inter-institutional collaborative projects and associated grants received

BARC is associated with several international projects including CERN; Fermi Lab; Indo-UK projects funded by EPSRC; Indo-US projects; CEA; ITER; INO, etc. In addition, BRNS provides funding to a large number of projects in universities and institutes in India and faculty from BARC works on these projects as Principal Collaborators.

19. **Projects funded by DST-FIST; UGC-SAP/CAS, DPE; DBT, ICSSR, AICTE, etc.; total grants received**.

Nil.

20. Research facility / centre with

- **state recognition**
- **national recognition**
- **international recognition**

BARC has no formal recognition from any agency.

BARC operates number of advanced facilities, such as accelerators, research reactors, high temperature loops, atom probe, material testing facilities, etc., which are being used by researchers from Universities and Academic Institutions in India.

21. Special research laboratories sponsored by/ created by industry or corporate bodies

HBNI is essentially a research university and research output of its CIs including BARC is deployed in industry, including industrial units and PSUs of the DAE. Many technologies are transferred to outside entities through a well established technology transfer mechanism. All research laboratories in BARC are sponsored by the Government for the purpose of deployment in the industry.

22. Publications:

Please see para 3.3 of the 'Criteria-wise inputs'.

23. Details of patents

According to Atomic Energy Act, 1962 invention related to atomic energy cannot be patented. While several patentable inventions have been made by the department, patents are few and are related to spin-offs. However, inventions based on research in BARC have been deployed in the industrial units and PSUs of DAE.
Please see Appendix 3 for a list.

24. Areas of consultancy and income generated

Not Applicable. Please see para 3.4 of the 'Criteria-wise Inputs'.

25. Faculty selected nationally / internationally to visit other laboratories / institutions / industries in India and abroad :

Visits within India are very large. For visits abroad, please see Appendix 4.

26. Faculty serving in

a) National committees b) International committees c) Editorial Boards d) any other (please specify) 10 national Constituted Institutes

Please see Appendix 3 of the 'Criteria-wise Inputs.

27. Faculty recharging strategies (UGC, ASC, Refresher / orientation programs, workshops, training programs and similar programs).

BARC encourages faculty to participate in and organise national and international workshop and conferences, go to universities abroad for

post doctoral fellowships and short term research assignments, act as consultants for developing countries under programmes sponsored by IAEA, participate in collaborative projects with universities in India funded by BRNS, participate in collaborative projects with laboratories abroad under various MOUs. All this helps to recharge the faculty.

28. Student projects :

- **percentage of students who have done in-house projects:** 100%
- **percentage of students doing projects in collaboration with other universities / industry / institute:** 0%

Situation in BARC is actually reverse of what is there in other universities. More than 1000 UG/PG students from other universities come every year to BARC for carrying out their project works.

29. Awards / recognitions received at the national and international level by

- **Faculty**
- **Doctoral / post doctoral fellows**
- **Students**

Please see Appendix 1 of the 'Criteria-wise Inputs'.

30. Seminars/ Conferences/ Workshops organized and the source of funding (national/ international) with details of outstanding participants, if any.

Please see Appendix 5.

31. Code of ethics for research followed by BARC

In addition to excellence in Science and Engineering, a strict adherence to high ethical standards is a necessity. The core ethical policy of DAE is to establish a tradition with highest ethical standards, ensuring a harmonious future for the entire humankind, where every individual can live with dignity and self-respect. In accordance with the guidelines of the DAE, adhering to highest ethical standards is one of the guiding values of BARC. Every complaint of malpractice or plagiarism received is investigated and appropriate action is taken.

32. Student profile programme-wise

Please see para 15 and para 28 of the 'Profile.'

33. Diversity of students

Please see Para 2.1 of the 'Criteria-wise Inputs'.

34. How many students have cleared Civil Services and Defence Services examinations, NET, SET, GATE and other competitive examinations? Give details category-wise.

Please see para 1.1.3 of the 'Criteria-wise Inputs. This question is not applicable to BARC.

35. Student progression

Students joining BARC Training School at BARC become employees of DAE and at some stage come back to enroll for Ph.D. Amongst those who complete DipRP or DMRIT or DRM programme, the first few join DAE as employee, while other get employment elsewhere. In addition to this, there are number of full time students carry out PhD in BARC who are supported financially by various scholarship schemes. After obtaining PhD, such students either get employment or proceed to join PDF abroad. Similarly M.Tech. students from BARC training school at Hyderabad join industrial units NFC and AMD after successful completion of their academic programs.

36. Diversity of staff

Please see para 2.4.3 of the 'Criteria-wise Inputs.'

37. Number of faculty who were awarded M.Phil., Ph.D., D.Sc. and D.Litt. during the assessment period

The minimum qualification of HBNI faculty members in BARC is PhD.

38. Present details of infrastructural facilities with regard to

a) Library: Please see para 4.2 of the 'Criteria-wise Inputs'. The library has adequate physical facilities such as reading-rooms, reprography, internet and is stocked with number of journals (111650), books (108811), theses (360), Microfiche (3.5 lakhs), e-books (126) and e-journals (3152). In addition the Department of Atomic Energy (DAE) has set up a consortium to subscribe 2405 journals through Science Direct and these are available to BARC. Similarly libraries at BARC-Hyderabad (Moula-ali) and BARC-

Hyderabad (Begumpet) are equipped with adequate facilities for the HBNI students to pursue their academic programs.

b) Extensive internet facilities are available to staff and students

c) Total number of class rooms: 15 Lecture Halls and 6 medium size auditoriums in BARC-Mumbai. Every class room is equipped with PC, internet facilities and overhead projectors. Similarly BARC-Hyderabad (NFC, Moula-ali) has 4 classrooms and BARC-Hyderabad (AMD, Begumpet) has 2 classrooms

d) Students' laboratories Yes

e) Research laboratories Yes

39. List of doctoral, post-doctoral students and Research Associates

Please see Appendix 6.

40. Number of post graduate students getting financial assistance from the university.

All students perusing their PG (Diploma) and Ph. D programme get financial assistance from the university. After a year in Training School students become employees and get salary. Students join DipRP or DMRIT or DRM get scholarship while pursuing their academic programme.

41. Was any need assessment exercise undertaken before the development of new programme(s)? If so, highlight the methodology.

Please see para 1.1.2 of the 'Criteria-wise Inputs.

42. Does BARC obtain feedback from

a. Faculty on curriculum as well as teaching-learning-evaluation? If yes, how does BARC utilize the feedback?

b. Students on staff, curriculum and teaching-learning-evaluation and how does BARC utilize the feedback?

c. Alumni and employers on the programmes offered and how does BARC utilize the feedback?

Obtaining feedback from faculty, alumni and employees is a continuous process. Feedback from students is obtained once every year at the end of the academic session. All feedbacks received is analysed and fed to an apex committee for deliberation and decision. Introduction of new programmes and changes in syllabus are decided as needed.

43. List the distinguished alumni of the CI (maximum 10)

The list below includes those, who received a Ph.D. based on the work done at BARC, or are from the Training School, but prior to the setting up of HBNI.

Engineering Sciences	
S.No	**Name**
1.	Anil Kakodkar
2.	Srikumar Banerjee
3.	R.B. Grover
4.	R.K. Sinha
5.	B.B.Bhattacharjee
6.	Sekhar Basu
7.	S.K.Mehta
8.	K.K. Sinha
9.	V.K.Mehra
10.	C.Ganguly

Physical Sciences	
S.No.	**Name**
1.	V.C. Sahni
2.	S. Kailas
3.	S.K.Sikka
4.	S.S.Kapoor
5.	V S Ramamurthy
6.	Praveen Chaddah
7.	Milan Sanyal
8.	C.Manohar
9.	Y.K.Yakmi
10.	P.D.Gupta

Chemical Sciences	
S.No.	**Name**
1.	J.P. Mittal
2.	K.L. Ramakumar
3.	V.Venugopal
4.	D.D.Sood
5.	B.N. Jagatap
6.	S.K. Kulashrestha
7.	Swapan K. Ghosh
8.	D.Das
9.	D. K. Palit
10.	S.B.Manohar

Life Sciences	
S.No.	**Name**
1.	K. B. Sainis
2.	S.F. D'Souza
3.	S.K.Apte
4.	J. K. Sainis
5.	Malini Krishna
6.	R. C. Chaubey
7.	T. Gopalakrishna
8.	M. Seshadri
9.	T. P. A Devasagayam
10.	M.V. Hosur

Health Sciences	
Sl. No	**Name**
1.	Chaitanya Divgi
2.	A.M.Samuel
3.	Bhudatt Paliwal
4.	A. N. Nandakumar
5.	Indra Das
6.	A. U. Sonawane
7.	C S Bal
8.	B A Krishna
9.	Vikram Lele
10.	Pradeep Garg

44. Give details of student enrichment programmes (special lectures/ workshops/ seminars) involving external experts.

BARC regularly hosts international experts to give seminars in their field of specializations. Several interaction meetings/workshops have been organized at BARC during last five years for utilization of the various state-of-the-art facilities available in its premises.

45. List the teaching methods adopted by the faculty for different programmes.

Besides standard class room teaching, interaction though discussions in laboratories.

46. How does BARC ensure that programme objectives are constantly

met and learning outcomes are monitored?

Professional programmes conducted at the Training School prepare students for a lifelong career in DAE. Their successful outcome is demonstrated by the success of construction of new nuclear reactors, accelerators, state-of-art laboratories, etc. These programmes have seen continuous evolution over the years in terms of updating of syllabus. Assessment of students includes end-semester viva voce which tend to look at what a student has learned in a holistic manner rather than subject wise. A mini project and viva voce following it evaluates problem solving abilities of students. It may be added that though not articulated formally so far, the expected outcome of programmes at BARC Training School is to equip its graduates to apply fundamental knowledge of nuclear science and engineering in day to day working in units of the DAE. The PG diploma program DRM is conducted as per the guidelines of MCI. Students after completion of DipRP or DMRIT or DRM programme get employment in various industries and there is ever increasing demand of such personnel.

Quality of theses produced by doctoral students is demonstrated by comprehensive research abilities acquired by students. Invariably number of publications in peer reviewed journals coming out of a thesis varies from one to several as can be seen from previous annual reports. Students after their completion of PhDs are generally selected for employment in national laboratories, universities or industry in India or abroad.

47. Highlight the participation of students and faculty in extension activities.

Please see para 3.5 of the 'Criteria-wise Inputs'. Further, faculty and students at BARC pursue various extension activities in the form of 'public outreach programme', 'project training programme' and 'young scientists' research programme'.

All students BARC are at post-graduate level and extension activities for them mean something different from participation in NCC etc. The main mandate of BARC is to promote nuclear power and non-power applications and extension activities are directed towards this mandate. A well structured programme is being pursued towards this end and includes appropriate set-ups at the level of institutions. Programmes being conducted involve delivering lectures, organizing exhibitions,

writing popular articles in print media and bringing out journals. Indian Association of Nuclear Chemists and Allied Scientists (IANCAS) regularly bring out IANCAS Bulletin on subjects of topical interest. IANCAS also conducts programmes in universities and colleges to explain basics of nuclear radiation to students. Several short-term courses are conducted by faculty regularly to train technicians in industrial radiography and to train scientists as radiation safety officers. These courses do not involve any certification by HBNI, but are very useful for the trained individuals for getting employment.

BARC attracts a large number of students for projects and training. These include under-graduate engineering students for training during summer vacation and regular projects during the final year of the under-graduate programme, graduate engineering students for one year projects, science students sponsored through science academies and several other categories of students. Number of summer trainees is about 1200 in BARC. Students selected by Indian National Science Academy, Bangalore also do projects and BARC. National Science Day and National Technology day programmes are celebrated in BARC in a suitable way and eminent persons are invited to deliver lectures, students from schools and colleges are invited to visit facilities or specifically organized exhibitions. Many from the faculty participate in various ways in programmes to train students for Olympiads etc. Objective of interaction with students is to enable students discover the true spirit of "creative thinking" develop a culture of free discussions.

The academic and knowledge communities of our society, in particular, have a tremendous strength and role to objectively communicate and engage in informed debates on policy-making as well as in public platforms – that include web-forums and the media - on issues of national interest, with an immense impact on the sustainability of our future growth. These issues include energy security, food security, water security, health security and national security. Atomic energy contributes to address each of these five issues. Keeping this in mind, Bhabha Atomic Research Centre has embarked on a public awareness programme to reach out to academic institutes, R&D institutions and industries. The programmes in academic institutes facilitate a multiplier effect by providing authentic technical information and exposure to the faculty members, and also help young graduates to make an informed decision to join the atomic energy programme.

48. Give details of "beyond syllabus scholarly activities".

The faculty is continuously engaged in research necessary for meeting the mandate of the DAE. A significant percentage of this engagement is scholarly and results in good publications in peer reviewed journals. The information on publication is shown under section 3.3 of "Criteria" The students and faculty give lectures very frequently in various forums like national and international symposia, workshops, awareness programmes and colloquia. They interact on a regular basis with scientist and technologists of repute from the country and from abroad. They organise high level knowledge dissemination activities like organization of advanced schools under the aegis of BRNS/ DST and other similar bodies. Faculties were also involved in organizing prestigious conferences, such as, 21st International Conference on Structural Mechanics in Reactor Technology (SMiRT 21) and National Conference on Cryptology (INDOCRYPT).

49. State whether the programme/ CI is accredited/ graded by other agencies? If yes, give details.

Yes, by UGC

50. Briefly highlight the contributions of BARC in generating new knowledge, basic or applied.

Bhabha Atomic research Centre has the mandate to carry out broad based scientific research and engineering development with a view to increase nuclear power generation capacity and deploy non-power applications of nuclear science. Nuclear science and engineering is a multi-disciplinary subject. Every project is executed by multidisciplinary teams. For example, for R & D programmes related to fuel reprocessing chemical engineers, mechanical engineers, chemists and metallurgists work together. Hence the contributions of BARC in generating new knowledge are shown below program wise which are multidisciplinary in nature.

Nuclear Power:

The Indian Nuclear Power Programme today comprises existing reactors, reactors under construction, and planning and design of future reactors which will provide long term energy security to the country. R&D activities in BARC in the area of nuclear power began with the construction and operation of research reactors. Today, BARC operates two research reactors Dhruva and the AHWR Critical Facility. These are

used for Neutron Beam Research, Fuel and Material Irradiation, Radioisotope Production, Neutron Radiography and Reactor Physics experiments. The Advanced Heavy Water Reactor (AHWR) (proliferation resistant with passive safety features, being developed with the aim of Thorium utilization), the Compact High Temperature Reactor (CHTR), the Indian High Temperature Reactor (IHTR) and the Accelerator Driven Subcritical System (ADSS) are part of R&D on future reactors, which envisage that besides electricity, nuclear energy would play a significant role in the production of alternate transportation fuel such as hydrogen, by splitting of water. Technologies for high temperature nuclear reactors capable of supplying process heat at a temperature of around 1000°C are also being developed.

Electronics, Instrumentation and Computers:

BARC's research and development program in Electronics, Instrumentation and Computers has made spectacular progress in recent years and contributed to areas such as: control and instrumentation systems for nuclear reactors, for improvement in performance and power output in various stages of India's Nuclear Power Program; computers and software; accelerator and electron beam technology; radiation detectors and applications; robotics and remote handling and electronics standardisation. Some recent developments include: Design and testing of three Application-Specific Integrated Circuits (ASICs): ANUSPARSH, ANUDRISHTI and ANUSUCHAK in 0.35 μm CMOS technology. ANUSPARSH is a front-end readout for Resistive Plate Chamber detectors of INO (India based Neutrino Observatory), ANUDRISHTI is a monolithic photodiode and readout electronics for compact gamma detection probes and ANUSUCHAK is low power front-end readout for silicon PIN detectors; Development of software for operator consoles of Reactor Trip Logic System and Alarm Annunciation System for Dhruva; Development of a Hand-scan Biometric Authentication System based on a novel algorithm; Software for Large Hadron Collider Computing Grid in collaboration with CERN, Geneva. A Time Domain Electromagnetic System with a high current pulse has been developed, to detect the presence of uranium under the Earth's surface up to a depth of 700-800 meters, by estimating the conductivity vs depth profile. The prototype equipment has been functionally proved on the ground, at ore bearing sites in Rajasthan, UP and AP. A Neutron Flux Monitoring System (NFMS) using five different types of neutron detectors integrated with Mineral Insulated (MI) cables has also been developed, which measures the neutron power and reactivity changes in the core, in all states of the Prototype Fast

Breeder Reactor (PFBR).

Nuclear Fuel:

Fuel is at the heart of a nuclear reactor and no indigenous nuclear power program can sustain without regular and assured supply of fuel to the reactors. BARC has mastered the fuel design and fabrication technology containing uranium, plutonium, thorium and uranium 233. Thorex process is still in the developmental stage. It has a major role in the third stage of the Indian Nuclear Power Program. R&D activities are in progress to meet the challenges of this fuel cycle. A variety of fuels such as Uranium fuel clusters for Dhruva, mixed carbide fuel elements for the Fast Breeder Test Reactor, mixed oxide fuel for the Prototype Fast Breeder Reactor, Fuel for ADSS program, Development of Low Enriched uranium fuel for modified core of APSARA reactor, Dispersion fuels and experimental fuel clusters for irradiation in research reactors are being fabricated at BARC. Development of flow sheets for manufacture of fuel for AHWR as well as for CHTR is in progress. Similar work is being carried out inthe development and fabrication of metallic fuels and CERMET fuel for fast reactors. R&D activities are being carried out in the characterisation, performance assessment, burn-up and fabrication parameters of reactor fuels and chemical quality control of fuels. Mechanisation and modifications of workstations, equipment and processes have been adopted to enhance productivity and to ensure safety.

Fuel Reprocessing:

BARC has come a long way since it first began reprocessing of spent fuel in the year 1964 at Trombay. The recycling and optimal utilisation of uranium is essential to meet our current and future energy security needs. Reprocessing of spent fuel followed by separation of minor actinides will also ensure reduction of radiotoxicity of radioactive waste and the need for long term isolation from the geosphere. Nuclear Recycle Program of DAE also includes recovery of strategic materials from spent fuel for recycling and R&D in the areas of spent fuel reprocessing and waste management. Presently, reprocessing plants are in operation at Trombay, Tarapur and Kalpakkam. Power Reactor Fuel Reprocessing Plant (PReFRe-1) at Tarapur was designed, built and commissioned in 1974 through indigenous R & D efforts. Kalpakkam Fuel Reprocessing Plant (KARP) is the second facility for processing fuel from Pressurised Heavy Water Reactors (PHWRs).

Reprocessing & Waste management plants will be integrated for the first

time with Integrated Nuclear Recycle Plant, Tarapur (IP-1) using "SOLID IN & SOLID OUT" concept with a plant design capacity of 600 Tones of Heavy Metal per annum. Engineering design and infrastructure development activities are in progress. The Power Reactor Fuel Reprocessing Plant (PReFRe-2), set up at Tarapur was inaugurated by Honourable Dr. Manmohan Singh, Prime Minister of India on January 2011 which is now in regular operation. New Gang type chopper and Automated charging facility have performed to their desired capacities. The operation of the Waste Management Facilities at Trombay and Kalpakkam for treatment and storage of radioactive waste is being done by BARC. Joule Melter used for vitrification of high level waste at Tarapur was shut down after operation for 3 years and has been decommissioned using indigenously developed tools. BARC also manages treatment and safe disposal of radioactive waste both in solid and liquid forms which are generated at BARC and NPCIL units at Tarapur. Various chemical processing methods are used to treat both low and high level wastes. India is one of the few countries to have mastered the technology of vitrification. BARC has the unique distinction of successfully operating two vitrification plants at Tarapur and Trombay for management of High Level Waste. In addition BARC manages spent radiation sources from all over the country from various medical centres, research institutions and industrial units.

Material Science:

Materials Science and Engineering plays an important role in all aspects of technological development and in the success of any programme incorporating advanced technology. Materials research in BARC is carried out in frontier areas with quest for hi-tech materials and innovative technologies blending thermodynamics, mechanics, modeling and simulation with experimental characterisation of materials, to meet the desired objective of development of materials for nuclear and other advanced technological applications. Major activities involve: establishing technoeconomic process flowsheets for the recovery of minerals and metals of interest to atomic energy program from conventional and non-conventional resources; process engineering and scale-up studies on uranium recovery from various ores in technology demonstration pilot-plant; research and development of zirconium-and niobium-based alloys and other advanced alloys such as shape memory alloys, superalloys etc., with a focus to develop components for the Pressurised Heavy Water Reactor and other advanced reactors and applications. The prominent R & D activities include: characterisation of alloys, their selection and design, preparation, processing, shaping and

fabrication of components and devices for actual commercial applications; development of new and improved mechanical tests and modeling mechanical properties and performance of nuclear structural materials under environmental conditions that are experienced both in processing and in service and structure-property correlation. Ageing management and establishment of corrosion behavior of materials used in the existing nuclear power plants and also for future generation reactors in simulated operating conditions by way of accelerated tests, is another important area of study. Other major highlights include: development of technology for the synthesis and preparation of enriched boron carbide pellets for control rod applications; fission type neutron sensors with enriched uranium coatings; neutron absorption based neutron sensors with boron carbide coating and liquid metal technology for electromagnetic pump driven loop.

Research and Development in Chemical Engineering:

Research and Development in the area of Chemical Engineering is focused on development of process and technologies for production, separation, purification and recovery of materials required in the nuclear fuel cycle. The key features underlying the development effort are self reliance, very high purity specifications, very low separation factors, high recoveries, optimal utilization of scarce resources, environmental benignity, high energy efficiency, stable continuous operation and automation. CFD modeling, process simulation, development of novel contactors, highly specific extractants, catalysts and membranes are being increasingly developed for process intensification. Non power application of nuclear energy has been demonstrated in the area of water desalination using the Multi-Stage-Flash (MSF) technique. Membrane technology has been deployed for desalination and in nuclear waste treatment. Recent developments include: Hydrodynamic studies of Liquid Phase Catalytic Exchange (LPCE) system; Development of fluidized bed technology for applications in nuclear fuel cycle; Synthesis and Evaluation of Novel Extractants; Development & Testing of Compact Electrolyzer Plant for Large Scale Hydrogen Generation. Under Advanced Technologies and applications, R&D for TBM materials has been initiated; Molecular modeling of hybrid calix-crown ligand for cesium metal ion extraction is in progress and Microchannelled contactors are being explored for various applications in the field of chemical engineering to exploit their unique process-intensifying features. Under R&D on Cryogenics, design and development work on turbo expander and other related equipment is in progress. Refrigeration load test was conducted on the indigenously

developed 20K helium refrigerator and a helium liquefier has been commissioned.

Physical Sciences:

Research in Physical Sciences covers a widerange of basic and applied topics in frontier areas of current interest. It also contributes to the indigenous development of advanced technologies of relevance to DAE. The R & D spans a wide dynamic range of distances and energy scales, cutting across disciplines and includes investigation of matter at extremes of temperature and pressure. Reactor, ion- and electron-accelerators and lasers are being employed as tools for this R&D. The major facilities operated by BARC for research in Physical sciences include the Pelletron plus Superconducting linear accelerator at TIFR, the FOlded Tandem Ion Accelerator (FOTIA) and PURNIMA fast neutron facilities at BARC, the 3 MV tandetron accelerator at the National Centre for Compositional Characterization of Materials, the TACTIC (TeV Atomospheric Cherenkov Telescope with Imaging Camera) telescope set up at Mt. Abu, the 10 MeV electron accelerator at the Electron Beam Centre at Navi Mumbai, National Neutron Beam Facility at Dhruva and a number of state-of-the-art beam lines at INDUS. BARC also has a sustained program of indigenous development of instrumentation, detectors, sensors, mass spectrometers, imaging techniques, multilayer mirrors required for DAE. Recent achievements include: the design and development of a 10 meter optical periscope for the PFBR program under a collaborative effort between BARC and IGCAR; the EDXRD, EXAFS and HRVUV beam lines at INDUS, commissioning of beam lines and associated detector facilities at TIFR, establishing an experimental station for Laser Induced Photo-Physics Studies (LIPPS) of thin films, multilayers and precision optical elements, use of Laser assisted methodology for cleaning of nuclear fuel; development of state-of-the-art Mass spectrometers.Some of the major ongoing programs are: The MACE telescope at Hanle; The Low Energy High Intensity Proton Accelerator (LEHIPA); R & D towards development of enabling technologies for high energy/current ion and electron accelerators; setting up of SAXS, Imaging, Protein, Infra red, ARPES/PES etc beam lines at INDUS and time-of-flight neutron spectrometer at Dhruva; coupling of fast neutrons from PURNIMA facility to a sub-critical core as part of ADS activity; R & D towards the India based Neutrino observatory; establishing a centre of excellence in optics and thin films at BARC-Vizag.

Chemical Sciences:

The research mandate on Chemical Sciences in BARC, encompasses both basic and applied areas of Analytical Chemistry, Bio-organic Chemistry, Materials Chemistry, Radiation and Photochemistry, Theoretical Chemistry, Water and Steam Chemistry, Fuel Chemistry, Radioanalytical and Radiochemistry, Radiopharmaceuticals, Radiation Technology, Radiation medicine as well as Isotope Applications and Compositional Characterisation of materials. Research on Basic Chemistry is focused on organometallic materials, nano and soft condensed matter, atomic/molecular clusters, catalysis, generation and storage of Hydrogen, speciation and migration of actinides and long lived fission products in aquatic environment, positronium chemistry, hyperfine interactions study by perturbed angular correlation spectroscopy, diffusion in membranes by radiotracers, etc. Research and development in applied areas focuses on: radioisotopes and radiation technology applications in industry, health care and for societal benefits. Some recent developments include: Determination of Uranium in seawater; Ultratrace Elemental Characterisation in high purity materials and biological samples; Testing of sorbents used for decontamination of potable water; Development of Solvents for An(III)/Ln(iii) as well as Zr(IV)/Hf(IV) separations in the Back-end of the fuel cycle; Design and synthesis of functional molecules required for various programs; Development of an indigenous database on thermophysical properties of Thoriumbased metallic alloy fuels for future advanced reactors; Provision of specialised analytical services to various programs of DAE; Establishing preparative methodologies for high purity materials of strategic importance; Development and Commissioning of State-of-the-art experimental facilities; Setting up of a Vibrational Sum Frequency Generation (VSFG) to investigate molecular structure and dynamics at surfaces and interfaces; Establishment of engineering loops for simulation studies of primary, secondary and tertiary coolant systems of PHWRs; Kinetic studies on oxidation behavior of alloys of relevance to nuclear technology and Development of Palladium alloy membrane for purification of Hydrogen isotopes. Radioanalytical techniques, like ion beam analysis, K0 neutron activation analysis, passive and active nondestructive assay of nuclear materials, ion selective electrodes, etc.

Life and Health Sciences:

Life Sciences activities in the Bio-medical Group at BARC is a vibrant program of basic and applied research, encompassing a wide spectrum of studies. The major flagship programs of the institute include, (a) use of radiations and radioisotopes in contemporary thrust areas of research, of excellence and relevance to the DAE programs and of national

interest (b) long-term studies on effects of high background natural radiations on human populations living in coastal areas of Kerala (c) radiation-induced mutagenesis for crop improvement (c) use of radiations and other technologies for disinfestation, hygienisation and preservation of food, improvement of nutritional quality and extension of shelf life, to enhance food security (d) development of radiopharmaceuticals and equipments for diagnosis and therapy of a variety of human diseases, and (e) development of appropriate technologies to strengthen the aforesaid programs and for application in environmental clean-up.

Biology of stress and adaptive responses of microbes and plants is one of the strong points of basic and applied research at BARC. Genomic, proteomic and bioinformatic approaches have been used to discover new genes, their functions and regulation, and to assess their role in the extreme radiation resistance of Deiniococcus radiodurans and radiation and agricultural stress tolerance of nitrogen-fixing cyanobacteria such as Anabaena strains. Recombinant DNA technology has been very effectively used to genetically engineer microbes for eco-friendly biotechnological applications as nitrogen biofertilisers in stressful environments, as biosensors of agronomically important pesticides or as biopesticides. Novel organisms have been discovered with unique abilities to sequester uranium from 3 ppb concentrations found in seawater or to degrade and utilize the major nuclear solvent tributyl phosphate (TBP). Radioresistant recombinant strains of Deinococcus have been constructed to bioprecipitate uranium over a wide range of concentrations and pH from high radiation environments.

Effects of high background natural radiation that prevails in monazite sands of Kerala are under investigation for last 4 decades in BARC. A survey of 1.5 lakh newborns has been carried out in recent years to reveal no significant effects attributable to radiation on congenital malformations, cytogenetic defects, Down's syndrome, DNA damage and repair, mutation rate etc. In parallel, radiation effects are being investigated in cell lines and animal models to assess bystander effects, damage caused by metals like uranium/thorium and methods of their decorporation from tissues, and molecular markers of carcinogenesis and metastasis. Heavy ion irradiation and alpha particle irradiation effects are also under investigation. Attempts are also on to develop natural products as immunomodulators and radioprotectors and as effective regulators of signal transduction pathways to alleviate/enhance radiotoxicity to normal/tumor cells respectively.

Radiation-induced mutagenesis for crop improvement is one of the very successful programs in Life Sciences at BARC. To date 42 new improved varieties of different crops have been developed by BARC and released by ICAR and State Agricultural Universities for cultivation in various states of India. While oilseed varieties, such as groundnut, mustard, soybean, and pulses, such as mungbean, urdbean and pigeonpea, are the more successful programs, varieties have also been developed in crops such as rice, jute, sunflower and cowpea. Gamma irradiation and electron beam based food irradiation programs have been designed by BARC for a variety of purposes, such as sprouting inhibition in onions and potatoes, disinfestations of grains and resins, shelf-life extension of several ready-to- cook and ready-to-eat items including meat products, and decontamination of spices, Applications have been developed for quarantine purpose for export of mangoes or foods for disaster management or for immune-compromised patients etc. BARC also designs and fabricates equipments required for such programs and makes them available to other users through technology transfer programs.

Development of radiopharmaceuticals, including production of 18F-FDG using medical cyclotron at BARC, and establishment of state of art imaging technologies using PET-CT machines have strengthened disease diagnostic capabilities at BARC and triggered substantial research on diagnosis of tuberculosis and other infectious disease, apart from variety of cancers and neural disorders etc. Design and fabrication of indigenous teletherapy machines (Bhabhatron) has greatly benefitted patients awaiting radiotherapy. Nisargaruna biotechnology, for conversion of organic waste to methane and to electricity, has not only proven to be technologically robust but has also been extremely popular as manifested by setting up of over 160 such plants all over the country in last 6-7 years. The solar dryers for food preservation, biosensors for pesticides and metal removal biotechnologies developed in last 2-3 years are likely to find field applications in near future. All the aforesaid research and development activities in Life Sciences have been published in high impact, peer-reviewed international journals and have been recognized in the form of very prestigious awards, fellowships and other such honors.

In health-care, in vivo Nuclear medicine diagnostic investigations related to cancers of various organs and functional imaging of heart, bone, kidney, lungs, GI tract etc. are being undertaken routinely utilizing

gamma camera based scintigraphy (planar and SPECT) as well as Positron Emission Tomography-computed tomography (PET-CT). The Radionuclide based therapeutic services include Radioiodine therapy for thyroid cancer, Peptide receptor Radionuclide therapy (PRRT) in Neuroendocrine tumors and radioisotope therapy for metastatic pain palliation. For in vitro diagnosis of thyroid disorders, a large number of radioimmunoassay (RIA) procedures are also being carried out. Apart from thyroid, diagnostic a PCR-based diagnostic kit has been developed for tuberculosis.

51. Detail five major Strengths, Weaknesses, Opportunities and Challenges (SWOC) of BARC.

Strengths

1. BARC is a unique premier institute in the country where research in all aspects basic sciences, engineering and technology development are carried out in one single campus. This provides a great opportunity to all HBNI students to work in multi-disciplinary areas with the availability of experimental facilities and guides. The funding is also very generous.
2. The quality of students is very good because of very rigorous selection process adopted. Since a vast majority of the students are scientific officers recruited by a tough selection process, a very high level of research output is ensured. After a tough selection, the initial training imparted to the students is of very high standard.
3. Besides the students, the faculty is also very strong, nationally and internationally known and there is very strong peer pressure on both the sides to do better.

Weaknesses:

1. Ensuring very high quality sometimes leads to very low number of students in some of the disciplines.
2. The embargo on supply of some items has resulted in lack of some of the sophisticated analytical equipment. This results in delays in research as alternate equipment has to be developed or innovative techniques have to be used for getting results.
3. Doctoral programme in engineering sciences has started expanding only in recent years. Faculty looks at themselves as scientists first and give lower priority to mentoring students. This is expected to improve over the years as faculty takes more and more students.

Opportunities

1. Opportunity to do high level research having immediate application in national programmes.
2. Opportunity to interact with scientist at national level and international level.
3. Opportunity to get various forms of national and international recognitions in the form of fellowships and awards.
4. Opportunity to develop various types of skills.
5. Opportunity to do interdisciplinary research.

Challenges

1. To balance various types of responsibilities for the faculty.
2. To balance between various types of responsibilities for the employees enrolled as students.
3. To publish results of research on strategic topics without compromising classified nature of information.
4. To ensure superiority in quality of research while doing doctoral research on large scale set ups.

52. Future plans of the BARC.

New programmes have been introduced at BARC. Details are as follows.

i) BARC Training School: Considering the increased emphasis on uranium exploration in the five year plans, the need to train human resources in this vital area arose and therefore, a programme in Exploration Geo-sciences was started in 2010 at the BARC Training School, Hyderabad. Intake qualification is M.Sc. in geophysics or geology and as is the practice in BARC Training Schools, the programme consist of one year of course work (compulsory) and one year of project work (optional). Those who do only course work get a diploma and those who go on to do project work get a M.Tech.

ii) Converting Diplomate of National Board (DNB) programme (accredited by National Board of Examinations) being run in BARC hospital to a MD/MS programme after getting all statutory clearances, and

iii) It is also proposed to start schools in Computer Science and Earth Sciences.

iv) It is also proposed to increase intake of students to Diploma in

Radiation Protection (DipRP) programme at BARC.

v) Taking a longer term view, a new campus of BARC is being planned at Vizag and land for the campus has already been acquired.

Expand the doctoral programme so as to utilise the full potential of the faculties and research infrastructure. Particular emphasis will be given to develop qualified human resources (both scientists and engineers) required to meet countries demand for more power, health care, food, clean water and security.

List of appendices (to be made available to the assessment team during their visit)

1. BARC: Appendix 1: Faculty profile referred to at para 11.
2. BARC: Appendix 2: Ongoing projects referred to at para 17.
3. BARC: Appendix 3: List of patents referred to at para 23.
4. BARC: Appendix 4: Visits of faculties to International Laboratories/ Institutions referred to at para 25.
5. BARC: Appendix 5: Seminar/ Meetings/ Conferences/ Colloquia referred to at para 30.
6. BARC: Appendix 6: List of doctoral students referred to at para 39.