



GOVERNMENT OF INDIA





ANNUAL REPORT 2015-2016

BOARD OF RADIATION & ISOTOPE TECHNOLOGY



DEPARTMENT OF ATOMIC ENERGY





From the Desk of Chief Executive

Greetings!

As you know BRIT is producing and supplying wide range of services which involves radiation and radioisotope based products for variety of applications. These products are used by various customers, which include healthcare, industry, research sector etc. Production by skilled hands ensures availability of good quality products which are comparable to international products. Our services are used for societal benefits and all these have become possible by effective utilization of our products by our prestigious customers.

All the departments of BRIT had excellent contributions towards achieving the intended objectives of BRIT, i.e. for improving the quality of human life.

Areas and ventures which are yet to be explored, could be taken up as new challenges in the future. Towards this, a good synergy and team work, not only among our colleagues but also with other units of DAE such as BARC, NPCIL, ECIL etc., would translate into making BRIT proud.

I am pleased to present you all Annual Report 2015-16 to indicate valuable contribution of BRIT. Remember that success is not a destination but is an ongoing journey.

Best Wishes for pleasant reading.

G. Ganesh Chief Executive, BRIT

CONTENTS			
Chapter 1	Executive Summary	01	
Chapter 2	Descriptive Part	09	
	Sales turnover in 2015-2016	37	
Chapter 3	Research & Development Activities at BRIT	39	
Chapter 4	Human Resources Development Activities of BRIT	61	

Executive Summary

Board of Radiation & Isotope Technology (BRIT), the unit of DAE, is focussed on bringing the benefits of the use of radioisotope applications and radiation technology across industry, healthcare, research and agricultural sectors of the society. Harnessing the spin-offs from the mainstream programmes of DAE, such as R&D programmes at BARC and Nuclear Power plants for generating electricity by NPCIL, BRIT has independently created a separate visible area of contribution to the society.

A. Products

I. Healthcare Products

(a) Radiopharmaceuticals Production (RphP) & Medical Cyclotron Facility (MCF)

- More than 20,000 consignments of ready to use Radiopharmaceuticals of Sodium Iodide (Na¹³¹I) in the form of both, solution and capsules, for diagnosis and therapy of thyroid disorders, ¹³¹I-meta Iodo Benzyl Guanidine (mIBG), for neuroendocrine tumor detection & therapy, ³²P, ¹⁵³Sm and ¹⁷⁷Lu for bone pain palliation were supplied to various nuclear medicine centres & hospitals all over India in the form of ready-to-use injectables.
- Total numbers of therapeutic treatments based on supplies are estimated to be more than 40,000. This major product includes doses of Na¹³¹I for treatment of thyroid cancer & hyperthyroidism.
- More than 75,000 cold kits for the formulation of ^{99m}Tc- Radiopharmaceuticals (15 products; BRIT Code-TCK) were supplied to nuclear medicine centres.
- Approx 71.5 Ci of Sodium Molybdate (Na⁹⁹MoO₄) solution in 342 consignments, for solvent extraction generator is supplied upto December 2015. A total of 377Ci of ⁹⁹Mo (1069 Consignments) in the form of sodium molybdate is supplied as ⁹⁹Mo-^{99m}Tc generators (both Gel and Coltech) to various nuclear medicine centres.
- Medical Cyclotron Facility (MCF), Parel, continued the supply of Positron Emitting Tomography (PET) radiopharmaceuticals such as ¹⁸F-FDG, ¹⁸F-NaF and ¹⁸F-FMISO to various hospitals in and around Mumbai. Approx 15,000 patients were benefited.
- Approx 3,000 Radioimmunoassay (RIA) and Immunometric Assay (IRMA) kits to carry at about 5,00,000 in-vitro investigations, were supplied to various hospitals, research centres and immunoassay laboratories throughout India.
- Approximately 2,45,544 In-vivo diagnostic investigations are estimated to have been carried and this year with varied diagnostic Radiopharmaceuticals, the major are ^{99m}Tc based cold kits and ⁹⁹Mo-^{99m}Tc generator systems.

(b) Quality Control Analysis & Quality Assurance of Radiopharmaceuticals (Allied Services to RPhP):

- Around 600 radiopharmaceuticals samples were analysed and certified by Quality Control section before despatch to nuclear medicine centres.
- Biodistribution studies (6 batches) were performed for Macro Albumin Aggregates (MAA) for

lung scan. Similarly these studies were performed for newly launched kits such as ¹⁷⁷Lu-EDTMP and ^{99m}Tc-TRODAT.

(c) Labelled Compounds (LC)

• Labelled compounds Programme of BRIT continued the synthesis and supply of a variety of ¹⁴C, ³H and ³⁵S-labelled products and various types of Tritium-filled self luminous sources (TFS). Since April 2015, approximately 7500 TFS sources of various sizes and shapes were supplied to defence establishments.

II. Engineering Products

(a) Sealed Radiation Sources

- Eleven teletherapy sources (CTS) containing 98,300 Ci of ⁶⁰Co were supplied to different cancer hospitals upto December 2015.
- Sixty six Irradiator sources in seven consignments with total activity of 10, 66,498 Ci were supplied to various radiation processing plants within the country and also exported.
- More than 850¹⁹²Ir & ⁶⁰Co Radiography sources containing 37,460 Ci of activity was supplied to NDT users. Reference and custom made sources (CMR) of ⁴⁶Sc and ¹³⁷Cs in 975 consignments containing 5.67 Ci of radioactivity were also supplied to various organizations.

(b) Radiation Equipments

- 81 Radiography Cameras, ROLI-2 and ROLI-3, were supplied to various NDT users within India.
- One Blood Irradiator containing 800 Ci of ⁶⁰Co was supplied to Ruby Hospital, Pune.
- First ¹³⁷Cs based Blood Irradiator is manufactured during this period.

B. Service

I. Consultancy and MoU for Radiation Processing Plant

- MoU for setting up Radiation Processing Plants was signed each with M/s Avantee Mega Food Park Pvt. Ltd. at Indore, M/s Electro Magnetic Industries at Sinnaur, Vadodra, Gujrat,
- M/s Aligned Industries Pvt. Ltd. commissioned Radiation Processing Plant for processing food and medical products at Dharuhera, Haryana. M/s. Maharashtra State Agricultural Marketing Board also commissioned the processing plant at Vashi Navi Mumbai.
- Total operational RPP's under MoU with BRIT are 14.

II. Gamma Radiation Processing Services (GRPS)

(a) Radiation Sterilization Plant for Medical Products (ISOMED)

- 5116 Cubic meters of healthcare products were processed using radiation for terminal sterilization at ISOMED, BRIT upto December 2015.
- Gamma Radiation Indicator Buttons were developed indigenously as an import substitute (Made in India) for qualitative indication of low and medium range gamma radiation dose delivery to the products.

(b) Radiation Processing Plant (RPP), Vashi

- About 2933 Tons of spices and other products like nutraceuticals and colour pigments were processed during the reported time period.
- NABL accreditation for dosimeter calibration laboratory of RPP, Vashi was obtained during this period.

III. Calibration Services for Portable Radiation Monitoring Instruments

- BRIT is providing calibration services for gamma radiation survey instruments.
- The laboratory is approved by AERB in accordance with the Rule-29 of Atomic Energy Regulatory Board (AERB) Radiation Protection Rules, 2004.

IV. Isotope Application Services (IAS)

- Isotope Application Services were provided to various industries such as BPCL, HPCL, IOCL etc. to trouble shoot catalyst cracking unit (CCU) by gamma scanning, leakage detections by radiotracer techniques etc. thereby saving crores of rupees.
- Shield integrity confirmation using radiotracer technique was also provided for APSARA nuclear reactor, BHAVINI nuclear reactor and for AREVA, U.S., a project by Larson & Toubro.

V. Radiation Physics Group

• Source loading pattern was designed for six Gamma Irradiators; dosimetry and radiation protection survey was performed for portable research irradiator and radiometry studies of shielding casks for NRB, DAE was undertaken during the reported period.

VI. Radioanalytical Laboratory (RAL) Services:

- Radioanalytical Laoratory carried out more than 3000 tests on export/domestic commodities and 900 tests on water samples for gross alpha, gross beta, ²²⁶Ra, ²²⁸Ra and total uranium content.
- In addition to the above, one steel survey was conducted for certification of surface radiation dose and 27 food samples imported from Japan were also analyzed and certified.
- Setting up of additional Radioanalytical Laboratory at BRIT Project House, Deonar is completed during the reported time period.
- A similar facility is also provided at RCR, Bengaluru and a total of 71 samples (12 Nos. Domestic and 59 Nos. Export samples) were analyzed at this centre.

VII. Electron Beam Processing Services (EBPS)

- The upgradation work of 2 MeV Electron Beam Accelerator (EBA) to 5MeV/15kW at BRIT, Vashi Complex has been completed during the reported period.
- BARC safety committee approved for initial trial operations @ 4.5MeV/9kW Beam power.
- During the reported period, products irradiated in the facility include fish, meat (for shelf-life extension), wheat powder for disinfection, polymer cable joint end-caps (for crosslinking and high temperature applications), waste water for hygeinization etc.

VIII. Services by RCR's and Quality Control Analysis of Radiopharmaceuticals for Outside Agencies

- Regional centres at Delhi, Bengaluru, Jonaki, Hyderabad, Dibrugarh & Kolkata, continued the supply of ready-to-use-radiopharmaceuticals to surrounding nuclear medicine hospitals. Around 3,000 consignments of in-vivo and in-vitro kits were supplied to RCR's for providing extended services to nearby Hospitals at these cities.
- Quality Control testing services was provided for kit efficacy and safety performance of cold kit for ^{99m}Tc-labelled Myoview for M/S GE Healthcare.

IX. Customer Support Services Cell (CSSC) and Customer Relation Cell (CRC)

- As the nodal agency for sales and supply, marketing and customer relations, Co-ordination & logistics support were continued to be provided for the regular and uninterrupted supply of radioisotopes & allied products and radiation technology equipment to about 2000 user institutions in the healthcare, industrial, research and agricultural sector.
- During the reported period, an initiative of requesting the radiopharmaceutical users to send scanned copies of their SA-4 forms along with AERB NOC's to update their requirement and so as to fasten up the process while being cost-effective for the users was highly appreciated. Also, the complaints received from the users were addressed to the satisfaction of the customers.

C. Events, Awards and Implementation of Hindi Language at BRIT

- The first Training course on "Radiotracer and Related Techniques for Diagnostic Laboratories" was conducted in RPh BRIT from 28th April to 9th May 2015.
- IAEA Interregional Training Course on "Practical Aspects of the Production of Molybdenum by the Neutron-Gamma Reaction" was conducted for the first time at BRIT-BARC Vashi Complex from 22nd to 27th June 2015. The course was attended by international paricipants and also part of the faculty was from IAEA.
- One DAE Group Achievement Award and one individual award in the category of Scientific and Technical Excellence Award were awarded to BRIT scientists and technologists during the time period.
- Along with the scientific events at Board of Radiation & Isotope Technology, it has also held various activities towards implementation of Official Language.
- Also, scientists and engineers at BRIT were involved in various R&D and HRD activities along with their services towards production & supply of their respective products.

D. Plan Projects

1. Project: DAE Medical Cyclotron Project: Radiopharmaceutical Facility

• **Progress:** Civil construction of Medical Cyclotron work is completed. Installation and commissioning is expected to commence soon after the physical inspection by the vendor and is expected to commence by June 2016.

2. Project: Indigenous HDR Brachytherapy Equipment (IHDR)

• **Progress:** Purchase Order for "Development of suitable TPS for IHDR-KARKNIDON" released. Two numbers of Ir-192 miniature source assemblies were made, but source holder did not sustain the trials. Subsequently, new design of SS source holder was finalized in consultation with DRHR/BARC and given for manufacturing in CDM by DRHR.

3. Project: Setting up of Fission based ⁹⁹Mo Production Facility

• **Progress:** The civil construction work of the buildings of ⁹⁹Mo Production facility is nearing completion. Installation of facilities for waste management, hoist and related piping are under progress. Work on design and fabrication of LEU targets for irradiation in Dhruva is in progress at BARC

4. Advanced Facilities for Radiopharmaceuticals Production

• Progress:

- New Effluent Treatment plant of capacity 150 CMD for BRIT, BARC Vashi complex commissioned is operational.
- Site clearance work for construction of new laboratory space at first floor over RPL extension building is in progress.

- State of the art analytical equipments installed and commissioned during year HPGe detector, Laser Uranium analyser, dose calibrators, Mass spectrometer at RPL Vashi, and electrophoresis, real time PCR and Alpha-Beta counting system at JONAKI, Hyderabad.
- As a part of project, New Pharmaceuticals services room, has been set up for preparing Water for injection, Sterile and pyrogen free glassware, equipment, glass vials etc. which are used in production and as important primary containers of all radiopharmaceutical products.

5. Project: Technology Development for Radiation Technology Equipment

• **Progress:** Specifications for I-125 seed manufacturing plant have been finalized. Old canteen building of BRIT has been demolished and construction of new building has been started. Equipment such as X-ray based low dose irradiator, Co-60 camera, source changer have been developed.

BRIT Website:

• BRIT website provided regular updates on various programmes and activities related to the developments in BRIT. Customer oriented reports were uploaded on website almost on daily basis enhancing coordination and communication with the customers.

Descriptive Part

The application of radioisotopes in healthcare, industry, agriculture and research is one of the most wide-spread peaceful uses of the nuclear sciences, next to nuclear power production. Realizing the importance of the use of the radioisotopes for societal benefits and national development, the Department of Atomic Energy has, over the years, built up adequate infrastructure facilities for the production and applications of radioisotopes which is in the form of Board of Radiation & Isotope Technology (BRIT). After completing its silver jubilee last year (March, 2014), it continues its endeavour towards providing its best services to mankind through meeting the demands of the users, be it in the fields of nuclear medicine, healthcare or towards advanced technologies such as engineering and radiation technology equipments for medical as well as industrial uses, radiation processing services, isotope applications or radioanalytical services.

[A] PRODUCTS

I. Healthcare Products

The combined revenue from the supply of healthcare products and its services useful for in-vivo and in-vitro investigations, labelled compounds and radiochemicals for varied research purposes, tritium filled sources (TFS) for defence establishments and radioanalytical services provided by BRIT amounted for a total of **Rs. 34.57 Crores upto March 2016**.

(a) Radiopharmaceuticals Production (RPhP)

In-vivo radiopharmaceuticals are meant mainly for diagnostic and/or therapeutic purposes. Since they are meant for in-vivo use as pharmaceutical grade products, compliance to good manufacturing practices (GMP) is mandatory.

- Regular, uninterrupted, production and supply of radiopharmaceuticals, all over India, was continued. BRIT has developed new production processes and capabilities towards increasing the production capacity and quality of products which has enabled RPhP to enhance production frequency, production volumes and regularize the production of new products introduced during previous years.
- Approximately 762.5 Ci of Na¹³¹I and over 30,592 consignments is processed, formulated and supplied to various nuclear medicine hospitals all over India in the form of solution and capsules. These are used for diagnosis and therapy of thyroid disorders.
- Thyroid cancer treatment with large dose Na¹³¹I capsules is one of the major challenges and towards this; milestone production of 7Ci per batch of radioiodine could be achieved. Denominations of 25mCi, 50mCi, 100mCi and 125mCi capsules are produced and supplied for the thyroid cancer treatment.
- AERB approval obtained for regular operation of NEW ¹³¹I capsules production facility hot cells for 10Ci batch of radioiodine.
- The revenue generated from the sale of Na¹³¹I based radiopharmaceuticals alone is of the tune of Rs. 9.55 Crores upto 31st December, 2015.

- ➤ As regular production, about 2500 consignments containing nearly 26.5Ci of ready-to-use radiopharmaceuticals of ¹³¹I-mIBG, ³²P, ¹⁵³Sm and ¹⁷⁷Lu in the injectable form were supplied to various nuclear medicine hospitals all over India. ¹³¹I-mIBG (both, diagnostic and therapeutic) is used for neuroendocrine cancers, while ¹⁵³Sm-EDTMP and ¹⁷⁷Lu-EDTMP Injections are used for bone pain palliation. Sale of all other therapeutic radiopharmaceuticals has resulted in the revenue collection of more than Rs. 30 Lakhs upto December 2015.
- > AERB approval obtained for handling 10Ci of ¹⁷⁷Lu at Radiopharmaceutical Laboratory at BRIT, Vashi Complex.
- Total revenue generated from the sale of injectable radioactive products during 2015-16 was Rs. 3.9 Cr, where Rs. 1.94 Cr# is obtained by the sale of ¹⁷⁷LuCl₃ alone.
- > Total number of therapeutic treatments based on supplies is estimated to be more than 40000 patients. This includes therapeutic doses of Na¹³¹I for the treatment of thyroid cancer and hyperthyroidism.

TCK Cold Kits Production Facility

Certificate of Registration
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"cGMP-Good Manufacturing Practices-Pharma Products" (In accordance with WHO requirements)

- Final commissioning and AERB approval obtained for regular operation of new ⁹⁹Mo-^{99m}Tc column generator (COLTECH) production facility hot cells for 50Ci batch during the year 2015-16.
- Single piece TCM-AUTOSOLEX ⁹⁹Mo-^{99m}Tc Generator was fabricated at RPhP BRIT, with technical support for installation of the software and running the chemical processing steps provided from RC, Kolkata, and supplied to RCR, Hyderabad.

- During the year 2015, more than 75000 cold kits for formulation of ^{99m}Tc radiopharmaceuticals (15 Products; BRIT Code-TCK) is processed, lyophilized and supplied to various nuclear medicine hospitals all over India generating the revenue of Rs. 5.59 Crores.
- Manufacturing facility for 'Kits for Preparation of ^{99m}Tc radiopharmaceutical injection (Cold kits)' has been accredited and certified for "cGMP-Good Manufacturing Practices-Pharma Products" (in accordance with WHO requirements) by United Registrar of Systems Certification (56022/B/0001/NA/Endt9, June, 2015).
- Nearly 90Ci of ⁹⁹Mo, in form of Sodium Molybdate solution, for solvent extraction generator, has been supplied. Approximately 378Ci of ⁹⁹Mo in the form of Sodium Molybdate is processed and supplied in form of ⁹⁹Mo-^{99m}Tc Gel Generator (46 generators) and 400Ci of ⁹⁹Mo (1200 generators) alumina column generator (COLTECH) whereby BRIT could earn revenue of **Rs. 4.70 Crores**.

COLTECH Generator Production Facility

AERB approval obtained for use of break-resistant HDPE vial (in-house BRIT design and development 10, 15 and 100 mL) for safe transportation of radioactive material ⁹⁹Mo in TPPI-1 and FRPB boxes. (Type A Package).

Inner view of the TCM-AUTOSOLEX Module

- More than 2,28,245 In-vivo diagnostic investigations are estimated to have been carried out this year with varied diagnostic radiopharmaceuticals, the major one being, ^{99m}Tc based cold kits and ⁹⁹Mo-^{99m}Tc generator systems.
- A total number of about 3500 radioimmunoassay (RIA) and immunoradiometric assay (IRMA) kits to serve about 3,57,700 in-vitro investigations were supplied to various hospitals, research centres and immunoassay laboratories throughout India. The revenue earned by BRIT from the sale of RIA and IRMA kits for the year 2015 is about Rs. 0.91 Crores.

Indigenously fabricated module for preparing sterile, injection grade [F-18] NaF

The Medical Cyclotron Facility (MCF), Parel, located in the basement of Tata Memorial Annexe Building, continued supplying about 133 consignments of PET radiopharmaceuticals

13

such as ¹⁸F-FDG, ¹⁸F-FLT, ¹⁸F-NaF and ¹⁸F-FMISO to various hospitals in and around Mumbai accounting for nearly 240Ci of radioactivity and generating the revenue of **Rs. 5.4 Crores** during the year 2015-16. **Approx. 14444 patients benefitted with PET investigations in the reported year.**

(b) Quality Control Testing and Quality Assurance of Radiopharmaceuticals (Allied Services to RPhP)

Quality Control group is responsible for the analyses of various ready-to-use radiopharmaceuticals, radiochemicals, TCK cold kits, certifying the product and the timely release of QC reports. During the year 2015, following are the QC reports:

- Routine sample analyses: Around 600 radiopharmaceutical samples were analysed and certified by QC during this period. These samples are tested for their performance in physicochemical analyses, sterility, tests, bacterial endotoxin tests and animal biodistribution studies. Additionally several kits were evaluated for stability beyond the assigned shelf life.
- Biological evaluation studies were performed for 'products under development' such as kit for Macro Albumin Aggregates (MAA) for lung scan and for newly launched kits such as ¹⁷⁷Lu-EDTMP and ^{99m}Tc-TRODAT.
- Correlation studies are being carried out for ^{99m}Tc-MIBI in collaboration with ACTREC with a view to stop animal sacrifice binding to the three R's of animal ethics.

Quality Assurance (QA): During the reported period upto November 2015, batch release was provided for 75 batches of TCK products and 261 batches of ready-to-use radiopharmaceuticals by Quality Assurance group to the production group for dispatch after scrutiny of production and QC documents. As per GMP guidelines, batch documents for TCK kits are being compiled.

(c) Labelled Compounds (LC)

During 2015-16 upto December 2015, Labelled Compounds Programme of BRIT continued the supply of more than 7900 sources of Tritium Filled Self-luminous sources of various sizes and shapes for defence establishments along with the custom synthesis & supply of a variety of ¹⁴C, ³H and ³⁵S-labelled products. The revenue earned was about **Rs. 80 Lakhs**. It is estimated to supply about 25000 nos. of additional TFS sources by March 2016.

II. Engineering Products

The various engineering products offered by BRIT included the supply of more than 1183 kCi of radioactivity in various forms and for varied uses. The combined revenue for the engineering products and radiation processing services is estimated to **Rs. 40.76 Crores and 9.14 Crores respectively during 2015-16**.

(a) Sealed Radiation Sources:

- Co-60 Teletherapy Sources for Cancer Hospitals: Eleven ⁶⁰Co-teletherapy sources with total activity of about 98.3 kCi in the range of 138 and 167 RMM were supplied to various cancer hospitals in India. Twelve decayed sources were unloaded from the teletherapy units and stored for fabrication of irradiator source. These sources were fabricated at RAPPCOF, Kota using Co-60 produced indigenously in nuclear power reactors. Total revenue generated is Rs. 5.50 Crores upto December 2015.
- Industrial Irradiator Sources: Sixty six irradiator sources with total activity of around 1066.5 kCi were supplied in seven consignments to various processing plants within the country and also exported. The irradiators to which these sources are supplied are namely, (a) KRUSHAK, Lasalgaon 55.4kCi; (b) AIIPL, Vasai 248.477kCi; (c) NIPRO, Satara 375kCi; (d) OEFL, Kolkata 96.5kCi; (e) GAMPPL. Hyderabad 100 kCi; (f) FIPLY, BARC 45kCi; (g) INNOVA, Bengaluru 146.135kCi. Total revenue earned from Co-60 Irradiator sources during the year was approximately Rs. 8.11 Crores upto December, 2015.
- A total of 700kCi of irradiator sources are planned to supply upto 31st March, 2016. These are: MSAMB, Vashi-350kCi; Aligned Industry, Bhiwandi-100KCi and Sri Lanka-250kCi.
- ▶ ¹⁹²Ir and ⁶⁰Co Radiography sources: Nearly 869 radiography consignments of Ir-192 and Co-60 with total activity of approx. 37.5 kCi were supplied to various radiography customers in the country. The revenue earned from radiography source replenishment and other service offered by BRIT during the year was approximately **Rs. 6.78 Crores**. It is planned to supply five hundred and fifty more radiography sources up to March 2016.
- Custom Made Sources (CMR) and Reference Sources: Custom Made Sources of Co-60, Cs-137 and Sc-46 were supplied on request, for Nucleonic Gauges and other calibration uses in 974 consignments upto December 2015. A total of 5.67Ci of radioactivity was supplied for reference and custom made sources for revenue of Rs. 26.91 Lakhs. Eighteen custom made ⁶⁰Co radiation sources with total activity of 1.656mCi were supplied till November 2015. It is planned to supply thirty two more Co-60 sources with an activity of 3.2Ci up to March 2016. It is planned to supply forty custom made ¹³⁷Cs radiation sources with 4Ci activity up to 31st March 2016.
- A contract is expected to be signed with Los Alamos National Laboratory (LANL), USA for providing technical support on repatriation of decayed radioactive sources in India back to USA. The work involves collection of devices containing sources such as ²⁴¹Am, ¹³⁷Cs and ²²⁶Ra from 5 institutes, removal of sources from devices and repatriation to USA.
- At RAPPKOFF, Kota, total activity of Co-60 which was processed during the year was about 63.52PBq (1717 KCi). Safe handling, transportation of adjuster rods from various reactors were transported to RAPPKOFF, Kota for processing of Cobalt-60 and subsequently transported for fabrication of sources at Mumbai and the necessary documentation of the records were performed.

⁶⁰Co Teletherapy sources (CTS) are prepared using indigenous pellets recovered after cutting 09 pellet capsules. This is the first time; we have successfully fabricated more than 200 RMM CTS using indigenous ⁶⁰Co pellets. Machine and procedure for cutting of pellet capsules, recovery of pellets and filling of pellets in inner CTS containers is developed at RAPPCOF, Kota and duly endorsed by various regulatory committees of AERB.

Sealed source fabrication using tig Welding inside hot cell

Cobalt sub-assemblies in storage pool

(b) Radiography and other Radiation Equipment Devices

- Radiography Camera: Supply of 81 new indigenous radiography camera model ROLI-2 and model ROLI-3, and servicing and inspection of BRIT manufactured as well as imported ROLI cameras were the highlights during the reported period. Apart from the above, production of 50 nos each of ROLI-2 and ROLI-3 cameras was carried out. Total revenue from the sales of radiography cameras and its services amounted to Rs. 3.03 Crores.
- Gamma Chamber 5000: Two units of GC 5000 were loaded with 14000Ci each of ⁶⁰Co and transported to Indian Institute of Horticulture, Bengaluru and University of Bengaluru. These Gamma Chambers are kept ready for despatch, waiting for site clearance. Decommissioning of two units of GC 900, one at Inter University Accelerator, New Delhi and the other at University of Pune was carried out during the reported period.
- Blood Irradiator: One Blood Irradiator with total activity of 800Ci is supplied to Ruby Hospital, Pune. Revenue generated with the supply of BI-2000 is Rs. 27 Lakhs.

First ¹³⁷Cs based Blood Irradiator is manufactured

(c) Engineering Design Development

- Co-60 based radiography camera developed having capacity 120 Ci testing of camera is completed.
- Multi Position Source Changer is designed and fabrication which can have 11 radiography sources at a time. This has been tested for Type B(U) package at Pune.
- Enhanced security features are added to Laboratory Research Irradiator to ensure radioactive source security.
- > Blast resistance test carried out for Laboratory Research Irradiator at DRDO Chandigarh

Co-60 based radiography camera developed having capacity 120 Ci testing of camera is completed

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Blast resistance test carried out for Laboratory Research Irradiator at DRDO Chandigarh

Enhanced security features are added to Laboratory Research Irradiator to ensure source security

[B] PRODUCTS

I. Consultancy and MoU for Radiation Processing Plants

MoU was signed with Avantee Mega Food Park Pvt. Ltd. for a setting up of Radiation Processing Plant at Indore on July 14, 2015 for radiation processing of food and medical products.

MoU was signed with Electro Magnetic Industries for a setting up of Radiation Processing Plant at Sinnaur, Distt. Vadodara, Gujarat on July 25, 2015 for radiation processing of food and medical products.

MoU signed with Apollo Agro Industries Ltd. for a setting up of Radiation Processing Plant at Gujarat on October 20, 2015 for radiation processing of food and medical products. Radiation Processing Plants for processing food and medical products by M/s Aligned Industries Pvt. Ltd. at Dharuhera, Haryana and M/s Maharashtra State Agricultural Marketing Board, Vashi, Navi Mumbai have been commissioned during the year 2015-16.

> Total operational RPPs under MOU with BRIT are 14.

II. Gamma Radiation Processing Services (GRPS)

(a) Radiation Sterilization Plant for Medical Products (ISOMED):

- ISOMED facility, engaged in contract gamma radiation processing services for terminal sterilization of the medical products has processed 5120 Cubic mtrs of products earning a revenue of Rs. 2.29 Crores. It is expected to generate total revenue of Rs. 3.47 Crores by the end of financial year 2015-2016.
- FOAK (First of a Kind) Integrated System Of Computer Aided Dosimetry (ISOCAD) which has been an innovative endeavour for providing counterfeit proof, computerized dose measurement system for the gamma irradiators, has been gaining wide popularity in the country. ISOCAD has till now been successfully installed in six gamma irradiators and is expected to be commissioned for four more irradiators by end of the current financial year.

- Another Graphic User Interfaced innovative application, viz, ISODIMM (Interactive Software of Drawing Interfaced Maintenance Management), has been designed, tested and successfully commissioned at the facility for the Gamma Irradiators. ISODIMM facilitates computerized engineering drawing associated centralized database management system for the System, Structure and Components of the facility.
- Gamma Radiation Indicator Buttons were developed indigenously as an import substitute for the qualitative indication of the low and medium range gamma radiation dose delivered to the products. These buttons would provide "Made in India" technological solution to the gamma irradiators in the country.

(b) Radiation Processing Plant, Vashi (RPP, Vashi)

- Radiation Processing Plant, Vashi has provided gamma radiation processing services for Spices, Ayurvedic raw material, healthcare products and pet feed etc. to 259 customers from all over the country. Fourteen new customers for Spice, Ayurvedic raw material and pet feed were registered with the facility during last 12 months.
- During the current financial year, uptil December 2015, 2933 MT of spices and other products were processed against the annual target of 4000 MT earning revenue generation of Rs. 2.67 Crores against the annual target of Rs. 3.50 Crores. During next four months, facility is expected to process approximately 1200 MT of various products realizing revenue of approximately Rs. 1.20 Crores.
- Facility was received re-certification for ISO-9001:2008 (Quality Management Systems) for three more years. Surveillance Audit for ISO-22000:2005 (Food Safety Management Systems) was carried out by certifying agency and found in full compliance with standard's requirements.
- Additional revenue from GRPS related products and services such as supply of dosimeters in 91 consignments, BRIT fetched revenue of Rs. 36.63 Lakhs.

(c) QA activities at RPP include the following:

- Acquired NABL accreditation for Dosimeter calibration Laboratory, RPP Vashi
- Export of 2000 Nos. of Ceric-Cerous dosimeters to Atomic Energy Agency, Srilanka.
- 1 Lakh Ceric-Cerous dosimeters were supplied to various private irradiators for low, medium and high absorbed dose measurement in radiation processed medical and food products.
- Commissioning dosimetry was carried out at M/S Aligned Industries, Haryana for Medical and Pet feed products.
- Re-commissioning dosimetry was carried out for 4 plants namely M/S Gujarat Agro Industries Corporation Ltd (GAICL), M/S Agrosurg Industries (India) Ltd., Vasai, M/S Organic Green Foods Pvt. Ltd., Kolkata, M/S Gamma Agro Medical Processing Pvt Ltd, Telangana for Gamma Radiation processing of food and medical products.
- Dose rate certification of Cesium-137 based Blood Irradiator to be supplied to Jankalyan Raktapedhi, Pune was carried out.

III. Isotope Application Services

Isotope Application Services Group of BRIT offered its valuable services to various industries. The total revenue from the IAS services since April 2015 to December 2015 is amounted to **Rs. 63.82 Lakhs.**

BRIT in collaboration with BPCL, Mahul, Mumbai, could troubleshoot Catalyst Cracking Unit (CCU) by combining Gamma Scanning with ⁶⁰Co and Radiotracer Technique. These services could help them to identify the misbehaviour of cyclones in the reactor and also to study the distribution of catalyst powder. Thus, IAS division of BRIT helped Bharat Petroleum Corporation Limited (BPCL) immensely to plan the shutdown and take necessary corrective actions, saving several crores of rupees by minimising the downtime.

Refinery at Bathinda, Punjab

Gamma scanning of stripper in Guru Gobind Singh Refinery at Bathinda was carried out to study the cause of poor product quality. Gamma scanning also helped Hindustan Petroleum Corporation Limited, Mumbai refinery to understand flow dynamics of hydrocarbons inside extract tower of the column.

> Leakage detection in each of the following underground oil pipelines were located successfully using ⁹⁹Mo radiotracer technique by BRIT during the reported period: (a) 12" diameter Mumbai-Pune Pipeline of Hindustan Petroleum Corporation Limited (HPCL); (b) 10" diameter Jawaharlal Nehru Port Trust (JNPT) to Vashi Pipeline of Indian Oil Corporation Ltd. (IOCL); (c) 14" diameter black oil pipeline of HPCL from Mumbai refinery to Vashi terminus; (d) 20" diameter black oil pipeline of HPCL from Mumbai refinery to Pirpav Jetty; (e) 14" diameter black oil and white oil pipelines of Indian Oil tanking Ltd. The results helped the respective oil companies to repair the leak and restore the pumping operations on immediate basis.

A pipeline carrying aviation tourbo fuel from Mumbai refinery of HPCL to Santacruz airport was suspected to have dent/ blockage. A cylindrical pig tagged with radioisotope was passed through 22 Km pipeline to identify the location of blockage. > A leaky heat exchanger was identified in a series of heat exchangers using radiotracer technique in IOCL refinery at Digboi, Bharat Oman Refinery Ltd. Bina, Madhya Pradesh.

Leaky heat exchanger

Shield integrity confirmation for APSARA nuclear reactor, BHAVINI nuclear reactor and for Areva, USA, a project by L&T Ltd.

IV. Radiation Physics Group, BRIT was involved in the following services during the reported period:

- Source loading pattern designed for six Gamma Irradiators (Category IV) for source replenishment.
- Dosimetry and Radiation Protection survey of Portable Research Irradiator (Category I).
- Feasibility assessment of utilizing canisters filled with vitrified nuclear waste for sewage treatment.
- Radiometry of Shielding casks for Nuclear Recycle Board M/s. MRR Engineers, Vasai.
- Radiological safety of radiation Processing Plant and Decayed Source Removal Facility at BRIT, Vashi.

V. Calibration Services for Portable radiation Monitoring Instruments

- > BRIT is providing calibration services for gamma radiation survey instruments.
- > The laboratory is approved by AERB in accordance with the Rule-29 of Atomic Energy Regulatory Board (AERB) Radiation Protection Rules, 2004.

VI. Radioanalytical Laboratory (RAL) Services

> Radioanalytical Laboratory is engaged in the measurement and certification of radioactivity content in commodities such as food items for human & animal consumption, water samples, environmental samples, steel and other miscellaneous items. Generally, food items are monitored for the presence of ¹³⁷Cs & 134Cs. Water samples are routinely analyzed for gross alpha/gross beta, uranium, ²²⁶Ra and ²²⁸Ra content, depending upon the requirement. ²³⁸U, ²³²Th, ²²⁶Ra and ⁴⁰K contents are measured and certified in environmental sam ples such as coal, fly ash, soil rock phosphate, gypsum etc. Steel samples are generally tested for the presence of ⁶⁰Co contamination. Steel survey at factory sites and warehouses is carried out to monitor the surface radiation dose. Since April 2015, RAL has carried out more than 3000 tests on export/domestic commodities and 900 tests on water samples (gross alpha, gross beta ²²⁶Ra & ²²⁸Ra).

In addition to above, one steel survey was conducted for certification of surface radiation dose and 27 food samples imported from Japan were also analyzed and certified.

Setting up of additional Radioanalytical Laboratory at BRIT Project House, Deonar is completed during the year.

Radioanalytical Laboratory Services both, at Vashi Complex and RCR, Bengaluru, together performed **approximately 3737 analyses of food and water samples for the presence of radioactivity**, and BRIT could earn revenue of **Rs. 0.98 Crores** during the reported period.

VII. Electron Beam Processing Services (EBPS)

- The upgradation work of 2MeV Electron Beam Accelerator (EBA) to operate upto 5 MeV/15 kW at BRIT, Vashi complex has been completed during the time period. BARC Safety Committee has approved for initial trial operations @4.5MeV/9kW Beam power. EBA facility characterization has been carried out using Film/alanine Dosimetry. The process thickness has been evaluated to be 12.5mm to 33.0mm for unit density material. Dose uniformity is within 5% over the multiple product packages of 800mm×600mm (l×b).
- The machine can deliver from a lowest dose of 0.5kGy and products can be processed on semi industrial scale, which can accommodate a range of low, medium and high dose irradiation of products viz. atta, pulses, spice, fish, meat, polymer materials and semi-precious stones etc. Both, the mesh conveyor and power roller conveyor have been repaired and restored back to operation so as to enable continuous irradiation at the speed of 0.9m/min to 4.2m/min. All the civil & mechanical modifications of the facility planned during upgradation work have been completed.
- During the year 2015-16, products irradiated in the facility include fish, meat (for shelf-life extension under chilled condition), wheat powder for disinfestation, polymer cable joint end-caps (for crosslinking and high temperature applications), waste water for hygienization, etc.

RF Cavity Replacement during ILU-EBA Upgradation

Electron Beam crosslinkable polymer composite, HDPE and EPDM, which are both, temperature-resistant and radiation-resistant has been developed for applications in cable insulation & nuclear gasket industry. Quality of product developed: 1) Excellent high temperature resistance for nuclear gasket applications. At 120°C, it can be used up to one month. At 100°C, it can be used for 2 months. At 70-80°C, this can be used for 4 months; 2) Excellent gamma resistance for nuclear gasket applications (up to 1300kGy); 3) Good processibility; 4) Tuneable mechanical properties. This material can be recommended to be applied for nuclear gasket application, where a high temperature and radiation resistant gasket is required.

VIII.Services of RCR's, BRIT and Quality Control Analysis at Vashi Complex Services for Outside Agencies

Regional centres at Delhi, Bengaluru, Jonaki, Hyderabad, Dibrugarh & Kolkata, continued the services of ready-to-use-radiopharmaceuticals to surrounding nuclear medicine hospitals, labelled compounds and radioanalytical certifications. Around 3,000 consignments of in-vivo and in-vitro kits were supplied to RCR's for providing extended services to nearby hospitals, research centres, or institutions at these cities. The total revenue collected from all these services provided amounted to be **Rs. 10.77 Crores**.

(a) RCR, Kolkata & Dibrugarh:

- TCM-AUTOSOLEX module: The revised new TCM-AUTOSOLEX module is in use with success at RRMC, VECC, Thakurpukur, Kolkata in association with technical support from RCR. The revised new TCM-AUTOSOLEX module at RMC, BARC for centralized radiopharmacy is in use. Patient studies have been started using pertechnetate and Radiopharmaceuticals using ⁹⁹Tc from autosolex. 750mCi Molybdenum batch have been used and the operation was found to be successful. The TCM-AUTOSOLEX module at BRIT, Mumbai is under evaluation stage for installation at RCR, Hyderabad (Jonaki). Technical support was given to install the software and running the chemical processing steps. The chemical processing unit of the AUTOSOLEX module has been manufactured at BRIT, Mumbai in association with technical support from RCR, Kolkata. A new unit of TCM-Autosolex module at regional centre, Kolkata has been installed for future up-gradation. IAEA training programme has been conducted at BRIT, Mumbai with this AOTOSOLEX module.
- Sale of cold kits for radiopharmaceuticals from the retail outlet at RC, Kolkata: About 362 cold kits (having sale value of Rs. 9.3 lakh) were sold this year (between Jan. 2015-Dec. 2015) in nuclear medicine centre at Kolkata.

> Services at RC, Dibrugarh: Regional centre BRIT, Dibrugarh located at Assam Medical College & Hospital is rendering RIA and IRMA diagnostic services for the benefit of patients of the entire North-Eastern region. The Radiopharmaceutical products produced and supplied by BRIT, Vashi complex are extensively used by the RC, Dibrugarh for the diagnosis & investigation of various diseases. More than 7000 patients of the region avail the services from this centre. The revenue collected from RCR, Dibrugarh from April to November 2015 is around Rs. 7.0 Lakhs. It is expected to collect the total revenue for the 2015-16 to be around Rs. 11 Lakhs.

Semi automated ⁶⁸Ga-post purification process system (One of the many R&D activities at RCR, Kolkata)

(b) RCR, Bengaluru:

- Regional Centre, BRIT, Bengaluru supplied ~80mCi of ready-to-use ^{99m}Tc-pertechnatate and 1119 TCK cold kits were sold through retail outlet and door delivery for the preparation of ^{99m}Tcradiopharmaceuticals to nearby nuclear medicine centres.
- Gamma irradiation services were provided for 2500 blood bags. Also, radioanalytical services for the measurement and certification of residual radioactivity in various commodities such as food items for human & animal consumption, medicine, steel and other miscellaneous items were provided.
- The total revenue generated from the services of RCR, Bengaluru from April 2015 to December 2015 is amounted to Rs. 12.06 Lakhs.

(c) RCR, Delhi:

Regional Centre for Radiopharmaceuticals, Delhi continued to supply clinical grade ready to use ^{99m}Tc-radiopharmaceuticals in compliance with GMP and RPC for diagnostic nuclear medicine centres in Delhi and NCR regions. Rs. 21.78 Lakhs was the total revenue collected by RCR, Delhi upto December 2015.

(d) RCR, Hyderabad (Jonaki):

During the period, Regional Centre of BRIT, Hyderabad (Jonaki) supplied ready-to-use ^{99m}TcO₄ (Pertechnatate) and ^{99m}Tc-Radiopharmaceuticals through their retail outlet to the nuclear medicine centres of Andhra Pradesh. Also, it continued to supply ³²P labelled nucleotides and a few molecular biology kits and enzymes, for research in frontier areas of Molecular Biology, Biotechnology, Biomedical and Drug Discovery research of the country. It markets ³⁵S-labelled amino acids products produced at BRIT, Vashi Complex. Total revenue earned by RCR, Hyderabad is Rs. 68.7 Lakhs upto December 2015.

(e) Quality Control Analysis Services from Vashi Complex for Outside Agencies

- Quality Control testing services was provided for kit efficacy and safety performance of cold kit for ^{99m}Tc-labelled Myoview for M/S GE Healthcare.
- Various services including the Quality Control Services (mentioned above), provided by Radiopharmaceuticals and Labelled compounds fetched BRIT total revenue of **Rs. 1 Lakhs** during the year 2015-16.

[C] Marketing & Sales Division of BRIT (M&S)

A dedicated Marketing & Services Programme was constituted in BRIT during 2015-16 which is committed to provide enhanced customer support, i.e. from the production site upto the customer needs. The ease in the process of registration for required product / service to delivery of the product / service, including payments for its valued customers, was kept as the topmost priority. Earlier the same task was carried out by the individual programmes that are responsible for production or providing the services.

As a new initiative, an **online payment facility** has been created for existing customers through **State Bank Collect payment portal**. For availing this facility, the customer will have to go onto BRIT Link and click to the to State Bank Collect in the Online Payment's page at

www.britatom.gov.in. This would take the customer to a disclaimer clause page. Once, the customer is on the disclaimer page, he is required to select the check box and proceed further which will lead to BRIT payment webpage at SBI Portal. The category of payment maybe selected as applicable i.e. 'Advance Payment' or 'Settlement Against Supply'. Upon selecting the appropriate option and filling the relevant information regarding the payment (fields marked * as mandatory) and proceeding; the portal would lead to payment options. The customer is now free to choose either Card Payment or Net banking or Other Payment Modes (Challan for cash/DD/ Cheque).

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[D] Events, Awards and Activities related to Official Language Implementation at BRIT

• A training course on 'Radiotracer related techniques for diagnostic laboratory' was conducted for the first time during 28th April–9th May, 2015 at Radiopharmaceutical Programme of Board of Radiation & Isotope Technology and was attended by doctors, pharmacists and research scholars. Nine students from varied fields underwent a thorough training in the use of radiotracers such as ^{99m}Tc, ¹²⁵I, ¹³¹I and ¹⁴C for diagnostic laboratory. A test was conducted at the end of the 10 working days and issued them the said certificates.

• IAEA Interregional Training Course on "Practical Aspects of the Production of Molybdenum by the Neutron-Gamma Reaction" was conducted for the first time at BRIT from 22nd to 27th June 2015 at Vashi Complex. The training course was attended by international (from 12 countries) and local participants. Faculty was from BRIT, BARC, AERB and IAEA. It was inaugurated by Dr. K.L. Ramkumar, Director, Radiochemistry & Isotope Group, BARC, Mumbai and the guest-of-honour was Dr. N. Ramamoorthy, Associate Director, International Collaboration & Technical Coordination. The course director was Shri S.S. Sachdev, SGM, Radiopharmaceutical Production (RPhP), BRIT.

• DAE Achievement Awards: Scientific and Technical DAE Excellence Award 2014 was awarded to Mr. Tariq Saeed Anwar, Head, Regional Centre, RAPPCOF, Kota, for 'Development of Indigenous High Intensity Co-60 Teletherapy, Irradiator Sources and Sealed Sources Fabrication'. Another Scientific and Technical DAE Excellence Group Achievement Award 2014 is conferred on Dr. V.N. Yelgaonkar and Dr. A.K. Kohli, Group Leaders of the team of Scientists/Engineers/Technical Personnel for their contribution for successfully accomplishing

the activity titled, 'Design and Development of Indigenous Co-60 Based Blood Irradiator and Innovative Technique for the Benefit of Industries'.

- HRD activities of BRIT: Apart from the services towards the commercialization of radioisotope activities in healthcare, industries and radiation processing, BRITians are also involved in human resource development programmes. These comprises of taking part in not only imparting training to post graduate students and research scholars from different colleges and universities in all sectors of BRIT programme, but also they are active in participating in various workshops and conferences. They are also active in pursuing various research projects pertaining towards their products or towards developing new designs and products which are useful for the society. Chapter 4 illustrates all HRD Activities of BRIT in detail.
- Activities related to the Official Language Implementation at BRIT: Along with the scientific activities, BRIT has also implemented the 'Official Language Act' in official works. The Official Language Section at BRIT continued to carry out its activities to promote the use of Rajbhasha, 'Hindi' in various disciplines of the board such as 'incentive schemes for stenographers and officers' to use Hindi in official work, documents related towards 'Annual Report' and reports of various committees were prepared bilingually. BRIT had organized many competitions and quiz contest for BRITians under the auspices of 'Hindi Day Celebration'. Prize distribution and respective certificates were distributed by the chief guest, Dr. Pankaj Chaturvedi, Professor and Head & Neck Surgeon at Tata Memorial Hospital, Parel, Mumbai. He also presented a talk on 'How to win over Cancer' which was well appreciated by the audience. Four Hindi Workshops were organized during this time period. Quarterly meetings of Official Language Implementation (OLIC) were held regularly and to monitor the progress of Hindi with review of the 'Quarterly Progress Report'.

Incentive Schemes offered to Stenographers to promote the use of Rajbhasha, 'Hindi' at BRIT

Hindi Diwas Celebration and Cerificate distribution
Under the auspices of 'Joint Official Language Coordination Committee', a 'Kavi Sammelan' was organized. Reputed dignitaries recited their poems and enthralled the audiences.



• BRIT Staff Sports and Cultural Club

This is a cohesive association of more than 325 employees of BRIT nurturing the sports and cultural talent in our staff. The objectives of this club are to have cognizance of the staff with each other, unite the staff through sports and various events, organize the functions involving families of the members for intermixing and to discern.



Kavi Sammelan and the enthralled audience

Various annual sports, quiz competitions, tele-games, rangoli competitions are organized by the club every year. Annually,DAE entrusts responsibility of conducting selection trials for one of the sports to our staff club. Every year staff club organizes celebration of Independence Day and Republic day, one monsoon trek and one picnic for the staff members.



Annual day function is celebrated by the club giving the stage to performers in BRIT. In addition staff club also organizes various informative lectures on current topics by eminent speakers.





President of the club is nominated by Chief Executive of BRIT. Currently Dr. Vivek Yelgaonkar is working as President of the staff club.

Annual General body meeting of the members is conducted once in a year to discuss the various issues and to approve the expenses incurred.

• Women's Day Celebration:

A women's cell has been set up in BRIT to take action against harassment of women employees if any. Few members are nominated by Chief Executive, BRIT. The current Chairperson of Women's cell is Dr. R. Vanaja. Meetings are conducted periodically to discuss the activities of the cell and take action against any complaints.

Women's day was celebrated on 8th March, 2015 and all women employees of BRIT took part in the celebration.



A. Plan Projects

a. Project: DAE Medical Cyclotron Project: Radiopharmaceutical Facility.

Progress: Civil construction work is in final stage of completion. Work on HVAC, electrical work, LCW system etc. are completed. It is expected that the installation of the Medical Cyclotron will start by June 2016.

b. Project: Indigenous HDR Brachytherapy Equipment (IHDR)

Progress: Purchase Order for "Development of suitable TPS for IHDR-KARKNIDON" released, and development work commenced. Implementation of the necessary action based on the feedback of cold trials of 2 units which were supplied to TMH & ACTREC was carried out during the period. Two numbers of Ir-192 miniature source assemblies were made, but source holder did not sustain the trials. Subsequently, new design of SS source holder was finalized in consultation with DRHR/BARC and given for manufacturing in CDM by DRHR. Cold trials of five units at BRIT continued for generation of record towards reliability studies. Improved design of PEEK moulded ovoid & SS applicator made & tested.

c. Setting up of Fission based ⁹⁹Mo Production Facility.

Progress: The production process of fission based ⁹⁹Mo is a sophisticated technology. It is similar to a small scale "back end nuclear fuel cycle" of a nuclear power plant, involving handling of large scale of activity, having scores of long/short lived isotopes and all kind of radioactivity namely alfa, beta and gamma. With the completion of this plant of BRIT, DAE will be able to meet long standing requirement of health care sector, by producing most crucial isotope ⁹⁹Mo (n, f). Indigenous production of ⁹⁹Mo will bring about stability in the current uncertain market and bring down the cost of ⁹⁹Mo-^{99m}Tc generator considerably. It will also facilitate the growth of nuclear medicine in India and finally, larger section of the patients would be benefitted due to availability of high-tech diagnostic procedures at affordable rate.



This project consists of setting up of a State-of-the Art GMP compliant facility capable of producing 300Ci (6 day pre-calibrated) /week ⁹⁹Mo, utilizing LEU targets. The scope includes commissioning of set of modern hot cells equipped with manipulators, in cell equipments, radiation surveillance instrumentation and data logging system, special AC & ventilation system, waste management equipments, civil construction of building and setting up of world class quality control labs, modern security system, construction of new building at approved site in ISOMED Complex, BRIT near South Gate BARC, etc.

After the site clearance by AERB, the design documents for the building have been submitted to AERB. As per requirements of security and safety authorities, the work of construction of new RCC boundary wall for the complex, new security watch tower is over and installation of new security and surveillance equipment is ongoing. The work on civil construction of laboratory

building is nearing completion. The work on installation of facilities for waste management, electrical supply, water supply etc. is progressing.

The procurement of the production plant, on turnkey basis, is progressing. During the year, the procurement vide Purchase order in favor of M/s INVAP, Argentina for design, fabrication, supply, installation and commissioning of facility, was cleared, after negotiations and discussions, from the IAEA and other bilateral (India, Argentina specific) safeguards and the supply of initial LEU targets from Argentina have been excluded from Purchase order as M/s INVAP, Argentina expressed their inability to supply to India as per their safeguard restrictions. This has been achieved by active involvement of NCPW, DAE, RC & IG, BARC, DPS, BARC and DAE. Work on design and fabrication of LEU targets for irradiation in Dhruva is in progress at BARC.

d. Advanced Facilities for Radiopharmaceuticals Production

The project scope comprises of building Advanced Radiopharmaceutical Manufacturing and testing facility for new generation Radiopharmaceuticals with radioisotopes using ⁹⁰Y, ¹⁷⁷Lu, ⁸⁹Sr, ¹³¹I, ³²P, ¹⁵³Sm. etc. Also the present production capacity of radiopharmaceuticals and services from RPL, Navi Mumbai and Jonaki Hyderabad would be enhanced under this project.

Progress of the Project is as below:

• New Effluent Treatment plant, as per requirement of Maharashtra Pollution control Board and Navi Mumbai Municipal Corporation, of capacity 150CMD for BRIT, BARC-Vashi complex commissioned is operational.



• Site clearance work for construction of new laboratory space at first floor over RPL extension building is in progress and re-routing of the return ventilation air duct, which was laid on the terrace of the RPL extension building, completed



Roof Top View New Laboratory



Ground ViewSpace Construction



• State of the art analytical equipments installed and commissioned during year are HPGe detector, Laser-Uranium analyser, dose calibrators, Mass spectrometer at RPL Vashi and electrophoresis, real time PCR and Alpha-Beta counting system at JONAKI, Hyderabad.

• As a part of project, new Pharmaceuticals services room has been set up for preparing water for injection (WFI), Sterile and pyrogen free glassware, equipment, glass vial etc. which are used in production and important primary containers for all radiopharmaceutical products.



New facility for Pharmaceutical services

e. Project : Technology Development for Radiation Technology Equipment

Specifications for I-125 seed manufacturing plant have been finalized. Old canteen building of BRIT has been demolished and construction of new building has been started. Equipment such as X-ray based low dose irradiator, Co-60 camera, source changer have been developed.

BRIT Website:

BRIT website provided regular updates on various programs and activities related to developments in BRIT. Customer oriented reports were uploaded on website almost on daily basis enhancing co-ordination and communication with the customers.

Sales turnover in 2015-2016

Appropriate Services and Sale of Radioisotopes & Allied Products Supplied by BRIT

S. No.	ltem	Sales turnover from April 2015 – March 2016
1	Consignments	~ 1, 05, 000
2	Activity	~ 1500 kCi
3	Total Sale	Rs. ~84.47 Crore







Chapter 3



Research & Development Activities At BRIT

I. Development Work carried out Radiopharmaceutical Programme, BRIT

1. Development of new infection agent, ^{99m}Tc-Cefprozil

Cefprozil is a promising diagnostic imaging agent belonging to second generation of cephalosporin class of antibiotics. A protocol has been developed and standardized for radiolabelling this antibiotic with ^{99m}Tc. Radiolabelling parameters such as pH, concentration of ligand and SnCl₂ were standardized. The stability of the labelled cefprozil was studied at room temperature over a period of 24 hours. ^{99m}Tc-Cefprozil was subjected to in-vitro bacterial binding studies with S. aureus (ATCC 25923). Effect of various parameters such as tracer concentrations, incubation time and temperature, bacterial culture strength, reaction conditions and challenging the tracer with different concentrations of cold cefprozil were all studied.

2. Development of novel material for preparation of ⁹⁹Mo-^{99m}Tc generator using medium ⁹⁹Mo specific activities

⁹⁹Mo-^{99m}Tc generator is used for the production of ^{99m}Tc where ^{99m}Tc can be specifically separated using a chemical procedure. Alumina column generator where ^{99m}Tc can be preferentially eluted with saline is a well-known separation system and is in commercial use. The acidic alumina used for column generator preparation has a loading capacity of 20mg of Mo of per gram of alumina and is suitable for high specific activity ⁹⁹Mo (fission produced). The present work aims in synthesizing a new sorbent material which will have increased loading capacity that may be used for low to medium specific activities ⁹⁹Mo. In this regard, mesoporous alumina (MPA) was synthesized using D-glucose and alumina isoperoxide. Sorption studies in dynamic condition with (n,g) ⁹⁹Mo were carried out using the synthesized MP alumina. Sorption capacity of MPA was found to be 60-70 mg/g of Mo per gram of alumina under dynamic condition, which is nearly three times the capacity of alumina. Performance studies of generator with MPA and the post-elution concentration of ^{99m}Tc eluates using DEAE cellulose anion exchange column are underway.

3. Separation of ⁹⁹Tc from decayed liquid waste produced from COLTECH generator facility

⁹⁹Tc is a useful radioisotope which has wide research based applications. It is produced by the decay of ⁹⁹mTc and is also directly produced by the decay of ⁹⁹Mo (12%). BRIT continues to supply ⁹⁹Mo activity in the form of COLTECH generator for more than a decade now. About 30L of ⁹⁹Mo liquid waste is generated during the years which was anaalyzed and the principal radionuclide in the liquid waste was found to be ⁹⁹Tc. Efforts are underway to separate ⁹⁹Tc from the waste stream using ion-exchange and/ or solvent extraction methods.

4. Extension of life of cold kits (TCK-7, TCK-16 & TCK-50) for the preparation of ^{99m}Tc radiopharmaceuticals

Cold kits constitute important inactive ingrediant in lyophilized powder form required for the preparation of ^{99m}Tc-radiopharmaceuticals at the hospital end. These inactive chemicals are present in millimolar concentrations and their integrity over the stated time determines the shelf-life of the cold kits. Most of the BRIT kits that were launched earlier presented reduced shelf-life. Hence, with an aim to extend the shelf-life of these cold kits, studies were undertaken to evaluate the performance of the kits such as ^{99m}Tc-DTPA (TCK-7), ^{99m}Tc-Phytate (TCK-16) and ^{99m}Tc-MIBI (TCK-50). 100 vials each of these cold kits from six consecutive batches were

used for these studies. Physicochemical tests were performed every month after the current expiry date of six months upto a period of 13 months. Bio-distribution studies were done post 13 months after production. The results showed that all the aforementioned kits comply with the specifications for the kits as per Radiopharmaceutical monographs/Indian Pharmacopoeia 2014 and approval for extension of shelf-life from existing six months to one year was granted by Radiopharmaceuticals Committee (RPC) for these three cold kits.

5. Microwave-assisted syntehesis of I-131 labeled meta iodo benzyl guanidine (mIBG)

^{123/131}I-mIBG can be synthesized by nucleophillic exchange reactions at high temperature and long heating time. Cu⁺ assissted nucleophillic exchange reaction for radioiodination of molecules by conventional heating at 160 \Box C takes 30 minutes to yield product with reasonable radiolabelling yields. Microwave heating is known to accelerate chemical reactions. Hence, the present work exploits the use of microwave for radiolabelling mIBG. mIBG reaction mixture containing Na¹³¹I (50mL, 37MBq, Specific activity ~20Ci/mg of Iodine) was heated to a temperature of 100°C in 2 minutes using a microwave reactor and maintained at this temperature for 4 minutes. Thereafter the reaction was discontinued and the radiolabelling efficiency was found to be > 95% with the radiochemical purity (RCP) ~98%. Due to shorter heating time, the microwave heating method significantly reduced the radiochemical impurities and is best suited for the development of cold KIT for the synthesis of iodine labelled mIBG.

6. A novel ¹⁸⁸Re analogue of ¹³¹I-mIBG with affinity for Nor-epinephrine transporter (NET)

¹³¹I-meta iodobenzylguanidine (¹³¹I-mIBG) is a well-known radiopharmaceutical used for the therapy of neuroendocrine tumors related to neural crest origin. Due to the volatile nature of radioiodine and cumbersome radiochemical operations involved in the synthesis of the radiolabelled product, there has been an inherent interst to develop a rationale substitute. In this respect, a ¹⁸⁸Re analogue of mIBG using $\Box 4+1$ ' complexation approach was synthesized and evaluated in-vitro for its potentiality in the neuroblastoma cells. A guanidine derivative bearing an isonitrile group ($\Box 1$ ') at the meta position suitable for Rhenium complexation via Re-4+1 cell uptake studies in SK-N-SH cell lines showed uptake similar to no-carrier added, nca-¹²⁵I-mIBG. This transport was specific as the uptake reduced (70-75%) with NET inhibitor desmethylimipramine. These results proved the affinity of the synthesized precursor for NET transporter. Further evaluation in tumor xenografts is underway for concluding the potential of ¹⁸⁸Re-4+1 complex in-vivo.

7. Estimation of ^{99m}Tc-4+1 benzylguanidine complex uptake in tumor xenografts using Micro-SPECT

The present work highlights the utility of small animal imaging system for quantifying the invivo distribution of radiotracer inside the animal body. In this regard, a new ^{99m}Tc-analogue of ¹³¹I-labelled meta-iodobenzylguanidine (mIBG) was evaluated in a tumor xenograft model bearing SK-N-SH neuroblastoma and its uptake in the region of tumor quantified using micro-SPECT imaging. Micro-SPECT image could not delineate any uptake in the region of tumor. However, the standard uptake value calculated by marking region of interest (ROI) in the tumor on co-registering with CT image was around 4% of Injected Dose (ID) per CC only. Although the potentiality of the present tracer for neuroblastoma imaging could not be completely established, the micro-SPECT-CT image thus obtained provided the utility of the technique for semi-quantitative estimation of the distribution pattern in target/non-target organs.

8. Synthesis and separation studies of no-carrier added (nca) ¹³¹I-metaiodobenzylguanidine from its precursor, meta-trimethylsilylbenzylguanidine

In continuation with our previous efforts to prepare nca-¹³¹I-mIBG for therapeutic applications, nca-¹³¹I-mIBG was synthesized successfully in high yields using a new precursor, m-silylated benzylguanidine derivative. The radiolabelled product thus obtained gets resolved on C18 HPLC column wherein the starting substrate gets retained on the column and labelled product elutes out of the column using a buffer elution system. Efforts are underway to separate the radiolabelled product quantitatively from its precursor using C18 resin colmn, so as to translate the labelled product for regular production use.

9. Hormone estimation in animals using modified human radioimmunoassay (RIA) kits

Commercial human RIA kits for progesterone and estradiol were modified for the measurement of these hormones in bovine samples for DGCN College of Veterinary and Animal Sciences of CSK Himachal Pradesh Agricultural University. More than 800 bovine serum samples were analyzed using this method and were found to be satisfactory.

10. Development and Validation of T₃ and T₄ RIA assay systems for the measurements of these hormones in rat samples

Rat models are extensively used for evaluating therapeutic effects of new drugs and carcinogenicity testing which includes measurement of hormone levels in rat serum. Due to the similarity between rat and human thyroid physiology, rat models are widely used for such studies. RIA procedures were developed and validated for the measurement of thyroid hormones, T_3 and T_4 , in rat serum. The samples analyzed provided satisfactory results.

II. Development work carried out at Regional Centre for Radiopharmaceuticals (RCR), BRIT, at Kolkata

1) Installation and evaluation of TCM-AUTOSOLEX generator for preparation and use of [99mTc]-pertechnetate in hospital

The revised new TCM-AUTOSOLEX module is in use with success at RRMC, VECC, Thakurpukur, Kolkata in association with technical support from RCR, Kolata. The revised new TCM-AUTOSOLEX module at RMC, BARC is also in use in association with technical support from RC. Patient studies have been started using pertechnetate and radiopharmaceuticals. 750mCi Moly batch have been attempted successfully. The TCM-AUTOSOLEX module at BRIT, Mumbai, is under evaluation stage for installation at RC, BRIT, Hyderabad. Technical support was given to install the software and running the chemical processing steps. The chemical processing unit of the AUTOSOLEX module has been manufactured at BRIT, Mumbai in association with technical support from RC. A new unit of TCM-Autosolex module at RCR, Kolkata has been installed for future upgradation. IAEA training programme has been conducted at BRIT, Mumbai with this AOTOSOLEX module.

2) Irradiation of Enriched ¹⁰⁰Mo for ^{99m}Tc production in VEC cyclotron and determination of radionuclidic purity of the cyclotron produced ^{99m}Tc

Enriched ¹⁰⁰Mo target as pellets (548 mg and 549 mg) were irradiated in VEC cyclotron with 18 MeV, 3μ A proton beam for 2h and 3h duration. The obtained experimental yield of ^{99m}Tc were

33.7mci and 46.9mci respectively (monitored in dose calibrator). Irradiated ¹⁰⁰Mo target pellets were dissolved in 6.5 ml hydrogen peroxide and the basicity of the solution was maintained with $3M (NH_4)_2CO_3$. Each set of pellet dissolved solution was fractioned in 5 sets. Separation of ^{99m}Tc from ¹⁰⁰Mo target was achieved by MEK solvent extraction and Dowex-HNO₃ method (in AUTODOWNA module, Fig. 1.). Recovery yield of ^{99m}Tc from MEK solvent extraction was >90 % (n=6) and from Dowex-HNO₃ method >80% (n=4). Physicochemical quality control tests of all the separated ^{99m}Tc fractions were performed and it was found that all are within the specified limit.



Radionuclidic purity (RNP) of final pertechnatate solution separated from enriched ¹⁰⁰Mo solution by MEK solvent extraction and Dowex-HNO₃ method was evaluated. For that, the decayed pertechnetate samples were counted in HPGe detector for overnight. It was found that RNP of pertechnatate samples was greater than 99.9% even at 24h after the separation. The level of different Tc radionulides produced along with 99mTc are analyzed and listed in Table-1.

Table-1. RNP of final ^{99m}Tc preparation at different time points after the end ofseparation (as % of ^{99m}Tc activity)

Impurity	EOB	After 6h	After 12h	After 24h
^{95g} Tc	1.46E-04	2.09E-04	3.86E-04	1.02E-03
95m Tc	5.30E-06	9.29E-06	2.11E-05	8.39E-05
[%] Tc	3.97E-05	6.70E-05	1.46E-04	5.40E-04

3) Production feasibility of ⁸⁹Zr from ^{nat}Y and subsequent radiochemical separation of ⁸⁹Zr from the target matrix

The emerging PET radioisotope, ⁸⁹Zr with 3.27d half life and decays by positron emission (23%, E+=0.897 MeV) and by electron capture (77%) is suitable for tumor diagnostics, tumor therapy and also for investigation of bio-kinetics of antibodies. This isotope can be produced from natural yttrium which has 100% abundance. To standardize the separation of ⁸⁹Zr from Y, some radiotracer of yttrium is required. Therefore, ^{nat}Y foil of 100µm thickness and weighing 69mg was irradiated in VEC cyclotron with 18 MeV, 1.3µA proton beam for 37h duration for production of ⁸⁸Y (half life 106 d), ⁸⁸Zr (half life 83 d) and ⁸⁹Zr. The experimental yield of ⁸⁹Zr,

⁸⁸Zr, ⁸⁸Y were 37mCi, 2.6mCi and 0.27mCi at EOB respectively. Natural Yttrium foil of 100µm thickness and weighing 72mg was irradiated in VEC cyclotron with 12 MeV, 1µA proton beam for 22h duration for production of pure ⁸⁹Zr. At this energy, the production yield of ⁸⁹Zr was 6.3mCi at EOB and no other isotopes of Zr and Y were found. Dissolution of irradiated ^{nat}Y targets were carried out in Conc. HCl (12M). The radiochemical separation of ⁸⁹Zr from irradiated Y target has been done with cation exchange, anion exchange chromatography. Anion exchange chromatography: Anion exchanger Dowex -1 x8 (CI[°]) resin (100-200 mesh) was used for the separation of ⁸⁹Zr from irradiated Y target. The elution profile curve of ⁸⁹Zr with 2N HCl is shown in the Fig. 2. The recovery yield of ⁸⁹Zr activity from the column was assessed by gamma ray spectroscopy with HPGe detector. The recovery yield of ⁸⁹Zr activity was not detected in the ⁸⁹Zr eluted fractions by HPGe detector.

Labelling of ⁸⁹Zr with oxine: ⁸⁹Zr activity in dilute HCl obtained from anion exchange chromatography separation was evaporated to dryness and reconstituted in 10% sodium

carbonate solution for radiolabeling. It was mixed with requisite amount of oxine in chloroform and vortexed for 15min. The chloroform phase was separated from the aqueous phase, dried with anhydrous sodium sulphate, evaporated and the residue obtained reconstituted with saline. The labelling yield was >93% and radiochemical purity (RC Purity) of the [⁸⁹Zr]oxine complex was above 95%.



4) Evaluation of ⁶⁸Ge/⁶⁸Ga generator: Elution of the ⁶⁸Ge-⁶⁸Ga generator (G-8) & Post Purification of Ga-68

The new ⁶⁸Ge-⁶⁸Ga generator (G-8) prepared from ⁶⁸Ge produced by irradiation of Ga target with proton beam was evaluated by daily elution for more than 300 days. Average elution efficiency of the column was found to remain constant at about 58%. A new method of purification of the primary eluate from the generator was standardized using a cation exchange resin. In the optimized method of purification the average yield of purified ⁶⁸Ga has been around 84% 8.6% (1SD, n=388), pH 6-7. Break though of Ge-68, before and after purification, were 0.046 and 0.00031 respectively. The process chemistry has been semi-automated (Fig.3).



Figure 3. Semi automated ⁶⁸Ga-post purification process system

5) A new method of direct Separation of ⁶⁸Ge from bulk Ga using SnO₂ column useful for in situ formulation of ⁶⁸Ge/⁶⁸Ga generator: Devoid of using Solvent Extraction process using Toluene

 68 Ge-Ga target dissolved solution at 1M HCl was directly loaded on a fresh SnO₂ column (mesh size 150-200) was used for the preparation of 68 Ge/ 68 Ga generator. The advantage of this method is that no separate solvent extraction is required for the isolation of 68 Ge from the Ga target matrix. Then the column was washed with 500 ml 1N HCl to wash trace amount of inactive Ga. All the fractions including the load solution were monitored in HPGe detector to assess the retention of 68 Ge in the column. It was found that >99% of loaded 68Ge has been retained in the column. Since Ga is inactive here, the estimation of Ga in the wash solution and in the load solution has been performed colorimetrically with chromazural-S reagent following the same protocol applied for determination of aluminum. It was found that most of the Ga has came out during loading of 68 Ge and the level of Ga decreased in the successive washing and it was very close to standard solution 10µg/ml. The Elution Efficiency of 68 Ga was 48% from the SnO₂ column with respect to loaded 68 Ge activity as determined by HPGe detector. Percentage of loaded Ge-68 activity broke through the column was 0.204 (n=7). This breakthrough is little higher as compared to the earlier column (G-8) prepared @ 0.1M HCl.

6) Synthesis of cross linked chitosan for preparation of ⁹⁹Mo/^{99m}Tc generator

The cross-linked chitosan is an emerging potential adsorbent matrix having large adsorption capacity for many metal ions, which can be extended to the preparation of ⁹⁹Mo/^{99m}Tc generator from low specific activity ⁹⁹Mo. The precursors for this cross-linked chitosan are Chitosan and glutaraldehyde. The cross-linked mass was separated from the solution and washed thoroughly with deionized water until the pH of the effluent solution was 7. Characterization of the synthesized cross linked chitosan has been carried out with X-ray diffraction method.

III. Development Work carried out at Medical Cyclotron Facility, Parel

1. Operational and Clinical Efficiency of TCM-AUTOSOLEX Generator at RMC, Parel

Due to aging and unexpected prolonged shutdown of nuclear reactors producing high specific activity ⁹⁹Mo via fission reaction of enriched U-235 which is used for ⁹⁹Mo/^{99m}Tc alumina column generator preparation, the nuclear medicine community has felt to explore the alternative ^{99m}Tc production methods. Production and utilization of low specific activity (LSA) ⁹⁹Mo produced by (n, •) ⁹⁹Mo reaction using natural molybdenum trioxide (MoO₃) target in low neutron flux research reactors is one of the alternative options to sustain the supply of ^{99m}Tc to the local user in national level. ⁹⁹Mo/^{99m}Tc-TCM-Autosolex generator, a closed cyclic self shielded, computer controlled module utilizes Methyl Ethyl Ketone (MEK)-solvent extraction methodology and is a technological solution to exploit the maximum utilization of low specific activity ⁹⁹Mo. Herein, we describe the optimization of a remotely operated module for separation and purification of sodium pertechnetate from a bulk solution of molybdate to prepare and the use of ^{99m}Tc-radiopharmaceuticals.

The extracted ^{99m}TcO₄⁻ from the Autosolex generator using 7.40 – 27.5 GBq of LSA sodium molybdate (⁹⁹MoO₄⁻²⁻) were labeled with various fourth generation technetium cold kits (TCK) [methoxyisobutylisonitrile (MIBI), hydrazinonicotinamide-Tyr3-octreotide (Hynic-Toc), human Serum Albumin - nanocolloid (HSA-NC), 2 β [N,N' - bis (2-mercaptoethyl) ethylenediaminomethyl]- 3 β -(4-chlorophenyl) tropane) (TRODAT) apart from regular TCK and used in routine scintigraphic imaging in patients with different clinical conditions at our

hospital radiopharmacy. The extracted 99m TcO₄ and various radiolabeled Technetium kits undergo stringent physico-chemical and biological quality control tests in accordance with United State Pharmacopeia (USP) monograph.

The extracted ^{99m}TcO₄⁻ from autosolex generator is clear and colorless solution having pH in the range of 5.0-6.5. The elemental molybdenum (Mo) and aluminum (Al) content is <10µg/ml, MEK levels is <0.1% (v/v) and radiochemical purity (RCP) >98%. All the extracted ^{99m}TcO₄⁻ batches complies sterility testing and endotoxin limit (EL) <5EU/ml. TCK cold kits were labeled with extracted ^{99m}TcO₄⁻ using standard procedure (3) and RCP of all these labeled TCK were >95% except ^{99m}Tc-TRODAT (>90%).

Conclusions: We were successful in obtaining ${}^{99m}\text{TcO}_4^-$ from LSA ${}^{99}\text{MoO}_4^{-2}$ using ${}^{99}\text{Mo}/{}^{99m}\text{Tc}$ -TCM-Autosolex generator. Its operational and clinical efficiency were established on labeling with various TCK and using these ${}^{99m}\text{Tc}$ labeled radiopharmaceuticals for routine scintigraphic imaging in patients with varied clinical conditions at our hospital radiopharmacy centre.





Image A: Primary NET patient administered with ^{99m}Tc-Hynic-Toc labeled from autosolex's ^{99m}TcO₄.



administered with same ⁹⁹"Tc-Hynic-TOC.

2. Synthesis of Mannose triflate (2-[¹⁸F]FDG Precursor) for regular production of 2-[¹⁸F]FDG:

Mannose triflate (1,3,4,6-tetra-O-acetyl- β -(D)-mannopyranose) is a precursor for 2-[¹⁸F]FDG. It is a key compound for the production of 2-[¹⁸F]FDG, which is highly sensitive towards

temperature and light. Hence chances of decomposition during transport and storage may reduce the reliability to the supply of $2 \cdot [^{18}F]FDG$ on daily basis. The precursor vial costs around Rs. 6.5 lakhs/year, when procured from other sources. The cost of production in-house would be Rs. 1.4 lakhs. Hence in-house production of mannose triflate reduces cost of $2 \cdot [^{18}F]FDG$ production (Rs. 5 laksh/year) and reliability of its regular supply. The precursor synthesis is a two step reaction starting from mannose. The precursor was synthesized, purified and evaluated for its quality. The compound was aliquoted in sterile and pyrogen free vials under dry and inert (N₂ gas) conditions. The vials are stored at -20°C and used for regular production for $2 \cdot [^{18}F]FDG$.

3. Production of [¹⁸F]FET (O-(2'-[¹⁸F]fluoroethyl)-L-tyrosine):

 $[^{18}F]FET$ is an important PET radiotracer which is used for imaging gliomas. It has a higher tumor to brain ratio compared to 2- $[^{18}F]FDG$. $[^{18}F]FET$ was synthesized from the commercially available TET precursor and purified by an indigenously developed simple solid phase extraction purification method. The product was evaluated for its quality for clinical studies. It was approved by radio-pharmaceutical committee. $[^{18}F]FET$ is now supplied regularly once in a week as per the hospital demands.



IV. Development Work carried out at Radiation Physics Group

1) Dose Rates in Tsetse Fly Blood – Diet Irradiator of Ethiopia

Gamma dose profile in blood–diet were estimated for a ⁶⁰Co based gamma irradiator in Ethiopia which was set up under IAEA's Southern Tsetse-Fly Eradication Project (STEP). The unique product irradiation configuration of the blood-diet required a twin-circle source geometry. Analytical & MCNP methods used for dose estimation required a modification in blood-diet vessels before commissioning dosimetry. Calculated DURs for all three distances were higher than the required DUR, the prescribed value for the blood-diet. Therefore the volume available in the vessels was required to be reduced /reworked in the central region of each vessel.

Alternatively the vessel diameter may be reduced to achieve the desired DUR. Experiments were set up for the same and optimized the dose-rate.

2) Dual-Source (¹³⁷Cs & ⁶⁰Co) Portable Irradiator

A portable multi-purpose small irradiator that can be used for ⁶⁰Co or ¹³⁷Cs based radiation source was designed. The strength of source, dose & shielding design were optimized by analytical method to get a suitable dose rate in the sample chamber for blood bags & samples for research purposes. Two AERB design parameters were required to be met, transportation requirements as Type B (U) package and the other as a Category I irradiator. After fabrication of the prototype of irradiator, radiation survey and dosimetry confirmed the designed source loading, shield adequacy and dose rates. Measured dose rates are also matching with the estimated values. This irradiator can be used for low dose irradiation studies with the option of ¹³⁷Cs or ⁶⁰Co source.

3) Dosimetry Aspects for the Development of an Irradiator for Cross-linking of Cables using ⁶⁰Co gamma rays

Cross-linking provides significant commercial benefits to wire and cable insulation. Ionizing energy is an efficient means of cross-linking the polymers to improve many cable properties including insulation. In this process chemical bonds are formed between layers of polymer molecule to produce three-dimensional insoluble network. The present methods of crosslinking are thermal/chemical/e-beam from accelerators. E-beam cross-linking is the latest and improves properties like fire resistance, flame properties, abrasion resistance, stress crack resistance etc. However there is a limitation of e-beam penetration in large diameter cables (>0.030 m dia.) restricting its application. Therefore the feasibility of processing multi core cables of large diameters with gamma rays was explored. The insulation jacketing of multi core cables are made of PVC or PE. The dosimetric aspects were studied for a cable irradiator-design which has been made in such a way that the cable will move through a pipe housed in Gamma Irradiation Cells (GICs) each of which have ⁶⁰Co source pencils (BRIT made BC-188) of 7.4PBq arranged around the pipe in a suitable diameter (PCD). The pipe can accommodate cables of diameters up to 0.072m. The cells have effective irradiation lengths (~1m) and lead shielding of adequate thickness. The objective of the study was to evaluate the dose profile in cables when irradiated in a gamma irradiation cell and to optimize the PCD of source pencil arrangement to get the appropriate Dose Uniformity Ratio with the specified target dose of 100kGy & to arrive at no. of irradiation cells required for a suitable through-put. Based on the results of the study a gamma irradiator with multiple no. of irradiation cells is under development in BRIT.

V. Development Work at Microbiology Laboratory, RPP

1) Isolation & studies of radiation resistant bacteria from irradiation cell environment & pool water of RPP

An attempt was made to isolate & study the radiation resistant microorganisms from pool water & irradiation cell environment of RPP. Number of samples have been collected from the pool water & exhaust air of irradiation cell area to isolate radiation resistant organisms. More than 25 bacterial isolates have been studied in details and the radiation sensitivity studies showed that three of the isolates were having D_{10} values of more than 4 kGy, one of the isolate showing D_{10} value as high as 4.7 kGy. Microscopic observations revealed that most of the isolated organisms were Gram positive rod-shaped microorganisms, some of them found arranged in long chains resembling Actinobacteria and were found to survive at 12 kGy of radiation dose. Thus these

bacterial isolates showing high radiation resistance can be exploited in the research & industrial applications of bioremediation of nuclear & radioactive waste.

2) Effect of gamma radiation on cooking time of Indian Rajma

The studies were carried out on effect of gamma radiation on cocking time of Indian Rajma. Two different varities of Indian Rajma were studied and the findings showed 14-42% decrease in the cooking time at radiation doses of 1-5 kGy. The observations on the cooking time revealed that the cooking time can be significantly decreased by gamma radiation to the maximum of 42% at radiation dose of as low as 2.5 kGy.

VI. Development Work carried out at Sealed Sources and Logistics Division of BRIT

1. Radiation Protection Aspects in Production, Processing and Transportation of Cobalt-60 Sources, from Reactor to Customer

Co-60 is extensively used for teletherapy treatment of cancer in healthcare and for irradiation of food and agricultural products for preservation and microbial decontamination, medical products for sterilization etc. BRIT handles several million curies of Co-60 activity per annum in a safe manner at RAPPCOF to supply these sources to healthcare and industrial sectors in India and abroad. Co-60 used in these sectors is produced in various PHWR power reactors as a byproduct of neutron regulation. The processing of Co-60 is a challenging job in view of radiological protection concern. Any occurrence or mishap during processing can result in exposure to personnel and a setback to the production of Co-60 sources. Here, a simple attempt has been made to describe the radiation protection aspects of the entire process and the efforts in ensuring radiological safety. Natural Cobalt (Co-59) is used in as adjuster rods for neutron regulation in nuclear reactors. Co-59 reacts with the neutrons in the reactor core and become radioactive Co-60 by ⁵⁹Co (n,g) ⁶⁰Co reaction with thermal neutrons(cross-section 37 barns). The produced Co-60 decays to stable Ni-60 by emitting 1b (0.332 MeV) & 2gs (1.173 & 1.332 MeV) with a half-life of 5.27 years. The processing of Co-60 includes a seies of steps: removal of adjuster rods from the reactor, transportation to RAPPCOF, discharging and storage of these rods in storage pool in minimum water shielding of 5m, cutting of adjuster rods, separating the sub-assemblies, recovering the raw activity in specially designed shielding enclosure having a wall thickness of 2m of concrete and radiation shielding glass windows of equivalent thickness called 'Hot Cell' which is equipped with remote handling MSM and EOT crane, followed by fabrication of different types of sealed sources for cancer treatment & industrial irradiators and finally transportation to the users in a type approved transportation flasks as Type B(U)package.

Health physics coverage along with strict radiation protection procedures have been followed to ensure the radiation safety in all the above steps. The radiation protection of personnel and public is ensured by keeping strict adherence to HP instructions by way of installing Area Gamma Monitors (AGM) in vulnerable locations, interlocking of 'Hot Cell' doors with In-cell monitoring of gaseous release through stacks, routine radiological survey of controlled and supervised area, installation of hand, foot & clothes monitors at inter-zonal points and portal monitor at the final check point of the facility, use of electronic pocket dosimeter (EPD) for all the radiological work, regular checking of performance and calibration of the various radiation protection instruments etc. The combined effort of HP group, experienced operation group, the valuable suggestions of Local Safety Committee (LSC) and AERB allowed the safe production and fabrication processes at RAPPCOF, BRIT. Meticulous planning, mock-up-trials, clear job roles and efficient time management has led to man-rem consumption within AERB limits and maximum individual dose reduced to less than one-third of the annual personnel dose limit.

49

2. Radiological and Operational Challenges in Fabrication of Co-60 Teletherapy Sources (CTS): from Reactor to Customer

Fabrication of CTS requires high operational skill and excellent radiation protection practices to avoid the spread of contamination and over-exposure to the personnel, especially the slug/pellet recovery which is obtained by cutting and separating the sub-assemblies stored in the minimum water shielding of 5m. The 5m water column is sufficient to shield 3MCi of Co-60. The most challenging and vulnerable job is that of cutting of these pellets/slugs capsules for recovery of Co-60 and filling it in standard CTS inner capsules for welding. Both, inner and vouter capsules are checked for leak contamination as per AERB guidelines. All these are performed in a specially designed shielding enclosure having a wall thickness of about 2m of RCC and radiation shielding glass windows of equivalent thickness called hot cell which is equipped with remote handling tools such as Master Slave Manipulators (MSM) and in-cell crane to avoid contaminations and over exposure to personnel. We designed and developed these machines for recovery of pellet/slugs and could successfully used them for CTS fabrication without much radiological consequences.

3. Availability of Co-60 Sources for Medical & Radiation Processing Applications: An Indian Scenario

BRIT is supplying 2-3 MCi per annum of Cobalt Teletherapy Sources (CTS) to about twenty cancer hospitals and irradiator sources to more than twenty irradiators in the country and abroad. As on today, India is completely self-reliant with indigenous activity of Co-60 for telecobalt units in India and thus making it very cheap and cost-effective. BRIT fabricated indigenously more than twenty CTS within this year with an output ranging from 140-180 RMM and planning to fabricate more (>200RMM), thanks to the active cooperation from the Indian Power Reactors in this year as per demand. This will drastically bring down the cost of the cancer treatment and the time taken for the treatment and in turn benefit the lower income groups of the country.

VII. Development Work carried out at Design & Development Section, Engineering Division, BRIT

a. Type Approval of Transportation Packages for Radioactive Material (f) BLC-30:

Package

A transportation package BLC-30 is designed by BRIT to Transport 25kCi of Co-60 activity in shield capsules. As the package needs to be transported by air also, there are stringent limits for package surface temperature which may increase due to heat emitting radiation source. To c o n f i r m t h a t t h e s e temperatures do not exceed regulatory limits, thermal simulations were carried out.



Additionally experiments were carried out with BLC-30 package to confirm the steady state temperatures obtained by simulations. The flask was loaded with 25kCi of Co-60 activity and surface temperatures were measured at specified locations. Results of experiments were found as expected and within IAEA specified limits of air transport.

b. BLC-800:

BRIT is designing a Transportation package for Co-60 activity upto 800 kCi. The package will be used for transportation of sub-assemblies of absorber rods coming out from 700 MWe reactors planned at RAPP Rajasthan site. As capacity of package is very high, the package temperatures and maintaining lead of package in solid state after source loading will be a challenge. High Package Temperatures may have detrimental effect of package material properties. This package with its impact limiters was simulated for impact test in multiple orientations using Finite Element Analysis. After qualifying several other tests, the package will qualify for transportation through road and sea route.



c. Operations with Mobile Hot Cell:

Mobile Hot Cell (MHC), is a unique hot cell type which can be dismantledand assembled as and when required. As sand, the shielding material for this cell, is easily available everywhere, it need not to be transported along with dismantled mobile hot cell. The cell is designed for 2kCi Co-60 activity with an internal size of 2mx1.5m. The cell is designed for disused source removal from old/ disused Radiation Technology Equipment (RTE) lying worldwide. These types of equipment (RTE) are potential risk as possibility of high radiation sources.

The cell (MHC) is presently installed at BRIT Vashi Complex with all its equipment and tooling. The cell was used for in house decayed source recovery operations. Total 180 disused radiation sources from thirteen GC-900 equipment, were recovered using mobile hot cell.



Figure 3: Mobile Hot cell after assembly



Figure 4: Source recovery using Mobile Hot Cell (A view from Radiation Shielding Window)

d. Multi-Source Exposure Device

Radiation shielding integrity of Multisource Exposure Device was verified by loading 40 Ci CO-60 at RLG, BARC. Radiation survey was carried out to measure the surface dose rate. The measured values were well within acceptable limits set by Safe Transport Regulatory AERB SC-TR 1 Code as well as IAEA Code. Also A Collimator with remotely operated attenuators was designed for the Multisource exposure device to enable the collimation of the radiation beam while performing the exposure of radiation source in Calibration Labs.



e. Portable Research Irradiator Modification (PRI)Sectional view of PRI CASK showing the pencil position (3nos.) on left side & sample loading port on right side

Manual mode Portable Research Irradiator (PRI), Category I Irradiator delivering the dose-rate of 36Gy/hr and was presented to SARCAR Committee (AERB). The committee suggested AUTO MODE operation of the device. This may reduce administrative control of the irradiation process. Hence existing Manually Operated Portable Research irradiator's Lead plug was modified to enable it to operate it in Auto mode. A Mild Steel Simplified SET UP for the Rotation of the Turntable and the Sample chamber in Auto mode was fabricated to verify the feasibility of the AUTO Mode operation.

Auto mode trials were successfully completed. Accordingly Lead plug was modified to suit the Auto mode Requirement. The unit is made ready for carrying out radiometry. **PRI being transported to Mobile Hotcell for loading source.**





PRI being transported to Mobile Hotcell for loading source.

f. Fabrication of 25 Tons of Turntable

Turntable (25 Tons.) was fabricated, installed and load tested at IFRT Site to enable changing the direction of travel of transfer cart for conveying materials in and around hotcell.

Fabrication & Testing of Transfer Cart Operational trials of Transfer cart

25 (Tons) at IFRTTransfer Cart (25 TONS) for Material handling in IFRT was fabricated and operational trials with load were conducted successfully in both manual mode and remotely operated through control panel.



Turntable (25 Tons) being load tested at IFRT



g. Panbit Flask

Panbit flask is used in Batch type Irradiator. A shock absorber was desinged to meet the specific requirments stated in national and international regulatory code for safe transport of radioactive material. Thermal simulations will be carried out to check the thermal performance of the package when subjected to thermal test as stipulated in the national and international Regulatory code.



h. Development work for Selenium-75 capsules for radiography device Capsule, Cap, Spacer and Se-74 Pellet.

Tungsten carbide lined DIE was fabricated for carrying out Pelletisation of Se-74 powder. Pelletisation of the natural Selenium -74 Powder as per the required size was achieved. Ten nos. of Se-74 Capsules with Se-74 pellets (Max. 6 Nos.), spacer and air gap were assembled by Laser welding technique. No weld defects were found in all the ten samples that were tested for laser weld quality for the capsule. Further test as per standards are to be carried out for AERB approval of the capsule design.





i. Co-60 based Exposure Device

BRIT has designed and developed 120Ci Co-60 based radiography exposure device that can be used for non-destructive testing. The device can detect flaw in the weld joints for a thickness of 50mm to 200mm. The device uses lead, tungsten and depleted uranium as shielding material to make the device light & compact. The shielding materials are encased in a stainless steel shell. A tube in the form of Sbent is provided in the centre to facilitate the movement of Co-60 radioactive source so that streaming of radiation is avoided. Since the exposure device will be transported in public domain, it is designed to confirm to AERB and IAEA requirement of Type B (u) package. While transportation, the device will be packed in an outer enclosure made of 304L and filled with Polyurethane foam.



Figure: Prototype of Co-60 based Radiography Exposure Device

j. Mo-99 Cask

Mo-99 cask has been designed to carry 1500Ci of Mo-99. The cask uses tungsten as shielding material cladded with stainless steel. The cask has an outer over pack which is filled with

Polyurethane foam to absorb the impact during 9m drop test. The main feature of the cask are light weight and ease of handling. Structural integrity of the cask under 9m drop test has been studied using commercial Finite element Code PAM-CRASH.





k. BLC-200 Transportation Cask

Prototype of BLC-200 cask has been completed. This is an upgraded version of BLC-125 where tungsten is used to replace lead partially. Radiometry of the BLC-200 cask was carried out using 50 kCi of Co-60. The maximum dose at the surface of the cask was found out to be 32 mR/hr for the designed strength i.e. 200 kCi of Co-60. The thermal analysis of the BLC-200 cask has been carried out using finite element method. Fig shows the result under post fire condition.

I. Safety and Security of Gamma chamber under blast loading:

Gamma Chamber are used in industries, laboratory, hospitals and research institute for application of radiation in different fields. As these equipments move in public domain, these can be easily targeted by terrorists for sabotage. Hence, it is imperative to study the safety of Gamma Chamber under blast loading. Actual test and Finite element simulation were carried out to study the performance of gamma chamber under blast loading.



Figure: Experimental set up of Gamma Chamber under Blast



IX. Development work carried out by Isotope Application Services, BRIT

i. Leak detection in Cooling water pipelines at BRIT

Water is chilled in air-conditioning plant near LCO for its supply to the laboratory cooling units and to other areas through underground pipelines. Two such underground pipelines, 10" supply pipeline and 10" return pipeline, were suspected to be leaking, as both of them were not holding the intended pressure. Both the pipelines were insulated with 75mm thick thermocoal lining covered with cement coating. The leaky section was approximately 45 m long. Several attempts were made to locate the leak using conventional techniques; however the leak location could not be identified. Hence Isotope Application Services was requested to help in locating the leak in this pipeline.

Tracer patch migration technique using radiotracer was employed for leak detection in chiller water pipelines.

Three pits were dug at susceptible locations and pipe surface was made accessible. Scintillation detectors were placed on the pipe surface and the detectors were coupled to PIGTRACKER unit.



The position of monitoring is given in Table1.

Table 1: Monitoring points				
Position No.	Location			
Pit no. 1 / D1	Near injection point			
Pit no.2 /D2	On the first bend towards north			
Pit no. 3 /D3	On the second bend towards east			
D4	Where both the pipelines emerge above ground			

To the extent possible, dewatering from the pits was carried out before starting the work. The pipeline was filled with water. The radiotracer was injected in to the pipeline near the pump house end (Fig 3). Pressure of the water in the pipeline was kept at ~ 1.5 kg/cm2.



 Figure 3. Detection at location D3



Figure 2. Arrangements for injection at location D1

Figure 4. Instruments used

The pipeline was continuously fed with water to make up the water loss due to leak and pressure in the pipeline was maintained to about 1.5 kg/cm2. Pig tracker instrument with 1" scintillation detector were used for monitoring the passage of tracer patch through the pipeline at the above mentioned points.

About 50mCi of Molybdenum-99 (Mo-99) as Sodium Molybdate was used as radiotracer in the supply pipeline on 04/05/2016.

57

Table 2: Tracer patch monitoring on 04/05/2016				
Position No.	Time	Radiation level/ Counts observed		
Radiotracer injection	1130 hours			
Pit no. 1 / D1	11.45 hours	18241 cps		
Pit no.2 /D2	1235 hours	16323 cps		
Pit no. 3 /D3	1320 hours	14021 cps		
D4	No indication till 1700 hours	50-60 cps (bkg)		

The count-rate of tracer patch at various locations is given in Table 2.

The radiotracer was detected upto D3 and no further indication of radiotracer patch movement was observed at D4. The sampling of this water was carried out and it showed presence of radioactivity (About 50 cps when the detector dipped in 15 litres sample bucket). Thus, the experiment revealed that the section between D3 and D4 is the suspected leaky segment.

About 30mCi of Molybdenum-99 (Mo-99) as Sodium Molybdate was used as radiotracer in the return pipeline on 05/05/2016.

The count-rate of tracer patch at various locations is given in Table 2.

Table 3: Tracer patch monitoring on 05/05/2016					
Position No.	Time	Radiation level/ Counts observed			
Radiotracer injection	1125 hours				
Pit no. 1 / D1	11.55 hours	1481 cps			
Pit no.2 /D2	1235 hours	1143 cps			
Pit no. 3 /D3	1320 hours	1065 cps			
D4	1612 hours	318 cps			

The radiotracer was detected upto D3. Sudden drop of the detected count-rate at D4 indicates that there is a leak in this pipeline also. However, the extent of leak could be less than the supply pipeline. The sampling of this water was carried out and it showed presence of radioactivity lesser than that during supply pipe detection (About 15 cps when the detector dipped in 15 litres sample bucket). Thus, the experiment revealed that the section between D3 and D4 is the suspected leaky segment.

Thus, it could be concluded from the experiments that

- Both the supply and return pipelines appear to be leaking between D3 and D4.
- Leak rate appears to be higher in supply pipeline than in return pipeline.

ii. Troubleshooting of Vacuum Distillation Unit in BPCL

Diesel produced from HVGO section of vacuum distillation unit was not as per specifications. Hence there was rejection of the produced diesel resulting in shortage of diesel in Bharat Petroleum Corporation Ltd. (BPCL); Mahul, Mumbai. The problem was referred to Isotope Application Services of BRIT by BPCL. It was decided to carry out gamma scanning of HVGO section of the vacuum distillation tower.

The gamma scanning was carried out using automatic gamma scanning unit in which BGO scintillation detector and Co-60 radiation source are employed to get the countrate distribution with respect to height of the column. The scanning revealed that distributor above packed bed in the HVGO section is not behaving properly. This investigation has helped BPCL to attend to the exact problem reducing the down time.



Chapter 4



Human Resource Development Activities of BRIT





Training and Lectures Imparted for Scientists/Researchers

- BRIT in collaboration with AERB and BARC conducted IAEA Interregional Training Course on 'The Practical Aspects of the Production of Molybdenum-99 by the Neutron-Gamma Reaction' during June 2015. Scientists from RPhP, QCP and SIR&P actively participated in conducting this course successfully. Fourteen participants from various countries were trained while two of the coordinators belonged to different parts of the world.
- First Training Course on 'radiotracer and Related Techniques for Diagnostic Laboratories' was conducted at RPhP, BRIT during Apr-May 2015. Nine cadidates, which comprised of clinicians, and post graduates from all over the country participated for the course.
- A two-day Radiopharmacy Training Programme for DRM and DMRIT students of HBNI University was conducted at RPhP, BRIT during the year 2015. Staff from Production, QA and QCP were involved for giving lectures and demonstrations.
- RPhP Staff, which includes Production, QA and QC were involved in giving lectures to Medical Technologists Course to the participants from INHS Aswini, Colaba, Mumbai, on 'Radiopharmaceuticals and its Quality Control', during July 2015.
- Two days Seminar on 'Radiation Protection and Safety Measures' was conducted at BRIT, Vashi Complex for the staff of Radiopharmaceuticals Programme (RPhP) and Labelled Compounds who are routinely handling radioactivity. The lectures were given by senior officers of RPhP, BRIT and RSSD, BARC.
- One day Awareness Programme was organized at BRIT, Vashi Complex which was conducted by Soham Engineering on GMP Certification and ISO Certification.
- Two M.Sc. (Biotechnology) students, one from School of Biotechnology and Bioinformatics, D.Y. Patil University, Nerul and Department of Biotechnology, Pillai College of Arts, Commerce and Science, New Panvel were guided by Dr. Sangeeta Joshi at QA Section of Radiopharmaceuticals Programme for projects, viz., 'Development of ^{99m}Tc-Labelled Cefprozil for Infection Imaging', and Correlation and Validation of Bacterial Endotoxin Test (BET) versus Pyrogen Test (PT) carried out on cold kits for Preparation of ^{99m}Tc-Radiopharmaceutical Injections'. Project Reports were prepared and submitted to respective universities.
- Two M.Pharm students from C.U. Shah College of Pharmacy, S.N.D.T. Women's University, are being guided, one each by Dr. Ravi Seshan for the project entitled, 'Development of ¹³¹I-NaI Parental Solution' and other student guided by Dr. R. Vanaja for the project entitled, 'In-Vitro Evaluation of Kit for the Preparation of ^{99m}Tc-ECD Kit, A Brain Perfusion Imaging Agent' (Jan 2016-June 2016).
- M.Tech (Intergrated) Biotechnology student from D.Y. Patil University, Department of Biotechnology & Bioinformatics was guided by Smt. Jayula Sarnaik for the project entitled, 'Characterization of Monoclonal Antibody for the Development of TSH Immunoradiometric Assay (IRMA)' (Jan 2015-May 2015).
- M.Tech (Intergrated) Biotechnology student from D.Y. Patil University, Department of

63

Biotechnology & Bioinformatics was guided by Dr. Anupam Mathur, Shri S.S. Sachdev and Dr. Yojana Singh for the project entitiled, **'Characterization of Synthesized Organic Ligands in Radiopharmaceutical Production by Compact ESI-Mass Spectrometer'** (Jan 2015-May 2015).

- Two M.Sc Biotechnology students from SIES College of Arts, Science and Commerce, Mumbai University, Department of Biotechnology were guided, one each by Dr. Anupam Mathur for the project entitiled, 'Synthesis of Amide Precursor used in the Preparation of Methoxy Isobutyl Isonitrile (MIBI) Ligand: Raw Material used for ^{99m}Tc-MIBI Radiopharmaceutical Preparation' and other student guided by Dr. Shubhagi Mirapurkar for the project entitiled, 'Studies on the Effects of Storage, Efflux and Cytotoxicity of Radioiodinated mIBG on Neuroblastoma Cell-lines' (May 2015–October 2015).
- M.Sc Biotechnology student from Pillai College of Arts, Commerce and Science, Mumbai University Department of Biotechnology was guided by Dr. Anupam Mathur for the project entitiled, , 'Synthesis and In-Vitro Evaluation of a Newly Designed ^{99m}Tc analogue of ¹³¹I-metaiodobenzylguanidine for its Potential use in Neuroendocrine Tumor Imaging' (Dec 2015-Feb 2016).
- A student from Mangalore University is being guided by Dr. Vijay Kadwad for her Ph.D degree in Bioscience on 'Development of Nanoparticle Based Biomolecule Probes for Detection and Management of Diseases'.
- Dr Tarveen Karir delivered a lecture on 'Role of BRIT towards Healthcare Applications of Ionizing Radiations' to the participants of the 45th Training Course on 'Safety Aspects in the Research Applications of Ionizing Radiation (IRA-45)' in collaboration with IARP at CT&CRS, Anushaktinagar, Mumbai on May 21, 2015. Nearly 30 scientists/technical officers from various research centres all over the country were benefitted from this course.
- Dr. Anupam Mathur delivered a talk on 'Cardiac Radiopharmaceuticals: Road Ahead' at 10th Biennial Meeting at Sanjay Gandhi Post Graduate Institute of Medical Sciences, Lucknow conduted between Oct 2-4, 2015.
- Dr. Yojana Singh Presented Paper at National Seminar on Atomic Energy Swaacch Bharat 'Use and Benefit of Atomic Energy in Agriculture and Medicine' at Hyderabad during Mar 17-18, 2016.
- Dr. S.K. Sarkar presented 110-Page document and delivered a report on 'Final Safety Analysis and Radiometry Report on ^{99m}Tc Column Generators (COLTECH)' to AERB while seeking its permission for operating 50Ci of ⁹⁹Mo at BRIT. AERB permission thus sought is valid upto October 2018.

Workshops/Seminars Attended

- Theme Meeting attended by Ms. Raksha Rajput, SO/D, Radiation Physics Group, on 'Radiation Metrology and Nation Standards on Ionizing Radiation' at BARC during July 9-10, 2015.
- INS National Workshop was attended by Ms. Raksha Rajput, SO/D, Radiation Physics Group, on 'Radiation Shielding Design and Analysis' at AERB during August 10-14, 2015.
- Dr Kiran Mehra attended a Training Programme for Women Scientists on 'cience for Progress in India: Focus on sustainability' conducted by National Institute of Advanced Studies at Bengaluru during Feb 08-12, 2016.

• Smt. Uma Sherikumar Participated as a faculty for workshop organized by Sir Parashurambhau College, Pune, in collaboration with Indian Association of Nuclear Chemists and Allied Scientists (IANCAS) at Pune during Aug 7-8, 2015. She performed **Practical Demonstration on 'Alumina Column Chromatography Generator'**.

Monitoring of BRNS Projects, Review of International Journal Article, Contribution towards IAEAActivities and General HRD

- Investigation of Therapeutic Efficiency of Phenytoin (PHT) labeled with Radioactive ¹³¹I in the Cancer Cell Lines'. Reviewed by Mr. V.V. Murhekar, for the International Journal, 'Journal of Radioanalytical and Nuclear Chemistry'.
- 'Evaluation of Therapeutic Efficiency of Liposomal and nanparticulated flavonoids in combating oxidative hepatocellular degeneration by nuclear imaging technology using ^{99m}Tc Radiopharmacuticals'. P.I. Dr. Mitra Chatterjee Debnath, IICB, Jadavpur & P.C. Dr. Sankha Chattopadhyay.
- Octreotide Derivative Modified Lipid Nanoparticles: Preparation, Radiolabeling & Applications as Tumor Targetted Chemotherapeutic Agents/Radiopharmaceuticals? P.I. Dr. Partha Chakraborty, IICB, Jadavpur & P.C. Dr. Sankha Chattopadhyay.
- The final report for 3 years IAEA Co-ordinated Research Project on Direct Production of ^{99m}Tc in Cyclotron'has been prepared and presented the same at IAEA'S final research coordination meeting on "ACCELERATOR-BASED ALTERNATIVES TO NON-HEU PRODUCTION OF MO-99/TC-99M" meeting at IAEA, Vienna during 22-26 June 2015 by Dr. Sankha Chattopadhyay.
- Dr. Sankha Chattopadhyay had participated as an expert at the IAEA's Technical Meeting on "New Ways of Producing Tc-99m and Tc-99m Generators", held at IAEA, Vienna, Austria, during 14 to 18 March 2016. He presented "Solvent Extraction Based System for Automatically Separating ^{99m}Tc-Radionuclide From Low-Medium Specific Activity ⁹⁹Mo".
- Dr. Geetha Rajagopalan was invited as 'Judge for an Event' by 'Pharma Solution' on 21-01-2016 held at Bombay College of Pharmacy.
- Shri S.S. Sachdev served in the capacity of 'Examiner' for 2nd Year M.Pharm Students of C.U. Shah College of Pharmacy, SNDT Women's University, Mumbai.
- Dr. Anupam Mathur and Dr Tarveen Karir have received registration for Ph.D. guideship with Mumbai University for 'Chemistry' Discipline. Also, Dr. S. Ravi, Dr. D. Padmanabhan, Dr. Anupam Mathur and Dr. Tarveen Karir are registered as Ph.D guides for Mangalore University for 'Chemistry' Discipline while Dr. Vijay Kadwad is registered for 'Bioscience' Discipline at Mangalore University.
- Smt. Geeta Rajagopalan was awarded Ph.D. Degree in Life Sciences under the guidance of Dr. N. Sivaprasad, by Mumbai University for her work on 'Studies on Development and Evaluation of some Radiolabelled Lead Molecules Suitable for CNS Receptor Imaging'.
- Mr. Kuldeep Kumar Sharma was awarded Ph.D Degree in Mechanical Engineering under the following Supervisors: Prof. A. Guha (Guide), IITB, Prof. D.N. Pawaskar (Co-Guide), IITB, and Dr. R.K. Singh (Ext. Guide), BARC. The degree was awarded by Indian Istitute of Technology, Bombay for his work on 'Design Optimization of Radioactive Material Transport Containers Under Impact'.

• Dr. V.N. Yelgaonkar attended international meeting on preparation and finalization of 'Guidebook on the preparation of radiotracers for industrial applications'. The guidebook contains categories and types of radiotracers, selection of radiotracers, calculation of activity required for radiotracer tests, radionuclide production techniques, preparation of irradiation targets, methods and techniques for labeling, preparation of radiotracers from radionuclide generators, validation of radiotracers, radiotracer field work. Dr. Yelgaonkar contributed for many of the topics but his major contribution was for making 84 figures of the whole book and all the protocols for the production.

Peer-Reviewed Journal Publications

- Double Sided Irradiation on Homogenous Products of Different Density at an Industrial Electron Beam Accelerator of 2MeV Energy'. Benny P.G., Khader S.A., and Sarma, K.S.S.
 Nuclear Instruments and Methods in Physics Research A 774 (2015) 25-28.
- * 'Influence of Electron Beam Treatment on the Crystallization and Thermal Stability of LDPE/EDPM Blends'.

Sharma, Subhendu R. Chowdhury, P.A. Mahanwarb, K.S.S. Sarma **American Journal of Engineering and Applied Sciences**, 7/3 (2014) 338-352.

- * 'Alteration of Thermal Stability and Crystallization Behaviour of EVA/EDPM Blends with VA Content Variation and EB Irradiation'. Subhendu R. Chowdhury, B. K. Sharma, K.S.S. Sarma Polym. Deg. Stab. (Communicated).
- Optimization of Parameters for Low Degree Grafting of Various ENGAGEs by Gamma Radiation? Atanu Jha, Subhendu R. Chowdhury, K.S.S. Sarma

Journal of Applied Polymer Science (Communicated).

- * 'Effect of Composition, High Energy Irradiation and MgO on Mechanical and Crystallization Properties of an Important Thermoplastic Composites'.
 B. K. Sharma, Subhendu R. Chowdhury, P.A. Mahanwarb, K.S.S. Sarma Journal of Applied Polymer Science (Communicated).
- Studies on Batch Formulation of a Kit for the Preparation of ^{99m}Tc-Ubiquicidine (29-41): An Infection Imaging Agent?

Chanda Arjun, Archana Mukherjee, Jyotsna Bhatt, Pradip Chaudhari, KrishnaMohan Repaka, Meera Venkatesh, Grace Samuel

Applied Radiation & Isotopes (Accepted for Publication).

Synthesis and Biological Evaluation of ^{99m}Tc-HYNIC Fatty Acid Complexes for Myocardial Imaging?

Anupam Mathur, Abhishek K. Sharma, V.V. Murhekar, Madhava B. Mallia, Shital Pawade, H.D. Sarma, Pradip Chaudhari, S.S. Sachdev, Sharmila Banerjee **Royal Society of Chemistry Advances**, **5** (2015) 93374-93385.

* "Ga labelled Ciprofloxacin Conjugates as Radiotracers for Targeting Bacterial Infection?

Drishty Satpati, Chanda Arjun, R. Krishna Mohan, Grace Samuel, Sharmila Banerjee **Chemical Biology and Drug Design (Accepted for Publication).**
* 'Radiopharmaceuticals Used in CNS Diseases and Disorders'. Geetha, R., Sivaprasad, N. Pharmatimes, 47/5 (2015).

- * Cell Uptake and Biodistribution Studies of Radioiodine Labelled mIBG for Clinical **Evaluation of a Therapeutic Preparation**? Soumen Das, Shubhangi Mirapurkar, Navin Sakhare, Anupam Mathur, R. Krishna Mohan, N.C. Joseph, H.D. Sarma, V.V. Murhekar, G. Prabhakar, S.S. Sachdev **Applied Radiation and Isotopes (Communicated).**
- * 'Metabolic Stability and Biological Evaluation of ^{99m}Tc-HYNIC-Tyr3-Octrotide as Somatostatin Receptor Positive Tumor Imaging Agent'. Behera A., De K., Chattopadhyay S., Misra M. Journal of Radioanalytical & Nuclear Chemistry 304/2 (2015) 595-602.
- * 'Synthesis, Characterization, Biodistribution and Scintigraphy of ^{99m}Tc-Paclitaxel: A Potential Tracer of Paclitaxel'.

Banerjee I., Behera A., De K., Chattopadhyay S., Sachdev S.S., Sarkar B., Ganguly S., Misra M. Journal of Radioanalytical & Nuclear Chemistry 304/2 (2015) 633-643.

***** 'Synthesis and Evaluation of Technetium-99m-Labeled Bioreductive Pharmacophores Conjugated with Amino acids and Peptides for Tumor Imaging? Baishya R., Nayak D.K., Karmakar S., Chattopadhyay S., Sachdev S.S., Sarkar B., Ganguly S., Debnath M.C.

Chem. Biol. Drug Des. 85/4 (2015) 504-517.

- * 'Production and Separation of ^{99m}Tc from Cyclotron Irradiated 100/naturalMo targets: A New Automated Module for Separation of ^{99m}Tc from Molybdenum Targets'. Malay Kanti Das, Madhusmita, Sankha Chattopadhyay, Sujata Saha Das, Luna Barua, Md. Alam Neyar, Umesh Kumar, Anirban De Journal of Radioanalytical & Nuclear Chemistry (Published Online on DOI 10.1007/s10967-016-4796-3, 19 March 2016).
- * 'Development of Simple Method for the Immobilization of Anti-Thyoxine Antibody on Polystyrene Tubes for Use in the Measurement of Total Thyroxine in Serum'. Rani Gnanasekharan, Shalaka Paradkar, Vijay Kadwad, Ketaki Bapat, Grace Samuel, S.S. Sachdev, N. Sivaprasad Journal of Radioanalytical and Nuclear Chemistry, 303/3 (2015) 2579-2583.
- * 'Application of Novel Magnetizable Cellulose Particles in the Development of Immunoradiometric Assay for C-Peptide'. R. R. Rasmi, K. Bhasker Shenoy, V. B. Kadwad, Jayula Sarnaik, H. M. Somashekarappa Journal of Radioanalytical and Nuclear Chemistry, 304 (2015) 1115–1122.
- * 'Preparation and Characterization of ¹²⁵I Labelled Bovine Serum Albumin. K.S. Ashwitha Rai, R. Jyothi, R. Rashmi, Jayula Sarnaik, V.B. Kadwad, K.B. Shenoy, H.M. Somashekarappa Indian Journal of Pharmaceutical Science, 77/1 (2015) 107-110.
- * 'Impact stress reduction by shell splitting in cask for transporting radioactive material Kuldeep Sharma, Anirban Guha, Dnyanesh N. Pawaskar, R.K. Singh Annals of Nuclear Energy, 79 (2015) 111-124

67

Presentation in Conferences and Abstract Publication

* 'New developments in the dosimetry for industrial electron beam processing applications'.

Benny P.G., Khader S.A., and Sarma, K.S.S.

Poster Presented at International Conference on State-of-the-art Radiation Processing (NICSTAR 2015), held at Mumbai during March 4-6, 2015.

Proceedings of International Conference on State-of-the-art Radiation Processing (NICSTAR 2015).

 Sterilization of Bacteriological Culture Media by high energy Electron Beam Machine'. K.P. Rawat, Chanda Arjun, S.A. Khader, D. Padmanabhan, Grace Samuel, K.S.S. Sarma Poster Presented at International Conference on State-of-the-art Radiation Processing (NICSTAR 2015), held at Mumbai during March 4-6, 2015. Proceedings of International Conference on State-of-the-art Radiation Processing (NICSTAR

2015).

- * 'Radiation grafting of an Industrially important Polyolefin Elastomer'. Atanu Jha, Subhendu R. Chowdhury, K.S.S. Sarma Poster Presented at International Conference on State-of-the-art Radiation Processing (NICSTAR 2015), held at Mumbai during March 4-6, 2015. Proceedings of International Conference on State-of-the-art Radiation Processing (NICSTAR 2015).
- * 'Upgradation of 2MeV Electron Beam Accelerator to 5MeV for its utilization to process thick polymers, packaged products and for waste treatment'. S.A. Khader, Ravindra K. Patkari, P.G. Benny and K.S.S. Sarma

Poster Presented at International Conference on State-of-the-art Radiation Processing (NICSTAR 2015), held at Mumbai during March 4-6, 2015.

Proceedings of International Conference on State-of-the-art Radiation Processing (NICSTAR 2015).

* 'Estimation of Dose Rates in Tse-Tse Fly Blood-Diet Irradiator of Ethiopia'. Jain Reji George, B.K. Pathak

Oral Paper Presentation at National Symposium on Radiation Physics (NSRP-20) at Mangalore University during October 28-30, 2015.

Proceedings of the 20th National Symposium on Radiation Protection (NSRP-20) (2015) pp. 770-772.

- 'Dose and Shielding Design for a Dual-Source (¹³⁷Cs & ⁶⁰Co) Irradiator'. Jain Reji George, Vaishali C. Yadav, Raksha Rajput and B.K. Pathak
 Paper Presented at National Symposium on Radiation Physics (NSRP-20) at Mangalore University during October 28-30, 2015.
 Proceedings of the 20th National Symposium on Radiation Protection (NSRP-20) (2015) pp. 301-304.
- ***** Radiological and Operational Challenges in Fabrication of Cobalt-60 Teletherapy Sources from Reactor to Customer'.

Ashraf T.M., Tariq S.A., Sastri K.V.S.

Paper Presented at International Conference on Medical Physics, Radiation Protection and Radiobiology (ICMPRPR-15) in Conjunction with Annual Conference of Association

of Medical Physicists of India held at SMS Medical College, Jaipur, Rajasthan during February 20-22, 2015.

Proceedings of the International Conference on Medical Physics, Radiation Protection and Radiobiology (ICMPRPR-15) in Conjunction with Annual Conference of Association of Medical Physicists of India.

Cobalt-60 Sealed Sources for Medical & Radiation Processing, the Fascinating Journey from Reactor to Customer'.

Tariq S.A., Ashraf T.M., Gupta S.P., Pintu B., Paul D., Sastri K.V.S.

Poster Presented at International Conference on State-of-the-art Radiation Processing (NICSTAR 2015), held at Mumbai during March 4-6, 2015.

Proceedings of International Conference on State-of-the-art Radiation Processing (NICSTAR 2015).

* 'Availability of Cobalt-60 Sealed Sources for Medical & Radiation Processing Applications: An Indian Scenario'.

Ashraf T.M., Tariq S.A., Pintu B., Gupta S.P., Paul D., Sastri K.V.S. **Poster Presented at 36th Annual Conference of Medical Physicists of India (AMPICON-2015) held at Kovalam, Thiruvananthapuram, Kerala during 20-22 Nov. 2015.** Proceedings of 36th Annual Conference of Medical Physicists of India (AMPICON-2015).

Studies on Formulation of a Kit for the Preparation of ^{99m}Tc-Ubiquicidine (29-41): An Infection Imaging Agent'.

Chanda Arjun, A. Mukherjee, P.R. Chaudhari, D.K. Ranganatha, M. Venkatesh, G. Samuel **Poster Presentaion at 12th National Symposium on Nuclear and Radiochemistry** (NUCAR-2015).

Proceedings of the 12th National Symposium on Nuclear and Radiochemistry (NUCAR-2015) in IANCAS Special Souvenir.

 'Application of the consistency approach to reduce animal usage in radiopharmaceutical, ¹⁵³Sm-Ethylene Diamine Tetramethylene Phosphonate (¹⁵³Sm-EDTMP) potency testing'. D. Padmanabhan, R. Krishna Mohan, Neelam S. Pilkhwal

Oral Presentation in the International Conference on Promotion of Animal Research, Welfare & Harmonization of Laboratory Animal Science'held at ACTREC, TMC, Navi Mumbai, October 15-16, 2015.

 'Development of ^{99m}Tc-Labelled Cefprozil – An Infection Imaging Agent'. Sangeeta Joshi, Sujith Sukumaran Nair, D. Padmanabhan, Grace Samuel Poster Presented at 25th National Conference Society of Nuclear Medicine (I), SNMICON 2015 held at Puducherry, India, Dec 2015. IJNM, 30 (2015) (Suppl) S53.

- 'Extension of Shelf-life of a kit for the Preparation of ^{99m}Tc Diethylene Triamine Pentaacetic Acid of BRIT'. Archana S. Ghodke, R. Krishna Mohan, R. Vanaja, S.S. Sachdev Poster Presented at 25th National Conference Society of Nuclear Medicine (I), SNMICON 2015 held at Puducherry, India, Dec 2015. IJNM, 30 (2015) (Suppl) S53.
- Stability Study to Evaluate the Shelf-life Extension of Phytate (TCK-16) Cold Kit of BRIT'.

Ashok R. Chandak, R. Krishna Mohan, Barkha Karkhanis, S.S. Sachdev, M.G.R. Rajan **Poster Presented at 25th National Conference Society of Nuclear Medicine (I), SNMICON 2015 held at Puducherry, India, Dec 2015.** IJNM, 30 (2015) (Suppl) S52.

- * 'Evaluation of MDP (TCK-30) Cold Kit of BRIT for the Shelf-life Extension Study'. Ashok R. Chandak, Sangeeta Joshi, R. Vanaja, S.S. Sachdev, M.G.R. Rajan
 Poster Presented at 25th National Conference Society of Nuclear Medicine (I), SNMICON
 2015 held at Puducherry, India, Dec 2015. IJNM, 30 (2015) (Suppl) S52.
- 'Extension of Shelf-life of Kit for the Preparation of ^{99m}Tc-Dimercapto Succinic Acid (DMSA)'.
 H. Sheela Muralidharan, Pramod Dodke, R. Vanaja, S.S. Sachdev
 Poster Presented at 25th National Conference Society of Nuclear Medicine (I), SNMICON 2015 held at Puducherry, India during Dec 2015.
 IJNM, 30 (2015) (Suppl) S53.
- 'No Carrier Added ¹²⁵I-meta Iodobenzylguanidine Suitable for Clinical Use: Synthesis and Separation Studies from its Precursor, meta-Trimethylsilylbenzylguanidine'.
 B.K. Tiwari, Vrinda, P.C., Anupam Mathur, V.V. Murhekar, S.S. Sachdev
 Poster Presented at 25th National Conference Society of Nuclear Medicine (I), SNMICON 2015 held at Puducherry, India, Dec 2015.
 IJNM, 30 (2015) (Suppl) S54.
- 'Microwave Assisted Synthesis of ¹³¹I labelled meta Iodo Benzyl Guanidine (mIBG)'. S, Ravi, A. Thulasidasan
 Poster Presented at 25th National Conference Society of Nuclear Medicine (I), SNMICON
 2015 held at Puducherry, India, Dec 2015.
 IJNM, 30 (2015) (Suppl) S56.
- 'In-Vitro Cell Uptake Studies of New ^{99m}Tc-4+1 Analogue of ¹³¹I-mIBG for Neuroendocrine Tumor Imaging'.
 S. Mirapurkar, Shalaka Paradkar, N.C. Joseph, A. Mathur, S.S. Sachdev Poster Presented at 25th National Conference Society of Nuclear Medicine (I), SNMICON

2015 held at Puducherry, India, Dec 2015. IJNM, 30 (2015) (Suppl) S22.

- 'Fluorine-18 PET tracer for diagnosis of Alzheimer"s disease'. Lakshminarayanan N, Arun Manikrao Bhusari, Mariam Sohel Degani, Harish Shashikant Kundaikar, Harikesh Nandkishor Janmanchi and M.G.R. Rajan Poster Presented at 25th National Conference Society of Nuclear Medicine (I), SNMICON 2015 held at Puducherry, India, Dec 2015. IJNM, 30 (2015) (Suppl) S32.
- * 'Development of Indigenous, Low Cost SPE-Purification Method for 2-[F-18]FDG Production'.

Nayak Shrinibas, Lakshminarayanan N and M.G.R. Rajan Poster Presented at 25th National Conference Society of Nuclear Medicine (I), SNMICON 2015 held at Puducherry, India, Dec 2015. IJNM, 30 (2015) (Suppl) S26. Studies on Antibody Affinity Constants on Operational Aspects of Liquid Phase and Solid Phase RIA Development'.

Shripriya Purohit, Vijay Kadwad, Jayula Sarnaik, Rani Gnanasekar, Shalaka Paradkar, Satbir Singh Sachdev

Poster Presented at 25th National Conference Society of Nuclear Medicine (I), SNMICON 2015 held at Puducherry, India, Dec 2015.

IJNM, 30 (2015) (Suppl) F54.

* 'Radioimmunoassay of Triiodothyronine in Rat Serum'.

Jayula Sarnaik, Shripriya Purohit, Vijay Kadwad, Shalaka Paradkar, Rani Gnanasekar, Satbir Singh Sachdev

Poster Presented at International Conference on Radiation Research: Impact on Human Health and Environment (ICRR-HHE 2016), February 11-13, 2016, Mumbai.

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